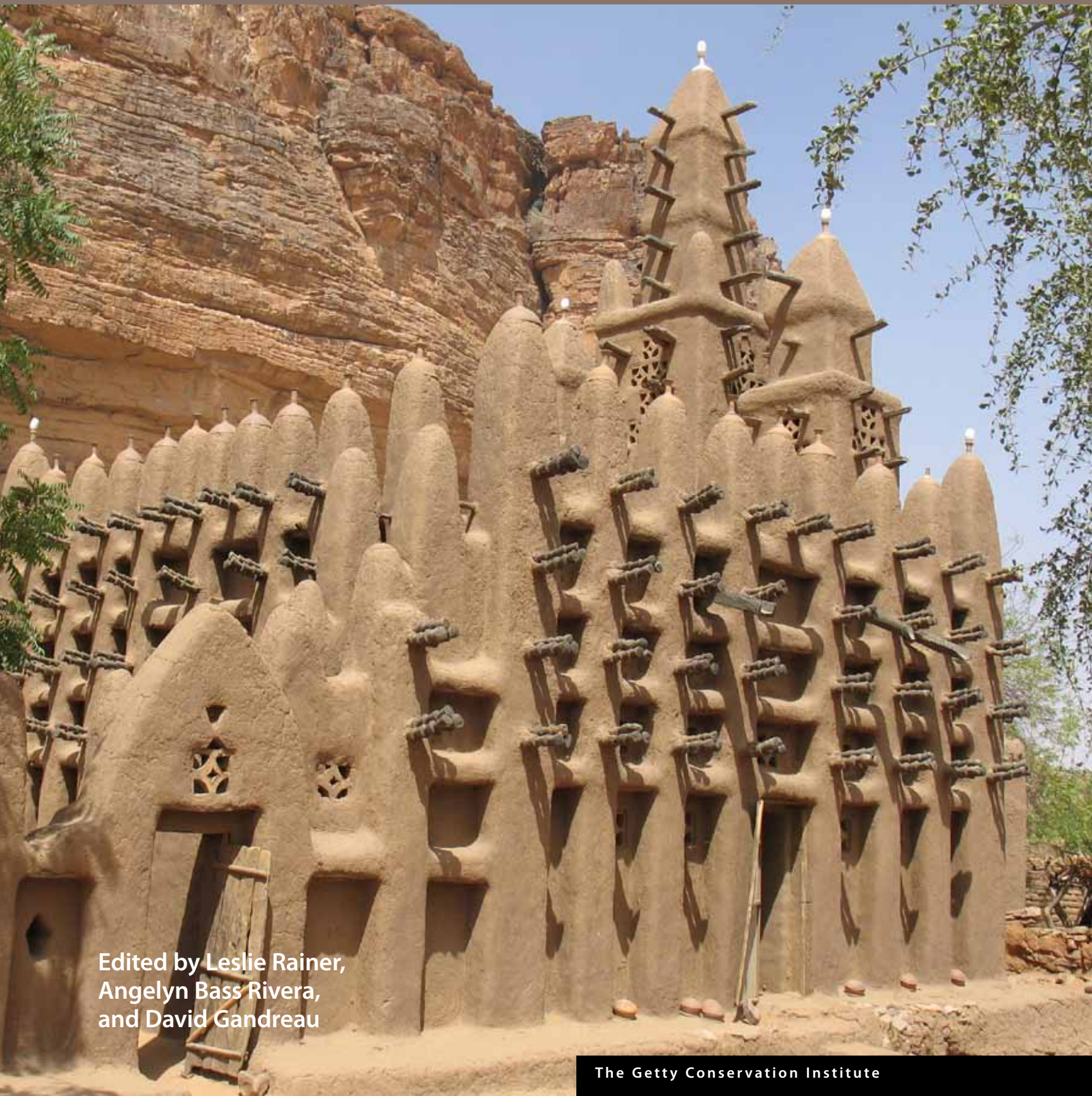


Organized by the Getty
Conservation Institute and the
Mali Ministry of Culture, Bamako,
Mali, February 1–5, 2008

Terra 2008: The 10th International Conference on the Study and Conservation of Earthen Architectural Heritage



Edited by Leslie Rainer,
Angelyn Bass Rivera,
and David Gandreau

Terra 2008

Proceedings of the 10th International Conference on the
Study and Conservation of Earthen Architectural Heritage,
Bamako, Mali, February 1–5, 2008

Actes de la 10^{ème} conférence internationale sur l'étude
et la conservation du patrimoine bâti en terre, Bamako,
Mali, 1–5 février 2008

Terra 2008 was organized by the Getty Conservation Institute
and the Mali Ministry of Culture

Terra 2008 a été organisé par l'Institut Getty de Conservation
et le Ministère de la Culture du Mali

Scientific Committee / Comité scientifique

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Lassana Cissé, Mission Culturelle de Bandiagara, Mali

Lazare Eloundou Assomo, World Heritage Centre, France

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Klessigué Sanogo, Direction Nationale du Patrimoine Culturel, Mali

Rasool Vatandoust, Research Center for Conservation of Cultural Relics, Iran

Debbie Whelan, ICOMOS South Africa

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*Publié sous la direction de Leslie Rainer,
Angelyn Bass Rivera et David Gandreau*

THE GETTY CONSERVATION INSTITUTE
LOS ANGELES

The Getty Conservation Institute

Timothy P. Whalen, *Director*

Jeanne Marie Teutonico, *Associate Director, Programs*

The Getty Conservation Institute works internationally to advance conservation practice in the visual arts—broadly interpreted to include objects, collections, architecture, and sites. The Institute serves the conservation community through scientific research, education and training, model field projects, and the dissemination of the results of both its own work and the work of others in the field. In all its endeavors, the GCI focuses on the creation and delivery of knowledge that will benefit the professionals and organizations responsible for the conservation of the world's cultural heritage.

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FRONT COVER: Earthen mosque in the village of Ende, Dagon Country, Mali. This construction is an example of the rich earthen cultural heritage found throughout this West African country. Photo: Leslie Rainer, 2006. © J. Paul Getty Trust.

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Foreword

On behalf of the Getty Conservation Institute, it is my great pleasure to present the *Proceedings* of Terra 2008, the 10th international conference on the study and conservation of earthen architectural heritage, which we had the distinct privilege of organizing with the Ministry of Culture of Mali. These *Proceedings* are an acknowledgment of our joint efforts and the outstanding work of all the contributors to this volume. Terra 2008 was a significant event that marked more than one important milestone: it was the tenth in a series of professional meetings organized under the aegis of ICOMOS concerning earthen architectural heritage; and, equally significantly, it was the first of these conferences to be held in Africa, a continent that embodies this heritage in its monumental public and religious structures, as well as its varied domestic and vernacular buildings constructed with earth. There is much to be learned from the earthen building tradition across Africa, and especially in Mali, where the living tradition is still valued and maintained as an important and integral part of the country's cultural heritage.

For these reasons it is not surprising that Terra 2008 drew a record number of participants from across Africa and internationally. The conference was also distinguished by the quality and range of material presented, which focused not only on the earthen architectural heritage but also on earth building as a continuing living tradition and the intangible, social, and cultural values associated with it. Terra 2008 counted seventy oral presentations and as many posters on topics ranging from earthen architectural heritage in the context of archaeological and historic sites to new construction. Advances in research in this specialized area of study, training, and education, intangible aspects of earthen architectural

heritage, and the challenges of conservation and development were also addressed.

The Getty Conservation Institute has long been involved in the conservation of earthen architectural heritage, through field projects undertaken on the Mogao Grottoes in northwestern China and the Royal Palaces of Abomey in Benin; scientific research on the cohesion of earth as a building material; the Getty Seismic Adobe Research Project (GSAP); and many educational training initiatives through the PAT courses organized with CRATerre-EAG and ICCROM in the 1990s. Terra 2008 brought together professional colleagues who have worked with us in the past and who continue to collaborate with us on projects in this area of specialization. This conference both expanded our reach and brought us into contact with professionals from all over the world who are leading research to conserve this vulnerable material and its built form in many different contexts. It is our hope that the *Proceedings* will advance conservation practice and deliver knowledge that will benefit professionals and organizations responsible for the conservation of the world's cultural heritage.

The GCI is privileged and honored to have organized this conference with the Ministry of Culture of Mali and its cultural agencies, including the Direction Nationale du Patrimoine Culturel (DNPC), the National Museum of Mali, and the Cultural Missions of Bandiagara and Djenné. I would like to acknowledge the scientific committee, which included representatives from the GCI, the Ministry of Culture of Mali and the Cultural Mission of Bandiagara, the ICOMOS International Scientific Committee for the Study of Earthen Architectural Heritage, UNESCO's World Heritage Centre, ICCROM, CRATerre-ENSAG, the Africa 2009 Program, and

ICOMOS South Africa. Because of their combined expertise and commitment, the conference offered a rigorous academic and scientific program covering a wide range of topics.

I would also like to recognize the many organizations that provided funding for the conference, including the Getty Foundation, the Ford Foundation West Africa, the World Heritage Centre, the partners of Africa 2009, and Misereor. Their generous contributions provided professionals from across Africa and around the world with the opportunity to attend the conference, present their research, and engage with the growing network of professionals working in this specialized field of study, now considered a discipline in its own right.

Particular thanks go to the editors of these *Proceedings*, Leslie Rainer, Angelyn Bass Rivera, and David Gandreau, for their outstanding work. Thanks also to Cynthia Godlewski and Kathleen Louw for coordinating these *Proceedings* from

initial submission of the papers to their final publication; to the superb team of translators and copy editors, Anne-Marie Driss, Sabine de Valence, and Sheila Berg; and to Tevvy Ball, editor, and the excellent design and production team at Getty Publications, including Pamela Heath, production coordinator.

With this volume we renew our commitment to the conservation of earthen architectural heritage worldwide. As we continue research in this field, we hope to strengthen and encourage new collaboration with both our national and our international colleagues and expand the growing network of professionals dedicated to preserving this vulnerable heritage as a legacy for future generations.

TIMOTHY P. WHALEN
Director
Getty Conservation Institute

Avant-propos

Au nom de l'Institut Getty de Conservation, j'ai le grand plaisir de présenter les Actes de Terra 2008, la 10^{ème} conférence internationale sur l'étude et la conservation du patrimoine bâti en terre, que nous avons eu l'honneur d'organiser avec le Ministère de la Culture du Mali. Ces Actes sont le témoignage des efforts conjoints que nous avons déployés et du travail exceptionnel de tous ceux qui ont contribué à ce recueil. Manifestation de grand envergure, Terra 2008 a marqué plusieurs jalons : elle fut la dixième dans une série de rencontres professionnelles organisées sous les auspices de l'ICOMOS sur le patrimoine bâti en terre et, tout aussi significativement, elle fut la première de ces conférences à avoir été organisée en Afrique, un continent qui incarne ce patrimoine à travers ses bâtiments monumentaux publics et religieux et ses très diverses constructions domestiques et vernaculaires en terre. Les traditions de construction en terre à travers l'Afrique sont riches en enseignements et particulièrement au Mali, où la tradition vivante continue à être valorisée et maintenue comme une partie importante et intégrante du patrimoine culturel du pays.

Ainsi, il n'est pas surprenant que Terra 2008 ait pu attirer un nombre record de participants provenant d'Afrique et du monde entier. Cette conférence s'est distinguée également par la qualité et la diversité des thèmes abordés, centrés non seulement sur le patrimoine bâti en terre mais aussi sur la construction en terre en tant que tradition vivante qui perdure, ainsi que sur les valeurs immatérielles, sociales et culturelles qui lui sont liées. Terra 2008 comprenait 70 communications orales, et autant de posters sur des sujets allant du patrimoine bâti en terre dans le cadre des sites archéologiques et historiques, à la nouvelle construction. Les progrès accomplis par la recherche dans ce domaine spécialisé, la

formation et l'éducation, les aspects immatériels du patrimoine bâti en terre et les défis posés par la conservation et le développement ont également été abordés.

Le GCI est impliqué depuis longtemps dans la conservation du patrimoine bâti en terre à travers des projets de terrain mis en œuvre dans les Grottes Mogao au nord-ouest de la Chine et les Palais Royaux d'Abomey au Bénin : la recherche scientifique sur la cohésion du matériau terre, le GSAP (Projet Getty de recherche sismique sur l'adobe) et de nombreuses initiatives en matière d'éducation et formation à travers les cours PAT organisés avec CRATerre-EAG et l'ICCROM dans les années 90. Terra 2008 a réuni des collègues professionnels qui ont travaillé avec nous par le passé et qui continuent à collaborer avec nous sur des projets dans ce domaine. Cette conférence nous a permis à la fois d'étendre notre portée et d'entrer en contact avec des professionnels de partout dans le monde engagés dans la recherche pour conserver ce matériau vulnérable et son bâti dans différents contextes. Nous espérons que les Actes permettront de faire avancer la pratique de la conservation et toute en mettant à disposition des professionnels et des organisations responsables pour la conservation du patrimoine culturel mondial des connaissances dont il pourront tirer profit.

Le GCI a eu le privilège et l'honneur d'avoir pu organiser cette conférence avec le Ministère de la Culture du Mali et ses institutions culturelles, y compris la DNPC, le Musée national du Mali et les Missions culturelles de Bandiagara et Djenné. J'aimerais exprimer ma reconnaissance au comité scientifique qui a œuvré à l'organisation de cette conférence avec les représentants du GCI, du Ministère de la Culture du Mali et la Mission culturelle de Bandiagara, le Comité scientifique international de l'ICOMOS pour l'étude du

patrimoine bâti en terre, le Centre du Patrimoine mondial de l'UNESCO, l'ICCROM, le CRATerre-ENSAG, le Programme Afrique 2009 et l'ICOMOS Afrique du Sud. Grâce à leurs compétences et engagements conjugués, la conférence a pu proposer un programme académique et scientifique rigoureux couvrant un large éventail de thèmes.

Je souhaiterais également citer les nombreuses organisations qui ont apporté leur soutien financier à la conférence, y compris la Fondation Getty, la Fondation Ford Afrique de l'Ouest, le Centre du Patrimoine culturel, les partenaires d'Afrique 2009 et Misereor. Leurs contributions généreuses ont fourni aux professionnels à travers l'Afrique et le monde l'occasion de participer à la conférence, de présenter leurs recherches et d'entrer en contact avec le réseau de plus en plus grand de professionnels travaillant dans ce domaine d'étude spécialisé.

J'adresse mes remerciements particuliers aux rédacteurs de ces Actes, Leslie Rainer, Angelyn Bass Rivera et David Grandreau pour leur travail exceptionnel pour la compilation de ces Actes. Remerciements aussi à Cynthia Godlewski et Kathleen Louw pour la coordination de ces

Actes depuis la soumission initiale des communications jusqu'à leur publication finale, et à l'équipe de la traduction et rédaction, Anne-Marie Driss, Sabine de Valence, et Sheila Berg; et remerciements aussi au Département des publications du Getty pour leurs excellentes équipes de conception et de publication, surtout Tevvy Ball, éditeur, et Pamela Heath, coordinatrice de la production.

Avec ce recueil nous renouvelons notre engagement envers la conservation du patrimoine bâti en terre à travers le monde. En poursuivant la recherche dans ce domaine spécialisé d'étude, désormais une discipline à part entière, nous espérons renforcer et encourager une nouvelle collaboration avec nos collègues nationaux et internationaux et élargir notre réseau de plus en plus grand de professionnelles qui se consacrent à la préservation de ce patrimoine vulnérable pour le laisser en héritage aux générations futures.

TIMOTHY P. WHALEN
Directeur
Institut Getty de Conservation

Foreword

Mali is a meeting point of cultures and civilizations. It is also a land built of earth over centuries by the empires and kingdoms that have shaped its cultural and historical identity. Terra 2008, the 10th international conference on the study and conservation of earthen architecture, held in Bamako February 1–5, 2008, supported and encouraged this tradition of using earth as a building material—a tradition that has always characterized the lifestyle and architecture of Mali and its peoples.

With a record attendance of over four hundred participants from five continents, the Terra 2008 conference, the first of its kind held in Africa, honored the Malian people and the Malian government. But first and foremost, it honored professionals from the housing and building (masons and others, architects, technicians, and civil engineers) and cultural heritage (managers and conservators) sectors, development partners (nongovernmental organizations and associations), academics, and students. It also provided an opportunity to enhance the knowledge of local government officials, who came in great numbers from all regions of the country to understand and appreciate the experiences, techniques, and earthen building traditions from every continent and from different parts of Mali. Of particular inspiration and beauty were the sculptural facades built specifically for the conference at the Modibo Keita Memorial by Malian masons from Bandiagara, Djenné, Mopti, Ségou, and Timbuktu. Each structure, with its distinctive geometry, combination of textures and colors, and meaning, was a cultural and geographic biography. The facades illuminated the vitality of earthen architecture in Mali and underscored the importance of local perspectives and traditional knowledge in promoting and sustaining the use of earthen architecture at the global level.

This important conference emphasized the need to promote the use of local materials, in particular, *banco*, which underlies all the building skills and expertise of earthen construction. In addition, Terra 2008 has contributed to promoting the image of Mali and of Africa as a whole, where the practice of earthen architecture is still very much alive and where local knowledge in the area of building is well preserved.

Earth has been used all over the world as a natural building material; all the great civilizations have employed it to build cities and empires, as attested by the large number of monuments inscribed on the prestigious UNESCO World Heritage List, one-third of which are constructed partially or entirely of earth. In a world where the effects of globalization are drastically reducing earthen architectural expression and heritage, it is the duty of all those who believe in the values of earthen architectural heritage to do more to restore its standing. The perverse effects of climate change should be further motivation for developing earthen architecture, especially in tropical arid and semiarid regions where heat and repeated drought have a negative impact on the rural way of life and, due to energy consumption, on the economy of urban centers.

We sincerely thank the institutions and organizations that contributed to this major conference, in particular, our partner the Getty Conservation Institute and through it the Getty Foundation. We look forward to the next international Terra conference, so that it can add to the achievements of the Bamako conference and lead to the development of concrete action.

MOHAMED EL MOCTAR
Minister of Culture of Mali

Avant-propos

Terre de rencontre de cultures et de civilisations, le Mali est aussi un pays bâti en terre depuis des siècles, par les empires et les royaumes qui ont façonné son identité culturelle et historique. TERRA 2008, la 10^e conférence internationale sur l'étude et la conservation du patrimoine bâti en terre, tenue à Bamako du 1^{er} au 5 février 2008, est venue conforter et soutenir cette tradition d'utilisation du matériau « terre » qui a toujours caractérisé le mode de vie et d'habitat de la population.

Avec une participation record de plus de quatre cents participants, la conférence Terra 2008, première du genre organisée en Afrique, a honoré le peuple malien, les autorités au plus haut niveau, mais aussi et surtout les professionnels des secteurs de l'habitat et du bâtiment (maçons et autres ouvriers, architectes, techniciens et ingénieurs du génie civil), du patrimoine culturel (gestionnaires et conservateurs), les acteurs du développement (ONG et associations), les formateurs et les étudiants. Elle permettra également d'améliorer les connaissances des responsables des collectivités territoriales venus en grand nombre de toutes les régions du pays, pour comprendre et apprécier les expériences, les techniques d'utilisation et les cultures de construction en terre de tous les continents et des différentes régions du Mali. La beauté singulière des façades sculpturales construites spécialement pour la conférence dans l'enceinte du Mémorial Modibo

Keita par les maçons maliens de Bandiagara, Djenné, Mopti, Ségou et Tombouctou fut une véritable inspiration. Chaque structure, avec sa géométrie bien particulière et sa combinaison de textures, couleurs et significations constituait une biographie culturelle et géographique. Les façades illustraient brillamment la vitalité du bâti en terre au Mali, soulignant l'importance de la perspective locale et des connaissances traditionnelles dans la promotion et la pérennisation de l'architecture en terre au niveau mondial.

Cette grande rencontre permettra certainement de souligner l'intérêt de promouvoir l'utilisation des matériaux locaux, et plus spécialement du *banco*, qui sous-tend les savoirs et savoir-faire en matière de construction. Elle va également contribuer à promouvoir l'image du Mali et de toute l'Afrique où l'architecture de terre est une pratique toujours vivante et où les connaissances locales en matière de construction sont encore bien préservées et mises en valeur dans le secteur de l'habitat et du développement en général. La terre a toujours été utilisée dans toutes les régions comme matériau initial de construction ; toutes les grandes civilisations l'ont utilisée pour bâtir des cités et des empires, comme l'atteste d'ailleurs le nombre important de monuments inscrits sur la prestigieuse Liste du patrimoine mondial de l'UNESCO (un tiers des édifices classés sont en terre). Dans un monde où les effets de la mondialisation et de la globalisation sont en

train de réduire de façon drastique les expressions architecturales et patrimoniales liées à la terre en tant que matériau de construction, il est essentiel, pour tous ceux qui croient aux valeurs du patrimoine bâti en terre, de s'investir davantage pour lui redonner ses lettres de noblesse. Les effets pervers des changements climatiques doivent encore plus inciter au développement de l'architecture de terre, surtout dans les régions tropicales arides et/ou semi-arides où la chaleur due à de grandes insulations et à des sécheresses à répétition, a un effet négatif sur le mode de vie rural et sur l'économie des centres urbains, en raison de la forte consommation d'énergie.

Nous remercions très sincèrement les différents organismes et instituts qui ont contribué à la tenue de cette grande conférence, notamment notre partenaire l'Institut Getty de Conservation (GCI) et à travers lui, la Fondation Getty. Nous souhaitons vivement que la prochaine Conférence internationale Terra renforce les acquis de celle de Bamako et permette le développement d'actions concrètes.

MOHAMED EL MOCTAR
Ministère de la Culture du Mali

Opening Remarks

Your Excellency the Minister of Culture, esteemed hosts and representatives of other national and international institutions, distinguished colleagues and friends. On behalf of the Getty Conservation Institute, I am very pleased to welcome you to the opening of Terra 2008, the 10th international conference on the study and conservation of earthen architectural heritage and the first to be held in Africa. It has been a pleasure and a great privilege to organize this conference with our Malian partners, the Mali Ministry of Culture and the Direction Nationale du Patrimoine Culturel.

It has now been thirty-six years since the first meeting of experts on earthen architecture took place in Yazd, Iran. At that meeting, 31 participants from six countries sowed the seeds for focused research and study and for many subsequent meetings and conferences, which have been hosted by organizations around the world under the auspices of ICOMOS and its international scientific committee on the earthen architectural heritage. Since that first meeting over three decades ago, this specialized field of study has grown tremendously, and the number of specialists and practitioners has increased worldwide. We are delighted to have with us here in Bamako over 450 participants from sixty-five countries, including more than 100 colleagues from Mali, who represent expertise in all areas of earthen architecture, from the conservation of archaeological and living sites to new design and construction, increasingly important as the “green building” movement and issues of sustainability gain status and importance worldwide. From the days when few opportunities existed to gain expertise in building with earth, training programs with a specialization in earthen architecture are opening in many universities and architecture schools around the world, further evidence of

the continued importance of earth building as a significant part of our shared cultural tradition.

Of course, the overwhelmingly positive response to this conference also shows the interest of the earthen architectural community in the extraordinary heritage of West Africa. With a large portion of the population in the region living and/or working in earth constructions of great variety and expression, it is entirely fitting that we have assembled in this part of the world to exchange information and experiences regarding the earthen heritage in its global dimensions. Indeed, the very rich earth building tradition, still in practice today in Mali, provides an important physical and cultural context for our meeting, reminding us both of earthen architecture’s vulnerability in the face of development pressures and new construction using so-called modern materials and of its tangible and intangible value to the culture of Mali, the region, and many other parts of the world.

On a more somber note, this conference comes at a time when we have seen several major seismic events in especially vulnerable areas with significant earthen architectural heritage. Since the last conference, in Yazd in 2003, there have been devastating earthquakes in Iran, Pakistan, and Peru, which have cost dearly in loss of life and loss of heritage. Such tragedy has spurred new scientific study, and at this conference we will hear results of some of this research on seismic issues and standards for earthen construction.

The conference will deal with these and other important issues, from the conservation and management of archaeological sites to local knowledge systems and intangible aspects of earthen heritage to issues of conservation and development through a series of themed sessions and, subsequently, an

afternoon of working groups and discussion. The conference will conclude with a presentation of the major points that have emerged from the sessions and summary recommendations that I hope may inform our future work in the field.

As always, such a large conference could not happen without the efforts of countless people. First and foremost, I would like to thank the Minister of Culture, His Excellency Mohamed El Moctar, and his predecessor for agreeing to work with us in planning this event. Needless to say, the support of the Ministry of Culture was essential to making this conference possible. Since those early days, the ministry staff, especially Al Hady Koita, Secretary General; Klessigué Sanogo, Director of Cultural Patrimony, and his staff; and Lassana Cissé, head of the Bandiagara Cultural Mission, have worked tirelessly to coordinate the conference program, speakers, and activities locally. Thanks also go to Alpha Diop, coordinator of the conference secretariat, and the assistant coordinator, Mme Fatima Sidibé, who have worked so hard to make all the logistics come together. We are very grateful, too, to Samuel Sidibé, Director of the National Museum of Mali, who envisioned and oversaw the exhibits to be held there and at the Memorial Modibo Keita, which are aimed at raising the awareness of the public for this unique and universal aspect of our cultural heritage.

Of course, many colleagues outside Mali also supported the development of the conference. In the first instance, I would like to thank Thierry Joffroy, President of CRATerre-ENSAG, who facilitated our early meetings in Mali and generously shared his knowledge of the country and its heritage. Particular thanks also go to the scientific committee that was put in place to advise on the conference content and program. The committee members, who are too numerous to mention individually but are listed in your abstracts volume, reviewed over 250 abstracts to select the oral and poster presentations and gave selflessly of their time and expertise. We could not have done this without them.

We are also extremely grateful to the organizations that have funded grantees to attend the conference: the Getty Foundation, the World Heritage Centre, the Africa 2009 partners, Misereor, and the Ford Foundation West Africa. This conference would not have such a diverse participation from so many areas of the world were it not for their generosity and support. I want to give special thanks to Marina Trappeniers from CRATerre-ENSAG, Lazare Eloundou and Jana Weydt of the World Heritage Centre, and Lassana Cissé of the

Bandiagara Cultural Mission, who administered the distribution of grant monies and ensured that the grantees actually arrived in Bamako.

I would be remiss if I did not also mention my own extraordinary staff at the Getty Conservation Institute who have worked so hard for over two years now to make this conference happen. In particular, I would like to thank Leslie Rainer, who has done a superb job of managing the organization of the conference from our end, and Kathleen Louw, who has gone above and beyond to handle not only all the conference logistics but also the coordination of the exhibits and postconference tours, with the able help of her assistant, Anais Khalatbari. Without their commitment, persistence, and endless attention to detail, this conference would not have been possible.

Finally, on a personal note, I would like to thank Alejandro Alva, recently retired as Director of Sites at ICCROM, and Hugo Houben, one of the founding directors of CRATerre, two people who taught me most of what I know about earthen architecture and who inspired a lifelong commitment to its conservation. I certainly would not be standing here without them.

I will close here to turn the proceedings over to His Excellency Mohamed El Moctar, the Minister of Culture of Mali, who will officially open the conference. Thanks to all of you for taking time from your very busy schedules to make the trip to Mali to attend this 10th international conference. I am sure that we can look forward to an exciting program filled with new information and thought-provoking discussion.

The Getty Conservation Institute remains committed to the study and conservation of our earthen architectural heritage, joining many national intergovernmental and nongovernmental organizations. In a world of diminishing resources for heritage, I would like to make a plea for continued international collaboration in this sphere so as to achieve maximum impact and to reduce duplication of effort. Hopefully, our joint work at this conference and beyond will move the field forward and will help to ensure that the world's extraordinary earthen heritage and the know-how that created it will survive for generations to come.

JEANNE MARIE TEUTONICO
Associate Director, Programs
Getty Conservation Institute

Allocution d'ouverture

Excellence, Monsieur le Ministre de la Culture, estimés hôtes et représentants d'autres institutions nationales et internationales, collègues distingués et amis. Au nom de l'Institut Getty de Conservation, j'ai le plaisir de vous souhaiter la bienvenue à l'ouverture de Terra 2008, 10^e conférence internationale sur l'étude et la conservation du patrimoine bâti en terre, et première du genre organisée en Afrique. L'organisation conjointe de cette conférence avec nos partenaires maliens – le Ministère de la Culture du Mali et la Direction Nationale du Patrimoine Culturel – est un plaisir et un grand privilège.

Trente-six ans se sont écoulés depuis la tenue de la première rencontre d'experts sur l'architecture de terre à Yazd, Iran. Cette rencontre, qui avait réuni 31 participants de six pays, a permis d'ouvrir la voie à la recherche, à l'étude et aux nombreuses rencontres qui ont suivi, organisées par différentes organisations à travers le monde sous les auspices de l'ICOMOS et de son comité scientifique international du patrimoine de l'architecture en terre. Depuis cette première réunion, il y a plus de trois décennies, nous avons assisté au développement spectaculaire de ce domaine spécialisé d'étude, et à la multiplication du nombre de spécialistes et de praticiens partout dans le monde. Nous sommes heureux d'accueillir à Bamako plus de 450 participants de soixante-cinq pays, dont plus de 100 collègues du Mali, qui rassemblent les connaissances spécialisées de tous les domaines de l'architecture en terre, depuis la conservation des sites archéologiques et des sites vivants jusqu'aux nouvelles conceptions et techniques de construction. Ce dernier domaine prend de plus en plus d'envergure avec le récent développement du mouve-

ment en faveur de la « construction verte » et des questions de durabilité. L'époque est révolue où il était difficile et rare de pouvoir approfondir ses connaissances en construction en terre. Actuellement, de nombreuses universités et écoles d'architecture proposent des programmes de formation avec une spécialisation en architecture en terre, ce qui montre bien l'importance constante des bâtiments en terre en tant qu'éléments importants de notre tradition culturelle commune.

Certes, la réponse extrêmement positive à cette conférence témoigne également de l'intérêt que porte la communauté de l'architecture en terre au patrimoine extraordinaire de l'Afrique de l'Ouest. Avec une partie non négligeable de la population de la région qui vit et/ou travaille dans des constructions en terre d'expressions très variées, il est tout à fait pertinent de nous réunir dans cette partie du monde afin d'échanger des informations et des expériences sur le patrimoine bâti en terre au niveau mondial. En effet, la très riche tradition de construction en terre qui continue à être pratiquée au Mali offre un contexte matériel et culturel important à notre rencontre. Elle nous rappelle à la fois la vulnérabilité de l'architecture de terre face aux pressions du développement et des nouvelles constructions employant des matériaux dits « modernes », et sa valeur matérielle et immatérielle pour la culture du Mali, de la région et de bien d'autres lieux à travers le monde.

Sur une note plus sombre, cette conférence se tient à un moment où plusieurs secousses sismiques se sont produites dans des régions particulièrement vulnérables possédant un patrimoine en terre de très grande valeur. Depuis la dernière conférence à Yazd en 2003, des séismes dévastateurs se sont

produits en Iran, au Pakistan et au Pérou, entraînant de nombreuses pertes humaines et la disparition d'un patrimoine considérable. De telles tragédies ont suscité de nouvelles recherches scientifiques et cette conférence permettra de prendre connaissance de certains résultats de recherche sur les questions sismiques et les normes en matière de construction en terre.

La conférence abordera ces questions, ainsi que d'autres problématiques importantes, allant de la conservation et de la gestion des sites archéologiques aux systèmes de savoirs locaux et aux aspects immatériels du patrimoine en terre, aux questions de conservation et de développement, à travers une série de sessions à thème, suivies dans l'après-midi par des groupes de travail et des débats. La conférence se terminera par la présentation des points forts émanant des sessions et par un résumé des recommandations qui, je l'espère, enrichiront notre travail en ce domaine.

Comme toujours, une conférence de cette envergure ne peut aboutir sans d'innombrables efforts conjugués. Je souhaite tout d'abord remercier le Ministre de la Culture, Son Excellence Mohamed El Moctar, ainsi que son prédécesseur, qui ont donné leur accord pour entreprendre avec nous la planification de cette manifestation. Bien entendu, sans le soutien du Ministère de la Culture, cette conférence n'aurait pas été possible. Depuis le début, le personnel du Ministère, notamment Al Hady Koita, Secrétaire général, Klessigué Sanogo, Directeur du Patrimoine culturel et son équipe, et Lassana Cissé, Directeur de la Mission culturelle de Bandiagara, ont œuvré sans relâche pour coordonner le programme de la conférence, les intervenants et les activités au niveau local. Mes remerciements vont aussi vers Alpha Diop, coordinateur du Secrétariat de la conférence et à l'assistante coordinatrice, Mme Fatima Sidibé, qui ont déployé d'énormes efforts pour assurer la logistique. Nous sommes également très reconnaissants au Directeur du Musée National du Mali, Samuel Sidibé, qui a imaginé et suivi les expositions organisées sur les lieux ainsi qu'au Mémorial Modibo Keita, afin de sensibiliser le public à cet aspect unique et universel de notre patrimoine culturel.

Évidemment, de nombreux collègues d'ailleurs ont aussi contribué à l'organisation de la conférence. Je voudrais remercier en premier lieu Thierry Joffroy, Président de CRATerre-ENSAG, qui a facilité nos premières réunions au Mali et qui a généreusement partagé sa connaissance du pays et de son patrimoine. Des remerciements particuliers vont

également au Comité scientifique mis en place pour donner des conseils sur le contenu et le programme de la conférence. Les membres du comité (trop nombreux pour être cités individuellement ici mais dont les noms figurent dans le recueil des résumés) ont passé en revue plus de 250 résumés afin de sélectionner les communications orales et les posters. Ils ont offert leur temps et leurs compétences sans compter et leurs conseils ont été extrêmement précieux.

Nous sommes aussi particulièrement reconnaissants aux organisations qui ont financé les boursiers, leurs permettant ainsi d'assister à la conférence – La Fondation Getty, le Centre du patrimoine mondial, les partenaires d'Africa 2009, Misereor, et la Fondation Ford Afrique de l'Ouest. Cette conférence n'aurait pu réunir une participation aussi diversifiée provenant d'autant de régions du monde sans leur générosité et leur soutien. Nous adressons des remerciements particuliers à Marina Trappeniers de CRATerre-ENSAG, Lazare Eloundou et Jana Weydt du Centre du patrimoine mondial et Lassana Cissé de la Mission culturelle de Bandiagara, qui ont géré la répartition des fonds en s'assurant de l'arrivée des boursiers à Bamako.

Je ne pourrais pas ne pas mentionner mon propre personnel extraordinaire de l'Institut Getty de Conservation, qui a travaillé sans relâche pendant plus de deux ans pour faire aboutir la conférence. Je souhaite remercier tout particulièrement Leslie Rainer, qui a fait un travail magnifique en gérant l'organisation de la conférence qui relevait de notre Institut, et Kathleen Louw, qui s'est surpassée en assurant non seulement l'organisation de la logistique de la conférence, mais aussi la coordination des expositions et des excursions après la conférence, avec l'aide de son assistante, Anais Khalatbari. Sans leur engagement, leur persévérance et leur attention aux plus petits détails, cette conférence n'aurait pas été possible.

Finalement, sur une note plus personnelle, je souhaiterais remercier Alejandro Alva, Directeur des Sites à l'ICCROM, qui a récemment pris sa retraite, et Hugo Houben, un des directeurs fondateurs de CRATerre – deux personnes qui m'ont appris à peu près tout ce que je sais sur l'architecture en terre, et qui m'ont inspiré un engagement de toute une vie pour sa conservation. Sans eux, je ne me trouverais certainement pas ici devant vous.

Je terminerai ici pour céder la parole au Ministre qui prononcera l'ouverture officielle de la conférence. Merci à vous tous pour avoir pris le temps de vous rendre ici au Mali, malgré vos emplois du temps très chargés, pour assister à

cette 10^e conférence internationale. Je suis persuadée que le programme sera très intéressant, riche d'informations nouvelles et de discussions passionnantes.

L'Institut Getty de Conservation maintient son engagement en faveur de l'étude et de la conservation de notre patrimoine bâti en terre, en collaboration avec de nombreuses organisations nationales, intergouvernementales et non gouvernementales. Dans un monde où les ressources consacrées au patrimoine diminuent, je souhaiterais lancer un appel pour la poursuite de la collaboration internationale dans ce

domaine, afin d'atteindre le maximum d'impact et éviter une duplication des efforts. Il faut espérer que notre travail commun lors de cette conférence et ensuite permettra de faire avancer ce domaine de connaissance et d'assurer le maintien de l'extraordinaire patrimoine mondial en terre, ainsi que des savoirs qui l'ont créé, pour les générations à venir.

JEANNE MARIE TEUTONICO
Directrice associée des Programmes
l'Institut Getty de Conservation

Keynote Address : L'architecture de terre, une discipline à part entière ?

Hugo Houben

Résumé : *En 1972, trente et un spécialistes participaient au Premier colloque international sur la conservation des monuments en brique crue, tenu à Yazd, Iran. Trente-six ans plus tard, la Dixième conférence internationale sur l'étude et la conservation du patrimoine bâti en terre, organisée à Bamako en 2008, rassemble quelque 450 participants d'une soixantaine de pays. Entre ces deux événements, il y a eu un changement d'échelle révélateur d'une évolution évidente du statut de l'architecture de terre. Est-il raisonnable de qualifier l'architecture de terre de simple sujet d'intérêt en 1972 et de lui attribuer un statut de discipline à part entière en 2008 ?*

Abstract: *In 1972 thirty-one specialists participated in the First International Colloquium on the Conservation of Mud Brick Monuments, held in Yazd, Iran. Thirty-six years later the 10th international conference on the study and conservation of earthen architectural heritage, organized in Bamako in 2008, has brought together about 450 participants from sixty countries. Between these two events there has been a change of scale that is an indication of the clear evolution of the status of earthen architecture. Is it appropriate to qualify earthen architecture as a simple subject of interest in 1972 and to attribute to it the status of a discipline in its own right in 2008?*

Entre le Premier colloque international sur la conservation des monuments en brique crue, tenu à Yazd en 1972, et la Dixième conférence internationale sur l'étude et la conservation du patrimoine bâti en terre, organisée à Bamako en 2008, peut-on observer un changement de statut de l'architecture de terre ? Est-il raisonnable de qualifier l'architecture de terre de simple sujet d'intérêt en 1972, et de lui attribuer un statut de discipline à part entière en 2008 ? Si c'est le cas,

quels sont les éléments contextuels d'une prise de conscience qui a provoqué l'évolution de cette perception de l'architecture de terre par ses acteurs et les milieux dans lesquels ils œuvrent, et qui a conduit à ce changement de statut ? Sur le plan institutionnel, selon quels processus et quelles modalités l'architecture de terre est-elle parvenue à s'implanter comme discipline dans les milieux académiques et à s'affirmer à l'extérieur ? Quelles sont ses délimitations précises ? Quelle est sa structure ? Qu'est-ce qui la différencie des autres disciplines ?

Il y a plusieurs définitions du terme « discipline ». Ainsi, « une discipline scientifique est un sous-ensemble de la science »¹. Ou encore, « une discipline est constituée par un sujet qui est enseigné, c'est une branche de l'enseignement, un champ d'étude »².

La notion de discipline peut aussi être définie comme un mode d'organisation des pratiques, des discours et des identités professionnelles par lequel ceux-ci se trouvent stabilisés, régulés et transmis, dans le cadre d'une production de savoirs. Stabilisation, régulation et transmission sont alors assurés par le jeu de dispositifs « spécialisés » de publication, de dispositifs éducatifs organisant la transmission de savoirs explicites et implicites désignés comme constitutifs de la discipline, comme par exemple de chaires, de séminaires, travaux pratiques, manuels et autres. Elles sont également assurées par des dispositifs organisant la démarcation entre le spécialiste et le profane en créant les conditions d'un territoire réservé, par exemple par l'intermédiaire de certificats, diplômes académiques, mythologie des fondateurs ou des précurseurs, un vocabulaire spécifique et bien d'autres dispositifs.

Le premier colloque international sur la conservation des monuments en brique crue a été organisé par l'ICOMOS

International et l'ICOMOS-Iran à Yazd, du 25 au 30 novembre 1972, avec le concours de l'UNESCO. Il y avait 31 participants, de 6 pays (Allemagne, États-Unis, France, Iran, Italie, Pays-Bas) et de 2 institutions internationales. Le 2^e colloque comptait 64 participants de 17 pays et 3 institutions internationales. Il s'agissait donc d'une petite communauté de spécialistes manifestement soucieux d'introduire une certaine régularité et normalité dans leurs échanges. Près de 40 ans plus tard, Terra 2008 est la dixième conférence du genre et rassemble plus de 450 participants d'une soixantaine de pays. Entre temps, ce colloque a fait le tour des continents. Aujourd'hui, l'architecture de terre est donc gérée par quelque chose de plus qu'une communauté puisqu'elle s'est notamment dotée d'un organe régulier de communication : le cycle des conférences Terra, et bien d'autres.

L'architecture de terre a acquis une certaine autonomie par rapport à l'architecture en tant que telle, dans la mesure où elle possède ses propres unités de recherche, donne ses propres formations et produit ses propres diplômes. Cela signifie qu'une discipline peut acquérir son autonomie institutionnelle, ou du moins une certaine marge d'autonomie, même en se développant à l'intérieur de la structure d'organisation d'une autre discipline ou d'une discipline plus large.

L'architecture de terre a émergé comme un domaine de spécialisation à l'intérieur des disciplines existantes comme l'architecture, la science des matériaux et l'ingénierie civile. Elle s'est graduellement transformée en une discipline autonome avec la mise en place de laboratoires ou groupes de recherches spécialisés dans le milieu universitaire et professionnel.

La première chose à faire pour une discipline, c'est d'en définir précisément le sujet. Dans le cas de l'architecture de terre, on pourra constater lors de ce colloque que des efforts considérables sont en cours, notamment de la part du Comité spécialisé américain de l'ICOMOS qui cherche à établir une taxonomie permettant de définir très précisément les champs d'application et les limites de l'architecture de terre.

Il reste évidemment à structurer le contenu de ladite discipline. Là encore, il convient de rappeler que le projet Terra a produit des contributions remarquables à cet égard dans les années 2000³. Ces efforts n'ont pas complètement abouti, mais des progrès appréciables ont été enregistrés, et ont d'ailleurs trouvé écho lors de la 8^{ème} conférence Terra 2000.

Toute discipline a pour objet de développer des savoirs permettant d'élargir le domaine de ses connaissances scientifiques et techniques – théoriques et pratiques, et à en faciliter ainsi le développement sur le plan scientifique et profession-

nel. Quelles sont les connaissances rassemblées et les réalisations de l'architecture de terre en tant que discipline dans les quatre domaines essentiels qui conditionnent son existence : recherche, enseignement, application et valorisation, ainsi qu'en matière de gestion des connaissances utilisées et produites par ces quatre domaines ? Et comment envisager l'évolution de cette nouvelle discipline qu'est l'architecture de terre ?

En matière de recherche

On assiste à une évolution. Depuis l'interrogation sur la nécessité d'une granulométrie et sur les moyens de la réaliser et de l'interpréter, on arrive, 30 ans plus tard, à utiliser des moyens scientifiques énormes pour percer les secrets de la terre au niveau macromoléculaire. Cela est de nouveau bien significatif d'une spécificité de l'architecture de terre, car on ne trouve pas de recherches à ce niveau de profondeur dans d'autres disciplines pourtant totalement consacrées à la terre, comme l'agriculture ou les travaux publics.

À plusieurs reprises dans l'histoire récente, les acteurs de l'architecture de terre ont ressenti le besoin de faire le point des connaissances en la matière. Les derniers travaux en date portent sur la revue de la documentation de recherche scientifique sur la conservation de l'architecture de terre⁴. En même temps, d'énormes efforts ont été déployés pour établir les besoins en nouvelles connaissances pour pouvoir faire évoluer au mieux les pratiques de construction et de conservation. Il s'agissait de définir les voies de la recherche, de déterminer les priorités, de préciser les termes de références, et de permettre la création de partenariats. Les derniers rapports à ce sujet ont été publiés en 2001 dans le cadre des stratégies établies par le projet Terra. Les conclusions de ces rapports, consultables sur les sites Internet des partenaires, restent d'une actualité extrême. La méthode utilisée pour les travaux qui ont permis de réaliser ces rapports était clairement multidisciplinaire. On a donc fait appel à tout un ensemble de disciplines voisines pour pouvoir déterminer l'ensemble des points qui constitueraient notre propre spécificité.

Des programmes de recherche nationaux et internationaux sont en cours au niveau de l'Union européenne (dans des pays scandinaves et des pays d'Europe de l'Est) (Westermarck 1998). Cela montre, une fois de plus, s'il fallait le rappeler, qu'il existe une importante communauté mobilisée sur la production de connaissances spécifiques à l'architecture de terre, et cela dans un cadre prédéterminé et relativement

précis. Il s'agit donc d'activités dont la nature et les méthodes s'apparentent à ce qui définit une discipline.

En matière d'enseignement

Les connaissances acquises sur les chantiers et à travers les résultats de nombreux programmes de recherche ont été rassemblées et capitalisées par de nombreuses publications – rapports, livres, manuels et autres. Ces publications visent réellement à être didactiques et structurées, de manière à pouvoir être utilisées comme documents de référence pour l'organisation de cours (Houben et Guillaud 2006). D'autres projets ont cherché à présenter des connaissances spécifiques sous l'aspect de kits pédagogiques prêts à l'emploi, parfois accompagnés de véritables programmes de transmission de connaissances dans des écoles professionnelles et institutions universitaires⁵.

Une discipline n'a pas seulement besoin d'outils pédagogiques pour transmettre le savoir, mais doit bien sûr disposer de canaux de transmission, de cours et de cycles de cours à tous les niveaux et de toute nature. C'est le cas ici. Il est actuellement devenu impossible recenser tous les cours dispensés à travers le monde sur l'architecture de terre. Il est cependant important de signaler que plusieurs réseaux se sont formés autour d'activités pédagogiques, notamment le projet Leonardo da Vinci de la Commission européenne⁶. Celui-ci a permis d'organiser des cours de formation professionnelle sur les enduits en terre dans six pays et d'obtenir l'équivalence des certificats professionnels délivrés et l'interchangeabilité au niveau européen.

Il existe aussi trois réseaux universitaires très étendus. Tout d'abord, UNI-Terra⁷, dont on peut consulter la liste de dizaines d'universités sur le magnifique site du Dachverband Lehm, situé en Allemagne. Le réseau Universiterra est domicilié en Italie. Enfin, le Consortium Terra est un réseau de 23 institutions universitaires et professionnelles dispensant des cours de très haut niveau sur l'architecture de terre et qui constituent le réseau UNITWIN/Chaires UNESCO, intitulé « Architecture de terre, cultures constructives et développement durable ».

En matière d'application

Les applications de l'architecture sont évidemment innombrables et s'exercent à un niveau planétaire. Cela ne constitue pas en soi un élément significatif d'une discipline. Ce sont

les éléments théoriques de la pratique qui constituent les éléments nécessaires à l'existence d'une discipline. Ces éléments théoriques sont constitués par des codes de bonne pratique, des textes normatifs, des procédures écrites sous formes de manuels, des textes juridiques spécifiques.

Tous ces éléments existent. Un inventaire récent a ainsi permis d'inventorier des textes normatifs dans plus de 60 pays du monde, dont 24 en Afrique.

Une discipline s'appuie aussi sur des moyens de communication. Plusieurs séminaires interprofessionnels et réunissant des entrepreneurs ont été organisés en Afrique. Dans certains pays, notamment en France et en Allemagne, il existe des regroupements de professionnels.

En matière de valorisation

De ce point de vue, dix ans après Yazd, il s'est produit un événement synthétique majeur et précurseur juste avant la 4^e Conférence internationale de 1983 « Adobe : Colloque international et atelier de formation sur la conservation de l'adobe »⁸ : la grande exposition « Architectures de terre – Passé, présent et futur » au Centre Georges Pompidou (Dethier 1982). Cette exposition a circulé dans une quinzaine de pays en 22 étapes. Elle a été visitée par au moins 2,5 millions de personnes et a suscité d'innombrables prises de conscience et vocations. La discipline naissante de l'architecture de terre disposait ainsi d'un premier outil médiatique de diffusion de connaissances à très grande échelle.

Plus récemment, on assiste à une avalanche de films et de reportages télévisés, de livres, de dizaines de rapports de recherche par an, d'innombrables sites sur Internet sur le sujet. Il ne se passe pas un mois sans séminaires, colloques ou conférences quelque part. Des revues innombrables circulent également parmi la communauté concernée.

Conclusion

Oui, l'architecture de terre est devenue une discipline à part entière. Pour ceux qui adoptent une attitude plus sceptique, on pourrait en tout cas dire que c'est une discipline en devenir. Pour ceux qui sont franchement dubitatifs, il devrait probablement suffire de distinguer l'architecture de terre en se fondant sur sa spécialisation et son utilité en termes de connaissances d'un problème dont l'importance est reconnue.

Pour nous, cette importance est directement liée à l'ampleur socio-spatio-temporelle de l'architecture de terre,

domaine qui concerne presque 20 % du patrimoine culturel de la Liste du patrimoine mondial de l'UNESCO et 30 % de la liste des villes du patrimoine mondial. D'autre part, l'architecture de terre renvoie à une culture de construction avec le matériau le plus largement utilisé au monde. On parle ici de plus de 50 % de la population mondiale⁹. Ce domaine si vaste qui concerne à la fois le mode de construction le plus ancien, le plus répandu et le plus universel, mérite par définition de devenir une discipline à part entière.

La vision d'avenir de la discipline a été élaborée par le Projet Terra. Il s'agit pour la recherche d'élaborer une science spécifique. En matière d'enseignement, l'architecture de terre doit devenir un sujet d'étude à part entière dont l'application exigera une véritable pratique professionnelle. Pour la valorisation, l'objectif est de créer une véritable mobilisation de la société autour de l'architecture de terre.

Une discipline a aussi besoin de théorie. Il reste donc à élaborer prochainement une théorie de l'architecture de terre, qui devra être fondée sur une analyse critique de l'histoire. Le travail le plus important et le plus urgent à effectuer est donc d'établir et d'écrire l'histoire de l'architecture de terre.

De tels objectifs exigent une coordination qui ne peut être animée que par des grands programmes ou projets visionnaires à l'échelle de la coopération internationale, comme le projet GAIA, le projet TERRA, Africa 2009, Central Asian Earth. Ces projets viennent malheureusement de se terminer ou arrivent prochainement à échéance. Heureusement, le relais est assuré par le nouveau programme « Architecture de terre – 2007/2017 », mis en place par le Centre du patrimoine mondial de l'UNESCO. Ce programme trouve ses racines dans le projet Africa 2009, donc en Afrique, et va s'étendre au fur et à mesure à tous les continents.

L'architecture de terre, une discipline à part entière, une discipline en devenir, ou une discipline à devenir ? Monsieur le Ministre de la Culture du Mali, Madame la Directrice adjointe de l'Institut Getty de Conservation, je vous remercie de me permettre de déclarer à l'occasion de la Dixième conférence internationale sur l'étude et la conservation du patrimoine bâti en terre – Terra 2008 –, ici en terre africaine du Mali, écrin de l'architecture de terre, que cette architecture de terre est devenue une discipline. Une discipline dont le façonnage demande encore beaucoup de travail, mais une discipline à part entière.

Notes

- 1 http://fr.wikipedia.org/wiki/Discipline_scientifique.
- 2 *Merriam-Webster's Unabridged Dictionary*, 2000.
- 3 Structuring the Discipline of the Conservation of Earthen Architecture, minutes of the June meeting in Grenoble, Project TERRA, 24–26 June 1998, CRATerre-EAG, GCI, ICCROM. Unpublished.
- 4 A Critical Review of Literature in the Field of Earthen Architecture Conservation (1985-2000). Project TERRA 2000 can be found at www.getty.edu/conservation/publications/pdf_publications/terra_lit_review.pdf.
- 5 University of Makerere, Kampala, Uganda. Abubakar Tafawa Balewa University, Bauchi, Nigeria. Centre national d'études et de recherches intégrées du bâtiment, Alger, Algérie. Institut supérieur inter-États de formation et de recherche dans les domaines de l'eau, l'énergie, l'environnement et les infrastructures, Ouagadougou, Burkina Faso.
- 6 Construire en terre aujourd'hui. Les enduits de terre. Projet pilote. Leonardo da Vinci. Commission européenne (Allemagne, Bulgarie, France, Grèce, Pologne, Royaume-Uni).
- 7 www.uni-terra.org.
- 8 Adobe: International Symposium and Training Workshop on the Conservation of Adobe, Lima-Cuzco (Peru), 10–22 September 1983.
- 9 U.S. Department of Energy, September 2004. www.eere.energy.gov/consumerinfo/reading_resources/ve6.html.

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PART ONE

**Earthen Architecture
in Mali**

**L'architecture de terre
au Mali**

Constructions en terre au Mali : Dynamiques sociales et culturelles d'une tradition ancestrale de construction

Lassana Cissé

Résumé : *Les constructions en terre constituent une grande partie du patrimoine architectural malien. Les traditions d'utilisation des matériaux en terre remontent aux premiers grands empires et royaumes médiévaux. Les péripéties de l'histoire et de l'évolution des sociétés n'ont pas radicalement bouleversé les pratiques de construction en terre. Bien au contraire, les périodes d'occupation et/ou de domination qui ont suivi ont su harmonieusement intégrer les techniques et savoir-faire anciens aux constructions monumentales en terre (mosquées, églises, palais royaux, résidences et autres). Aujourd'hui encore, le patrimoine bâti en terre conserve toutes ses lettres de noblesse dans beaucoup de régions, malgré les mutations socio-économiques et le phénomène de la mondialisation.*

Abstract: *Earthen constructions represent a majority of the architectural heritage of Mali. The tradition of earthen building dates to the first large empires and medieval kingdoms. Despite Mali's history of tribulations and societal changes, earthen building practices have not disappeared. On the contrary, the various phases of occupation or dominant rule in Mali have allowed the harmonious integration of traditional techniques and knowledge with monumental earthen constructions such as mosques, churches, royal palaces, and residences. Earthen architectural heritage today maintains a noble status in many regions, despite current socioeconomic trends and globalization.*

Vieille terre de civilisations, le territoire occupé par le Mali a développé différentes cultures constructives basées sur le matériau terre. Entre le VII^e et le XI^e siècle déjà, la première grande formation politique étatique, le Royaume du Ghana, a

créé des cités remarquables telles que Koumbi Saleh dont les vestiges révélés par l'archéologie attestent le développement d'une architecture médiévale en terre caractérisée par des constructions monumentales (palais, maisons familiales et lieux de culte) et un habitat écologiquement adapté.

Ce royaume, dévasté en 1076 par les Almoravides, sera suivi à partir de 1235 par une autre entité territoriale politique (sans doute la plus grande), l'empire Mandé, fondé par Souliata Kéita. À son apogée au XIV^e siècle, les dirigeants de cet empire ont su développer une architecture spectaculaire dont subsistent certains témoins matériels comme les mosquées de Manfara (ouest de Bamako) et de Djingarey Ber (Tombouctou), ou la case sacrée de Kangaba, communément appelée *kamablon*. Des cités urbaines anciennes comme Tombouctou, Niani, Djenné et Dia ont été entièrement bâties en terre au Moyen Âge.

L'empire Songhay (XV^e-XVI^e siècles) a perpétué l'architecture de terre dans le Delta intérieur du fleuve Niger et au-delà, avec le développement de centres et cités historiques (Koukia, Gao, Hombori) et la construction à Gao d'un monument en terre inscrit en 2004 sur la Liste du patrimoine mondial de l'UNESCO sous l'appellation de « Tombeau des Askia ».

Les Royaumes Bambara de Ségou et du Kaarta (XVII^e-XVIII^e siècles), les empires Peulh et Toucouleur du Macina ont développé ce patrimoine architectural en terre et l'ont enrichi en élaborant les composantes stylistiques, en variant les typologies constructives et en diversifiant les fonctions des bâtiments (fig. 1).



FIGURE 1 Tradition de construction en terre (banco rouge) à Ségou : la galerie d'art et d'artisanat de l'association Kasobane. Photo : L. Cissé, 2007

Le Delta intérieur du Niger (DIN) et la zone inondée

Connu comme « le pays de l'eau et de l'herbe », le Delta intérieur du fleuve Niger a été très convoité par plusieurs chefferies, royaumes et empires au cours du temps. Dans cette région, des témoignages d'occupation humaine existent encore sous forme de sites historiques et/ou archéologiques. Les buttes anthropiques (en peulh, *toгуéré*), souvent très hautes, constituent des vestiges qui témoignent matériellement de l'existence et de l'évolution de cultures constructives en terre encore vivantes.

L'architecture de terre de cette contrée est unique au Mali et dans la sous-région ouest africaine. Les populations ont su développer, au fil des siècles, des formes et des techniques de construction en terre qui sont à la base du style architectural dit « soudanais », largement mis en valeur pendant la période coloniale, avec la construction de bâtiments dans les villes de Kayes, Ségou, Mopti et Bamako.

Plusieurs méthodes et façons de bâtir se sont développées au fil du temps : les fortifications ou *tata*, les maisons et palais royaux, et surtout les façades ornementales connues dans la région de Djenné, du Delta intérieur du Niger (façades toucouleurs ou marocaines), du pays dogon (façade des *gin'na*) et de Tombouctou, entre autres.

Une autre architecture en terre assez remarquable s'est massivement répandue sur le territoire du Mali bien avant la période coloniale : l'architecture des greniers disséminés dans toutes les aires culturelles.

Les constructions en terre au Mali : Typologies et tendances évolutives

Les maisons d'habitation traditionnelles

Au moins 70 % de la population malienne (estimée à environ 13 millions d'habitants) vivent en milieu rural et habitent dans des maisons en terre. C'est dire que l'architecture de terre est une tradition d'habitat millénaire, encore très perceptible dans les villages et les villes.

L'espace habité exprime le plus souvent le mode social et économique de vie des communautés. Celui-ci se caractérise toujours par une solidarité active qui a assuré à cette architecture sa survie et sa pérennité. Les travaux d'entretien régulier ont toujours été assurés par les membres de la famille, du clan ou des groupes d'âge.

Les maisons sont généralement construites en adobe ou en pisé. Elles comprennent les éléments suivants :

- les pièces d'habitation
- la cuisine
- le vestibule ou lieu des rencontres et des palabres
- des toilettes

Toutes les régions du Mali sont marquées par un système d'habitation caractérisé par des constructions en terre. Même dans des zones comme celle du pays dogon, où prédomine la pierre en tant que matériau le plus abondant, l'architecture de terre est très présente dans le système d'habitation. Les maisons de lignage (*gin'na*) les temples et sanctuaires totémiques et les greniers connexes sont, pour des raisons écologiques, construits en argile recueillie dans les bas-fonds des vallées ou dans la plaine.

Pour illustrer le mode d'habitation en terre, Djenné et sa région semblent être un cas assez typique et exceptionnel. Forme d'habitat humain et significatif du *pondo* (vallée du fleuve), la ville ancienne de Djenné, métropole soudanaise, présente une expression spécifique de l'architecture en terre et de l'urbanisme du Delta intérieur du Niger ; ses techniques de construction en terre, notamment ses briques cylindriques (ou *djenné ferey*), furent exportées jusqu'au nord du pays.

Djenné est un centre d'échanges commerciaux habité depuis 250 avant Jésus-Christ. Ses maisons traditionnelles édifiées sur des buttes anthropiques (*toгуéré*) sont bien adaptées pour résister aux inondations récurrentes de certaines périodes de grandes pluies.

Djenné est aussi bien connue pour sa mosquée monumentale édifiée entre 1905 et 1907, sous la conduite de

l'administration coloniale. Ce monument en terre est une grande attraction touristique, et compte parmi les plus grands édifices en terre au monde.

Quoique bien présente et relativement bien conservée, l'architecture en terre des villes et campagnes est soumise à la forte pression des matériaux importés moins périssables : ciment, tôle ondulée, béton armé et autre, mais également au relâchement des traditions ancestrales d'entretien dû à l'abandon progressif de certains savoirs et à la raréfaction de certains liants entrant dans la composition du banco.

L'architecture monumentale des mosquées et autres édifices religieux

Les monuments en terre sont nombreux et variés sur le territoire malien. Depuis longtemps, des chefs politiques et religieux ont édifié des constructions colossales pour diverses raisons (prestige, volonté politique, expression identitaire). Les traditions orales racontent le caractère gigantesque de monuments édifiés par certains rois et empereurs. Parmi ces monuments, certains existent encore et d'autres ayant disparu, sont relatés dans les *tarik*s (El Fettach et Es Soudan) écrits par des chroniqueurs arabes et andalous ou racontés par les griots. Le palais (disparu) du chef Toucouleur Mademba Sy à Sansanding (région de Ségou) à la fin du XIX^e siècle en est une illustration.

Kankou Moussa, un des empereurs du Mandé, a réalisé des monuments en terre impressionnants à Tombouctou et Gao. En 1325, il construisit, avec appui et conseil techniques de l'architecte Abu Ishaq Essahéli, la célèbre mosquée de Djingarey Ber, qui signifie littéralement « grande mosquée » en sonrhaï. C'est l'une des trois mosquées en terre de Tombouctou inscrites sur la Liste du patrimoine mondial de l'UNESCO depuis 1988 (fig. 2).

Les palais royaux et les maisons de chefs

Les palais et maisons de chefs (fig. 3) font partie des constructions monumentales réalisées pour mieux symboliser le pouvoir temporel et/ou spirituel. Des édifices monumentaux ou leurs vestiges liés à la chefferie traditionnelle ou à la royauté existent encore dans des villes ou des villages : les sept vestibules de Ségou Sikoro du Roi Da Monzon Diarra récemment reconstruits, les ruines du palais (ou de la mosquée ?) de Kankou Moussa à Gao, les vestiges du *tata* de Sékou Ahmadou du Macina à Hamdallaye (près de Mopti), les maisons et temples de Hogon (chef politique et spirituel chez les Dogon), les maisons des chefs de villages et/ou de cantons dans plusieurs localités.



FIGURE 2 La célèbre mosquée Djingareyber à Tombouctou construite en 1325 par l'empereur Kankou Moussa à son retour du pèlerinage de la Mecque. Photo : L. Rainer, 2007



FIGURE 3 Temple du Hogon de Arou, chef traditionnel politique et temporel chez les Dogons. Arou est considéré comme une des places les plus prestigieuses des traditions sociales et religieuses des Falaises de Bandiagara. Photo : L. Cissé, 2008

Les greniers

Il s'agit de constructions dont la fonction et le rôle paraissent déterminants dans l'organisation et l'occupation de l'espace habité. Suivant les régions et les aires culturelles, ils sont soit séparés des maisons d'habitation, soit entièrement



FIGURE 4 Greniers en terre à Yendouma Ato, un des plus beaux villages de la région Nord des Falaises de Bandiagara. Photo : L. Cissé, 2006

intégrés aux espaces habités, cela souvent pour des raisons de sécurité.

Leur forme architecturale est aussi variée que diversifiée, en fonction de la quantité et de la variété des productions céréalières saisonnières.

Les greniers sont une expression forte du patrimoine bâti en terre au Mali. Malgré les changements perceptibles dans beaucoup de localités, ils continuent d'être des repères fondamentaux de l'architecture traditionnelle (fig. 4).

La gestion du patrimoine en terre dans un contexte de développement local

Pratiques anciennes de conservation du patrimoine bâti en terre

L'art de bâtir en terre au Mali et dans bien d'autres pays voisins de l'Afrique subsaharienne est une tradition millénaire. Le mode d'habitat est une partie intégrante des expressions culturelles, des savoirs et savoir-faire des hommes.

Dans les sociétés communautaristes, les constructions furent au départ des œuvres collectives issues des schémas sociaux d'entraide et de solidarité. Au fur et à mesure du développement économique et surtout politique, la division sociale du travail a favorisé l'émergence de corporations de métiers ou de castes spécialisées dans l'art de construire. Non seulement ces corporations s'occupent des constructions,



FIGURE 5 La mosquée de Niono (région de Ségou), prix Aga Khan 1985 de l'architecture monumentale en terre. Photo : L. Cissé, 2005

mais elles ont pour mission, dans bien des cas, d'entretenir et de conserver des ensembles architecturaux en terre, aussi bien familiaux que collectifs. C'est le cas des corporations de maçons à Djenné (*barey ton*) et Tombouctou, liées à des familles et chargées de veiller sur l'architecture de ces cités anciennes.

Certains rois avaient leurs propres bâtisseurs qui servaient d'architectes conseils pour des grands projets de construction de monuments ou d'établissements humains, en fonction de leurs mouvements de conquêtes ou de replis tactiques (fig. 5).

La conservation et la mise en valeur des savoirs et savoir-faire traditionnels

Les bâtisseurs traditionnels ont su perpétuer leur art par un système efficace de transmission de père en fils. Les ouvriers qui réalisent les constructions en terre possèdent souvent des savoirs ésotériques qu'ils ne transmettent qu'à des proches parents. D'autres professionnels ont appris le métier en se mettant entièrement à la disposition de maîtres maçons réputés.

Les corporations de maçons subsistent dans des villes comme Djenné ou Tombouctou où les savoirs et savoir-faire locaux ont pu être conservés et valorisés grâce à ce système de transmission.

Malgré le développement de nouvelles techniques et l'utilisation effrénée de matériaux de construction importés, les savoirs et savoir-faire traditionnels dans le domaine de l'architecture de terre sont encore très bien maîtrisés dans des villages et certaines villes. Les constructions en terre restent encore très nombreuses en milieu rural et les connaissances qui les sous-tendent sont assez bien conservées et transmises de génération en génération.

Quelques innovations dans le domaine des constructions en terre au Mali

L'architecture traditionnelle de terre au Mali bien que déclinante dans certains centres urbains comme Bamako ou Kayes, est encore visible dans des cités telles que Ségou, Djenné, Gao ou Tombouctou où des pratiques innovantes sont en cours depuis la période coloniale.

Perspectives de gestion du patrimoine classé du Mali : Les sites inscrits sur la Liste du patrimoine mondial de l'UNESCO

Au Mali, quatre biens sont inscrits sur la Liste du patrimoine mondial de l'UNESCO : les Villes anciennes de Djenné, les Mosquées et mausolées de Tombouctou, le Tombeau des Askia de Gao et les Falaises de Bandiagara (Pays Dogon).

Le caractère exceptionnel du patrimoine architectural de ces sites motive leur conservation et leur mise en valeur pour mieux exprimer les identités sociales, préserver l'histoire locale et régionale et entrevoir un développement harmonieux par le biais du tourisme et d'un urbanisme écologiquement adapté (fig. 6).

Le Ministère de la Culture a créé des Missions culturelles sur plusieurs sites. Ce sont des structures décentralisées chargées de la gestion et de la mise en valeur de ces sites majeurs. Le gouvernement malien a sollicité l'assistance de la communauté internationale pour aider à préserver ces sites du patrimoine mondial pour les générations futures.

Le projet néerlandais de conservation du patrimoine en terre du Mali

À cette occasion, les Pays-Bas ont été le premier pays à s'engager dans une coopération culturelle directe et importante. Grâce à l'expertise technique et aux financements réussis du gouvernement néerlandais, le Mali a pu mener des interventions significatives sur le patrimoine architectural de terre. Le Ministère des Affaires Étrangères néerlandais et l'Ambassade du Royaume des Pays-Bas à Bamako ont financé



FIGURE 6 Bibliothèque des manuscrits récemment construite par des maçons de Djenné. Les traditions de construction en terre se perpétuent de génération en génération. Photo : L. Cissé, 2007

un certain nombre de projets destinés à revaloriser l'architecture traditionnelle locale, avec comme résultats une extension des savoirs et savoir-faire locaux et un grand nombre de monuments restaurés.

Le premier projet de restauration dans la ville de Djenné (1996–2003) comportait la restauration d'une centaine de maisons monumentales isolées. Avec ces travaux de restauration, la ville a été remise en état, revalorisant ainsi le patrimoine culturel sur le plan local comme sur le plan national et international.

Le projet n'a pas seulement abouti au sauvetage physique des monuments restaurés mais il a aussi redynamisé les savoirs locaux, comme ceux des corporations de maçons (le *barey-ton*), et déployé de nouvelles initiatives dans le secteur de la construction en terre.

Pendant la deuxième phase (2004–8), les travaux ont consisté à restaurer des ensembles monumentaux qui ne figuraient pas dans les objectifs de la première phase. Les restaurations ont eu lieu également sur des bâtiments monumentaux à l'extérieur de Djenné. Ces travaux se sont concentrés sur les *saho*, maisons richement décorées où les garçons séjournent pendant une certaine période.

Le champ d'action s'est étendu au Pays dogon, en tant que site du patrimoine mondial de l'UNESCO. Dans cette région de falaises, beaucoup de villages ont été abandonnés



FIGURE 7 Architecture monumentale de Saho (Maison des Jeunes) à Kouakourou dans le Delta intérieur du Niger, non loin de Djenné. Un des monuments restaurés dans le cadre du projet néerlandais. Photo : L. Rainer, 2006



FIGURE 8 Édifice en terre à San (région de Ségou). Mosquée ancienne encore bien entretenue par les communautés locales. Photo : L. Cissé

à cause de la difficulté des conditions d'existence. Les actions menées ont concerné la restauration d'anciens sites à Téli et à Kani Kombolé et la réalisation d'un système d'adduction d'eau à Bolimmba pour éviter que les populations n'abandonnent le site haut perché à l'architecture de terre remarquable.

C'est avec les maçons de Djenné que les meilleurs résultats ont été obtenus. Au cours de la deuxième phase du projet, les maçons se sont réunis en groupement d'intérêt économique (GIE) et, par le biais de contrats, ont pris en charge les travaux de restauration du projet, avec l'aide, le contrôle et la supervision de la Mission culturelle et de leurs partenaires néerlandais (fig. 7).

Conclusion

L'architecture de terre au Mali est abondante riche et variée ; elle constitue la première attraction touristique de certains sites comme Djenné, Tombouctou, Ségou ou le Pays dogon. Beaucoup d'efforts sont en cours pour la réhabiliter et la promouvoir dans le cadre du développement touristique et de l'habitat rural. Des initiatives sont soutenues en ce sens par la coopération bilatérale ou multilatérale.

Cependant, dans beaucoup de villes, la tendance très visible de substitution des constructions en parpaing et la perte progressive de savoirs et savoir-faire liés au *banco* consti-

tuent de graves menaces pour le patrimoine bâti en terre. Ce phénomène s'étend malheureusement aux villages même si cela n'est pas aussi prononcé qu'en milieu urbain (fig. 8).

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Le site de la mosquée de Kankou Moussa à Gao (Mali) : Problématique liée à l'aménagement d'un complexe architectural médiéval en Afrique de l'Ouest

Mamadi Dembelé

Résumé : *Le site de la mosquée de Kankou Moussa se trouve dans le vieux quartier de Gao, dans le Nord du Mali. Cette mosquée est l'œuvre de l'empereur mandingue Kankou Moussa. Les travaux ont été dirigés par l'architecte andalou Abou Ishaq Es Sahéli, auquel est attribuée la construction de la mosquée Djingareyber de Tombouctou. Contrairement à d'autres monuments de la même époque (Tombeau des Askia, mosquée de Djingareyber), l'édifice a totalement disparu. Les investigations faites n'ont toujours pas permis la découverte de la mosquée. Cependant, des structures appartenant à un bâtiment colossal de même qu'un nombre considérable de pièces de mobilier ont été mis au jour. Le travail à réaliser demeure encore immense et nécessite des moyens importants.*

Abstract: *The site of the Kankou Moussa mosque is in the old neighborhood of Gao in northern Mali. The mosque was built at the behest of the Manding emperor Kankou Moussa. Work was conducted by the Andalusian architect Abou Ishaq Es Saheli, who is assumed to have also built the Djingareyber mosque in Timbuktu. Unlike other monuments of the same period, such as the Tomb of Askia, the building has totally disappeared. Investigations have still not revealed its location. However, structures belonging to a large building as well as a considerable amount of furnishings have been uncovered. Much work remains to be done, requiring considerable resources.*

Le site de la mosquée de Kankou Moussa se trouve dans le vieux quartier de Gao, dans le même secteur que le célèbre tombeau des Askia, sur le bord du fleuve Niger, à la jonction entre le Sahara et le Sahel. Il s'étend sur une superficie de près de 15 ha, dont au moins 6 ha sont occupés par des habitations avoisinantes.

D'après la tradition orale, la mosquée aurait été construite par l'empereur du Mali, Kankou Moussa, à son retour du pèlerinage à La Mecque en 1324. L'ouvrage serait l'œuvre du célèbre architecte andalou, Abou Isaac Es Saheli, qui était un proche de l'empereur. Signalons, que la cité de Gao, capitale du prestigieux empire songhay fut un important carrefour du commerce transsaharien, principal levier sur lequel reposait l'économie des empires du Soudan Occidental, à savoir, le Ghana, le Mali et le Songhoy.

Gao dans l'histoire du Soudan occidental

Dès le X^e siècle de notre ère, les chroniqueurs arabes ont fait allusion à un État sur le Niger de l'Ouest africain qu'ils appellent *kuku* ou *Kaw kaw*. Sur la base de ces sources historiques et des informations fournies par les traditions orales, les historiens modernes ont interprété *Kuku* ou *Kaw kaw* comme la ville actuelle de Gao. Celle-ci devint la capitale de l'empire songhay qui atteint son apogée au XV^e siècle, sous le règne d'Askia Mohamed (1492–1528).

Vers la fin du XII^e siècle, Al Idrisi décrit la ville de *Kaw Kaw* comme l'une des plus renommées du pays des Noirs, avec « un roi indépendant disposant d'une suite nombreuse, une cour importante, des officiers, des soldats » (Mauny 1961). Le voyageur Ibn Batouta qui y séjourna en 1353 la présente comme « l'une des villes les plus belles et les plus grandes du Soudan » (Mauny 1961).

Au milieu du XIV^e siècle, cette prospérité de Gao reposant essentiellement sur les échanges transsahariens, aiguïsa les appétits de son puissant voisin occidental, l'empire du Mali, qui l'annexa et en fit une de ses provinces. C'est notamment sous ce joug mandingue, que le *mansa* Kankou Moussa,

empereur du Mali, aurait séjourné dans la ville en 1324, de retour du pèlerinage à La Mecque et y aurait édifié la mosquée qui porta son nom. Il faudra attendre le milieu du XV^e siècle pour que le Songhoy recouvre son indépendance, avec d'abord Sonni Ali Ber, fondateur de la dynastie des Sonni, et ensuite, avec Askia Mohamed, fondateur de la dynastie des Askia. C'est sous le règne des Askia, que l'empire songhoy atteint son apogée. Il s'étendait alors de l'Atlantique à l'Air (d'Ouest en Est) et du désert à la forêt (du Nord au Sud). Plaque tournante du commerce du Nord au Sud du Sahara, sa population était estimée à plus de cent mille habitants (Kati 1964).

Vers la fin du XVI^e siècle, des troubles liés à des querelles de succession, et surtout l'abandon progressif des routes caravanières au détriment des routes maritimes, portèrent un coup dur à l'empire, qui sera anéanti par le sultan du Maroc (Abitbol 1979) (fig. 1).

Gao, la plus grande métropole du Nord du Mali, s'illustre dans l'historiographie de la sous-région, grâce à ses nombreux sites archéologiques et monuments historiques témoignant tous du passé de cette cité millénaire (Isesco 1988). Parmi les nombreux sites on peut retenir :

- le Tombeau des Askia, imposant monument en architecture de terre, inscrit sur la Liste du patrimoine mondial de l'UNESCO (fig. 2) ;



FIGURE 1 Carte de l'empire songhoy à son apogée. (DNPC 2006)



FIGURE 2 Vue d'ensemble du Tombeau des Askia. (DNPC 2006)

- la grande butte anthropique (cité antique) de Gao-Sanèye et sa vaste nécropole islamique, ancienne capitale du Songhoy ;
- le site ancien de Gao, sur les berges du fleuve Niger ;
- le site de la mosquée de Kankou Moussa.

Historique des recherches

Les premières recherches archéologiques sur le site remontent à la période coloniale, pendant laquelle il attira l'attention des administrateurs (Mauny 1961).

- 1949 : D. Michel, alors commandant de cercle de Gao, identifia des fondations qui furent fouillées par D. P. de Pedrals et J. Kikoïne, géologues. Ces fouilles opérées par des archéologues amateurs ont révélé des soubassements de murs, des tombes et un élément en oméga.
- 1950 : Raymond Mauny, alors chef de la section Préhistoire-Archéologie de l'Institut français d'Afrique noire (devenu Institut fondamental d'Afrique noire), pratiqua des fouilles dans la zone de l'élément en oméga qu'il identifia comme une mosquée. Il découvrit le mur nord-est de la mosquée et le mihrab. Aux alentours de la mosquée, il signala des tombes comportant des stèles épigraphées, similaires à



FIGURE 3 Aire principale de fouille, secteur sud-ouest : entrée, couloir principal et pièces. (DNPC 2004)

celles trouvées sur la grande nécropole royale de Gao Saney, à environ 7 km de la ville.

- 1993 et 1996 : deux campagnes effectuées par Timothy Insoll, alors étudiant à l'Université de Cambridge, en collaboration avec l'Institut des Sciences humaines, ont révélé des fondations de pierres et un important mobilier comprenant des perles d'orient et des défenses en ivoire, destiné au commerce transsaharien et probablement oublié sur place (fig. 3).
- 2003 à nos jours : une série de campagnes de fouilles est engagée par la Direction nationale du patrimoine culturel, en collaboration avec l'Institut des Sciences humaines et le Musée national d'Ethnologie d'Osaka (Japon) sur le même site, avec comme objectif de découvrir la mosquée tant évoquée par les chroniqueurs et la tradition orale (fig. 4)¹.

Résultats sommaires

Les différentes campagnes de fouilles menées de 2003 à nos jours ont permis d'exhumer des structures de bâtiments et de collecter un mobilier important et varié.

Les structures

Il s'agit d'un système de couloirs, dont deux sont bien identifiés, donnant sur un certain nombre de pièces. Les murs et fondations sont des structures colossales construites en pierres (grès dur), en briques de terre cuite et en briques de



FIGURE 4 Secteur Est, entrée secondaire, couloir et pièces. (DNPC 2007)

terre crue. Dans le secteur sud, le couloir le plus important (sud-est/nord-ouest) mesure 22 m de long sur 1,15 m de large. Il donne de part et d'autre sur une douzaine de pièces de dimensions inégales.

Dans le secteur est, un second couloir en pierres, nord-sud, donne également sur plus d'une dizaine de pièces. Ici, le matériau est constitué de grès associé à des blocs de latérite.

Dans le secteur nord, un gros bâtiment rectangulaire constitué de murs en pierres (grès dur) de 9 m sur 6,15 m est exhumé. L'entrée est bien circonscrite à l'est. Trois rangées de deux piliers chacune, également en pierres, sont dressés ; ils ont servi de support pour la toiture du bâtiment. Le même bâtiment est contigu à l'ouest à un autre également rectangulaire (une chambre ?) dont le mode de construction dénote qu'il s'agit d'une structure relativement plus récente (utilisation de plus de mortiers et de blocs de pierres moins massifs). Une sorte de plancher en pierre massive (schiste) de forme rectangulaire (1,40 m de long sur 0,80 m de large) dont l'usage reste encore énigmatique a été mis au jour dans l'angle nord-ouest de cette pièce.

La configuration de la nature des structures exhumerées, les dimensions des compartiments, représentent autant d'indices qui indiquent qu'il ne s'agit pas de restes d'une mosquée, mais plutôt de compartiments d'un bâtiment colossal : un marché avec ses *souks*, ou un palais avec ses couloirs et pièces. En effet, il est important de signaler que les structures exhumerées ne sont nulle part signalées, ni par les chroniqueurs arabes, ni par la tradition orale.



FIGURE 5 Secteur Nord, grande pièce rectangulaire avec piliers en pierres. (DNPC 2007)

Cependant la tradition orale ne devrait pas être muette sur ce site qui se singularise par un style architectural unique dans la région avec une maçonnerie très élaborée et parfaitement mise en œuvre (symétrie, netteté des angles, droiture des murs), qui n'a rien à envier à celle des temps actuels. Il s'agit d'une œuvre gigantesque ayant nécessité le déploiement d'une main d'œuvre importante à la fois pour l'extraction et le transport des pierres qui ne se trouvent pas sur place (fig. 5).

Signalons qu'au cours d'une exploration récente dans les alentours, à environ 6 km sur la rive droite du fleuve, dans la localité montagneuse de Sadoukoïra, des carrières d'extraction de pierres ont été découvertes. C'est donc à partir des villages de Tièdo, Goundia, Tinin El, tous dans la zone de Sadoukoïra, que le matériau principal, la pierre, était transporté par pirogues et acheminé sur le site à dos d'âne ou de chameau, car on est à environ un kilomètre du fleuve. D'ailleurs, un imposant site d'habitat de la même envergure que Saney a été découvert dans ce secteur².

Le mobilier

Un riche matériel, constitué de céramique, d'objets en fer et en cuivre, de perles, de fusaïoles, de pendentifs, et de bijoux a été récolté. Ces objets, notamment les perles en cornaline ou en verre, les objets en cuivre (bagues, pendentifs, boucles d'oreilles), des fusaïoles, révèlent la richesse de Gao et sa participation au lucratif commerce transsaharien, qui a fait la prospérité des empires médiévaux du Soudan Occidental. Il convient de noter la quantité particulièrement importante de perles exhumées : à titre indicatif dans le seul niveau arbitraire de 20 cm du sondage GMK-24 (campagne 2007/2008), il a été recueilli plus de 500 perles, et dans l'ensemble des 6 niveaux plus de 1600, dont une grande partie en verre.



FIGURE 6 Objets mobiliers (perles, fusaïoles, fragments de verre) découverts lors des fouilles. (DNPC 2005)

Ce matériel riche et varié est pour la plupart issu du commerce transsaharien, en particulier les fragments de céramique vernissée, les objets en cuivre, les perles en cornaline et en verre. D'ailleurs, il n'est pas exclu que ces dernières aient fait l'objet d'une fabrication locale à partir du verre provenant du bassin méditerranéen. Une situation similaire est observée à Gao-Saney, la grande agglomération voisine du XI^e siècle, située seulement à 7 km. Cette hypothèse se justifie par la quantité importante de perles inachevées trouvées sur place (fig. 6)³.

On peut donc retenir pour le moment que le complexe architectural du site dit de la mosquée de Kankou Moussa à Gao ressemble à un marché ou un palais dont tous les contours ne sont pas encore précisés. Il se rapproche beaucoup du style de murs découverts à Koumbi Saleh, à Aoudaghost, dans l'Empire du Ghana (Mauny et Berthier 1996).

Toutefois, en l'état actuel des recherches, aucun vestige appartenant à la mosquée n'a été exhumé. Cela est dû au fait que la mosquée est supposée être située dans le secteur est, actuellement occupé par des habitations. Il convient aussi, de signaler que, pour le moment, aucune datation carbone 14 n'a pu être opérée dans ces structures, ce qui aurait beaucoup aidé à interpréter le site. Cependant, des dates comprises entre les VI^e et XII^e siècles sont signalées à partir des sondages opérés par Timothy Insoll (Insoll 1996).

Conclusion

Les investigations montrent que le travail à réaliser demeure encore immense et nécessite surtout des moyens humains et matériels plus importants. Les efforts devront porter sur la poursuite des fouilles, afin de pouvoir atteindre l'objectif premier, à savoir, l'excavation de la mosquée, les activités de

restauration et de protection devant aboutir à l'aménagement d'un complexe touristique tant sollicité par les populations de la ville de Gao, les activités de sensibilisation et d'éducation en direction des décideurs et de la population en général. Les prochaines activités seront notamment centrées sur :

- *La poursuite de la fouille* : elle s'avère indispensable car elle seule permettra de circonscrire les limites des structures exhumées et de cerner la nature et la configuration du/des bâtiment(s). Les opérations de fouilles seront transposées vers d'autres secteurs, notamment à l'est où la mosquée est supposée se trouver. La partie nord sera davantage explorée. Toutefois, une condition doit être remplie pour que ces activités puissent se dérouler normalement. Il s'agit de l'évacuation des habitations se trouvant dans ces secteurs ;
- *La protection* : il s'agit d'une activité essentielle et urgente qui consistera à édifier une toiture en tôle ondulée afin d'assurer une protection durable aux découvertes contre les eaux de pluies et les animaux. En raison de l'immensité du site et de la faiblesse des moyens alloués par l'État, cette activité pourrait être réalisée progressivement. Le concours des partenaires serait également le bienvenu⁴ ;
- *La restauration et l'aménagement* : c'est aussi une activité essentielle, mais assez délicate. Il s'agira de reconstituer – à partir des matériaux anciens –, toutes les parties désagrégées, surtout du fait des eaux de pluies (pans de murs, pavements de briques cuites et autres). Cette activité doit être obligatoirement accompagnée d'un processus d'embellissement, avec l'aménagement de zones piétonnières, la mise en place de barrières de protection de structures fragiles ou dangereuses (par exemple, la fouille-témoin de plus de 6 m de profondeur, secteur sud-ouest), la décoration des piliers à l'aide de carreaux en briques cuites locales, du plafond à l'aide de natte tressées, par exemple. Les activités d'aménagements devraient être complétées par la construction d'une clôture, d'une boutique artisanale, d'une buvette et d'une case de gardien ;
- *Le tourisme* : Tout ce vaste ensemble accueillera un espace de formation pour les jeunes et la population en général. Une fois opérationnel, ce complexe culturel contribuera à la valorisation du potentiel touristique dont la ville de Gao a tant besoin.

Notes

- 1 Ces différentes campagnes de fouilles ont été possibles grâce à l'appui financier de l'État malien, du Musée National d'Ethnologie d'Osaka (Japon), de l'Ambassade des États-Unis d'Amérique à Bamako et de l'Agence Suédoise pour le Développement International (SIDA-SAREC).
- 2 Cette prospection a eu lieu pendant la campagne 2007.
- 3 D'après les renseignements rapportés par notre collègue du Musée National d'Ethnologie d'Osaka (le P^r Takezawa Shoichiro, obtenus de Shindo Youko, spécialiste du verre au Centre du Proche-Orient de Tokyo), il ressort que le verre trouvé sur place, remonterait au IX^e siècle (Période fatimide), et son utilisation dans le trafic vers le X^e siècle. Il s'agit bien entendu d'hypothèses, car les études et analyses se poursuivent.
- 4 Le Ministère de la Culture, sur financement de la Coopération Française, a entrepris (été 2008), la construction d'une toiture sur le site (espace ayant fait l'objet de fouilles).

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Protection et sauvegarde des mausolées des « saints » dans la ville de Tombouctou et leur place dans le contexte culturel saharien

Pietro M. Apollonj Ghetti, Mauro Bertagnin, Klessigué Sanogo et Ali Ould Sidi

Résumé : *Cet article présente les résultats d'une étude approfondie sur la spiritualité de la ville de Tombouctou, sur ses mausolées et sur les saints qui y reposent. Cette étude réalisée par le Centre du patrimoine mondial de l'UNESCO s'inscrit dans un programme visant à conserver les sites maliens figurant sur la Liste du patrimoine mondial. Bon nombre des mausolées en terre crue de Tombouctou en font partie. Pourtant les nombreuses lacunes révélées par les campagnes de terrain ont mis en évidence la nécessité de réviser et d'élargir l'inventaire actuel des mausolées inscrits sur cette liste.*

Abstract: *This paper presents the results of a comprehensive study of the spirituality of the city of Timbuktu, its mausoleums, and the saints resting in them. This study, carried out by the UNESCO World Heritage Centre, is part of a program aimed at conserving the Malian sites inscribed on the World Heritage List. Many earthen mausoleums in Timbuktu are on this list. Yet many gaps have been identified by campaigns in the field, revealing the need to revise and expand the present inventory of mausoleums inscribed on the list.*

Cet article présente le travail du Centre du patrimoine mondial de l'UNESCO mené par Pietro M. Apollonj Ghetti et Mauro Bertagnin, ainsi que de l'architecte Giovanni Fontana Antonelli, réalisé au cours des différentes missions d'étude sur la spiritualité de la ville de Tombouctou, sur ses mausolées et sur les « saints » qui y reposent. L'architecte Cristina Guerrini a, pour sa part, collaboré à la phase de recherche sur le terrain ainsi que, en Italie, à la mise au propre et à la restitution des relevés.

Bon nombre de ces mausolées, bâtis en terre crue, sont inscrits sur la Liste du patrimoine mondial de l'UNESCO.

Pourtant, les nombreuses lacunes révélées durant les campagnes de terrain ont mis en évidence la nécessité de réviser et d'élargir l'inventaire actuel des mausolées inscrits sur cette liste.

Tombouctou a joué un rôle central dans le développement et la diffusion de la pensée islamique dans le cadre saharien, grâce à sa position stratégique et à son université, reconnue comme une de plus importantes pendant plusieurs siècles.

Le travail réalisé jusqu'alors a permis d'identifier et de localiser les mausolées, d'en relever les plans et les façades, de dessiner des croquis et d'établir leur documentation photographique.

Compte tenu de l'importance que les « saints » revêtent dans la culture de la ville, dénommée justement « la ville de 333 saints », il est envisagé de faire un inventaire complet et une étude approfondie pour mieux identifier, classer et restaurer les mausolées inscrits sur la Liste du patrimoine mondial. Ce travail, mené en stricte relation avec Klessigué Sanogo, Directeur national du patrimoine culturel auprès du Ministère de la Culture du Mali, et Ali ould Sidi, Chef de la mission culturelle de Tombouctou, devra aussi être complété par l'étude des textes sur le développement de l'islam dans cette région, et par un aperçu des notices biographiques de chaque « saint ».

Il faut souligner que la clé de lecture du patrimoine culturel malien doit être recherchée dans l'histoire pluriséculaire de son territoire et de sa population. On ne peut pas considérer ce patrimoine comme fruit d'un hasard, mais plutôt comme le résultat d'une association de différents facteurs culturels qui a amené, entre autre, à élaborer une architecture autochtone.

Préalablement à la recherche sur les mausolées, il est apparu nécessaire d'établir un cadre de référence pour mieux saisir cette architecture dans la perspective historique et typo-morphologique des cultures constructives sahariennes.

L'architecture « *takrouienne* »

La culture et l'architecture soudanaise, devraient, en effet, être appelées « culture du *Takrou* » et « architecture du *Takrou* », ou, pour créer un néologisme, « architecture *takrouienne* ». Ceci en hommage à ceux que Lanier appelait « les indigènes » (Lanier 1889) et pour marquer un point de départ pour comprendre et apprécier une culture absolument originale bien que, ensuite, métissée par différents apports. Les échanges entre l'Afrique Noire et les pays du Maghreb ne se limitaient pas seulement aux produits marchands. La sphère culturelle est beaucoup plus présente qu'on pourrait imaginer, l'architecture étant l'un des meilleurs exemples.

L'architecture « *takrouienne* » est entrée en contact avec celle des pays comme l'Espagne islamisée, les pays du Maghreb et les territoires du Haut Nil. La terre crue étant la liaison *materica* de l'habitat saharien, on retrouve dans l'espace oasien des éléments qui démontrent les influences mutuelles entre l'habitat saharien et l'architecture *takrouienne*. Par exemple, au centre du Sahara, la ville de Timimoun présente un tissu urbain ancien en terre crue et, à côté, une « ville nouvelle », d'époque coloniale, édifiée elle aussi en terre crue suivant le « style soudanais » (fig. 1).

Ainsi, les villes du Gourara et du Touat et du Souf algérien montrent plusieurs marques de contact avec celles de l'aire *takrouienne*. Des analogies se retrouvent aussi avec l'architecture de la Libye, bien qu'une étude beaucoup plus approfondie soit nécessaire pour faire le point des apports et des rapports culturels entre les populations au nord et au sud du Sahara.

Un rapprochement peut être fait, par exemple, entre les villes bâties en terre comme Germa, capitale du Fezzan, Malut, Gasr El Haj, Ain-El-F'ra, Sahit, El-Tuut et Kabaw, qui rappellent l'architecture du Pays dogon, et celle de l'actuel Mali. De nombreux indices attestent aussi l'influence, bien que marginale, de l'Arabie Saoudite, par l'intermédiaire des Ibadites de l'Oman.

D'autres éléments témoignent des influences dues aux échanges avec le monde juif dont l'empreinte est visible, tout spécialement de nos jours, à Tombouctou, comme par exemple les manuscrits en langue juive conservés dans la ville, les corporations juives de menuisiers ou encore la maison dite des



FIGURE 1 Ville nouvelle de Timimoun (Algérie) : porte de style soudanais. Photo : Mauro Bertagnin. © Mauro Bertagnin

Juifs. Même pour ce qui concerne la technique de fabrication des briques faites à la main, à l'aide des moules en bois (*banco*), on peut supposer une influence méditerranéenne, liée aux corporations de maçons juifs, dont la présence était signalée un peu partout dans le monde saharien. Cette technique aurait permis de remplacer l'ancien système piriforme, bien que jusqu'à nos jours cette méthode soit toujours utilisée.

Sans aucun doute, l'architecture *takrouienne* est née dans un territoire caractérisé par une origine culturelle commune et son histoire est intimement liée à l'alternance des grands royaumes africains tels que celui du Mali et du Songhaï. Toutefois sa propagation serait due plutôt aux marchands qui y voyaient un symbole d'appartenance à une classe sociale économiquement et socialement différenciée. Il est aussi intéressant de constater que cette culture constructive, malgré les transformations récentes, reste toujours vivante et profondément ancrée chez les populations locales.

Morphologie urbaine

Par l'intermédiaire du désert, le territoire *takrou* est au centre des échanges transsahariens. C'est ainsi que des villes, telle que Tombouctou, se sont formées et, à partir de ces lieux d'entrepôt et de stockage, que les marchandises sont transportées partout, à travers le Niger. La structure et la morphologie de ces villes suivent le « *pattern* » typique de la ville islamique, tandis que dans la majorité du territoire, se sont plutôt les religions animistes qui influencent l'habitat.

La culture urbaine *takrouienne* fait référence à « l'archétype de l'enceinte » pour marquer la séparation entre espace nomade et sédentaire, entre l'espace du désert et celui oasien, entre zones arides et terrains irrigués. Avec l'affirmation de l'islam il devient choix de vie ainsi que matrice figurative de la morphologie urbaine. En effet cette image de l'enceinte urbaine, formellement définie, s'oppose aux alentours informels. Elle a inspiré les travaux de nombreux chercheurs, fascinés par cette caractéristique unificatrice de la ville islamique. Toutefois cette image, selon Lapidus, est trompeuse : « lorsqu'on examine de près, la géographie et l'habitat des villes islamiques en relation avec l'intérieur des terres, se révèlent plus complexes. En effet, dans de nombreux cas, il est impossible d'établir une distinction absolue entre ce qui est rural et ce qui est urbain » (Lapidus 1969). Le même « archétype de l'enceinte » est aussi à la base, selon Miquel, de la « formation d'un réseau de villes-relais aux débouchés des pistes sahariennes branchées sur le commerce et, plus généralement, sur l'intense circulation des marchandises et des idées » (Miquel 1977).

Dans ce cas, il s'agit du commerce transsaharien et de celui entre les populations du Sahel et celles de la savane.

Typologie architecturale

Les influences et les langages qui déterminent la typologie architecturale dans les tissus urbains des « villes soudanaises » sont nombreuses, dues à l'alternance des royaumes et des populations qui ont déterminé l'évolution des établissements urbains dans l'aire *takrouienne*. Par exemple, l'influence d'un architecte tel qu'As-Sahili, ramené du Caire par le souverain malien Mansa Musa, lors de son voyage à la Mecque, n'est pas seulement limitée aux langages des mosquées soudanaises, mais concerne aussi l'architecture des bâtiments publics (à partir de la salle d'audience de Niani) et des habitations. De même « l'influence culturelle de la présence marocaine dans des villes telles que Tombouctou et Djenné est difficile à évaluer, mais elle fut certainement importante dans le domaine de l'architecture » (Domian 1989).

Cette influence est plus lisible à Djenné où les deux typologies dominantes sont liées à une « migration typologique » due à la présence des Marocains et des Toucouleurs. Les Marocains d'Al Mansur et les Toucouleurs d'El Hadj Omar ont laissé leur marque dans l'architecture puisque les deux typologies dominantes sont nommées « *maison marocaine* » et « *maison toucouleur* ». Elles sont le résultat d'un métissage culturel et architectural, lisible dans les deux typologies. En

effet, on y retrouve une recherche de monumentalité, associée à la plasticité due à l'emploi du matériel terre, et des effets esthétiques bien marqués, aussi bien dans les détails que dans la façade. Pour ce qui concerne l'architecture dans le milieu rural, on retrouve des typologies toujours liées à « l'archétype de l'enceinte » avec la présence des greniers comme éléments caractéristiques.

La typologie architecturale, bien qu'influencée en milieu urbain par l'archétype de l'enceinte, présente des variations liées à la culture constructive locale ou au climat. Du point de vue de l'utilisation des matériaux de construction, on retrouve, par exemple à Djenné et à Tombouctou, des différences marquées. Djenné est une ville bâtie entièrement en terre crue, tandis qu'à Tombouctou, à côté du *banco*, l'*al-hor* ou pierre calcaire est parfois utilisé pour protéger contre l'érosion éolienne les façades des maisons et des mosquées. La façade donnant sur la route est dans les deux typologies privilégiée par rapport aux autres.

On retrouve aussi, dans l'habitat soudanais, une certaine continuité au niveau typologique, puisque le souci de préserver l'espace central est systématique : le *west-ed-dar* ou *haouch* (colonne céleste, qui mène vers le haut dans un cosmos sacralisé et saint), avec des variantes liées au climat et à la culture locale.

Dans le cas de Tombouctou, des maisons sans contact avec l'extérieur et avec des murs presque aveugles et une petite porte unique donnent sur l'espace filtre de la *squiffa*, ou directement sur l'*haouch*.

Lieux de culte, mosquées et mausolées

Tout l'espace saharien est caractérisé par la présence des mosquées, mausolées et lieux de culte – la plupart en terre crue –, qui marquent le territoire ainsi que par des *zaouïas* qui représentent des « nœuds très importants pour la compréhension de la relation entre société et culte dans la culture saharienne » (Domian 1989). Les petites mosquées du milieu rural, dans les villages du Mali, préparent à la magnificence et aux richesses plastiques des grandes mosquées de Djenné, de Mopti et de Tombouctou. Tandis que pour les mosquées, les différences entre celles bâties en ville et celles des villages ne sont pas évidentes, puisqu'elles suivent le même langage architectural « soudanais », pour les maisons les différences sont plus claires, liées surtout à la fonction en milieu urbain et en milieu rural. Pour ce qui concerne le style architectural des mosquées, Domian le fait remonter à l'influence de Mansa Musa. « Mansa Musa fit-il construire des mosquées dans les

lieux où il se rendait en voyage pour pouvoir prier, et il marqua le style des mosquées soudanaises de son empreinte » (Bertagnin 1992).

Tandis que les lieux de culte animistes sont traditionnellement éloignés du village, la mosquée occupe délibérément une position centrale et le plus possible visible dans le tissu urbain. Sur le plan de la structure architecturale, la mosquée typique soudanaise est en terre et présente un plan rectangulaire avec une cour clôturée et, à l'intérieur, une maille serrée de piliers ou de colonnes massives, avec les arcs parallèles aux murs de la *qibla*. Pas de décoration à l'intérieur, suivant la tradition islamique, et le sol est en sable ou en terre, couvert par des nattes. Les enduits, à l'intérieur comme à l'extérieur sont en terre. À l'extérieur, on a la tour du *mihrab* à section pyramidale ou conique, la toiture à terrasse avec une cage d'escalier d'accès et des trous d'aération fermés par des couvercles en terre cuite. Des gargouilles en terre cuite visibles sur les façades permettent d'évacuer l'eau loin des parois. Le bois en saillie est employé pour renforcer le bâti, pour servir d'échafaudage lors des entretiens périodiques des façades et comme élément décoratif. Plusieurs portes sont présentes, sauf dans le mur de la *qibla*. Le matériel utilisé est la terre sous forme de briques de *banco* et les enduits sont aussi en terre.

D'une partie à l'autre du Sahara, par exemple à Ouargla (Algérie) et à Tombouctou, les minarets gardent le même style particulier qui marque l'architecture soudanaise.

Le rapprochement avec l'ancienne mosquée de Oujla en Libye est très intéressant, bien que son intérieur soit caractérisé par des espaces beaucoup plus vastes. À l'extérieur, au contraire, le jeu des masses et des volumes rappelle la beauté plastique des mosquées de Tombouctou. Le système de prise d'air et de lumière sur la terrasse est un autre élément pratiquement semblable aux fours disséminés face aux maisons de Tombouctou.

Le cimetière et les mausolées de Tombouctou

À Tombouctou, on retrouve une série de petits mausolées, reliés idéalement à un réseau de tombeaux des « saints » qui marquent tout le territoire saharien (figs. 2-4).

Les *marabouts* et les tombeaux-mausolées « marquent dans le désert les parcours des pèlerins et constituent des signes dans le territoire désertique avec leur blanc des badigeons à la chaux et le rouge des terres et leurs volumes, soit cubiques, couvertes par des coupoles ou bien de forme ogivale » (Bertagnin 1992).



FIGURE 2 Tombouctou (Mali) : le tombeau de Cheick Sidi Mouhammed Mahmoud (cimetière de Cheick Sidi Mouhammed Mahmoud). Photo : P. M. Apollonj Ghetti. © P. M. Apollonj Ghetti



FIGURE 3 Tombouctou (Mali) : tombeau de Chaykh Sidi Ahmed Ben Amar Ragagydy (cimetière de Zeyane Kaly). Aquarelle par Cristina Guerrini

Ils sont nombreux et se trouvent dans le tissu urbain et dans les alentours de la ville. Ils constituent d'abord un rempart psychologique solide autour de la ville, la protégeant de tout malheur selon les croyances populaires. Le grand nombre de ces lieux tient à celui des « saints ». Les plus connus sont au nombre de 17, chaque « saint » étant enterré avec son groupe.



FIGURE 4 Tombouctou (Mali) : tombeau de Sidi Boukou ou de Sidi Khivar. Aquarelle par Cristina Guerrini

Recommandations

L'approfondissement des études sur les mausolées mené par l'équipe d'experts du Centre du patrimoine mondial de l'UNESCO au cours des différentes missions en liaison avec Klessigué Sanogo, directeur de la Direction nationale du patrimoine culturel auprès du Ministère de la Culture du Mali, et Ali Ould Sidi, chef de la mission culturelle de Tombouctou, concerne notamment les levées architecturales, la documentation photographique, les dessins des planimétries et des façades, des esquisses, ainsi que l'individuation des mausolées sur la planimétrie.

Le travail a révélé, entre autres, une série d'incohérences au niveau de la liste ICOMOS, établie lors de l'inscription des mausolées sur la Liste du patrimoine mondial. Il a donc fallu revoir la liste des mausolées inscrits au patrimoine mondial et en classer d'autres. Il serait donc souhaitable d'établir un inventaire et une publication actualisée, compte tenu de l'importance des « saints » dans la culture de la ville, dénommée justement « la ville de 333 saints ». Ce travail devrait être supporté par l'étude des textes et par un aperçu et des informations biographiques de chaque « saint ».

Il faudra, aussi, définir les mesures à prendre pour protéger les mausolées et pour mieux les faire connaître à la population de Tombouctou, ainsi qu'aux voyageurs de passage dans la ville.

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Negotiating Tradition in Practice: Mud Masons and Meaning Making in Contemporary Djenné

Trevor H. J. Marchand

Abstract: *This paper, based on fieldwork with Djenné's masons, explores the relation between local knowledge, vernacular architecture, and a changing world. Djenné's distinct character has endured because of the dynamic and responsive transmission of skill-based knowledge across generations of builders. Craftsmen acquire a mixture of technique, trade secrets, cultural understanding, and social duty, enabling them to respond to contemporary needs and the aspirations of clients. Master masons strategically locate change and innovation within a discourse of continuity and tradition. A final case study reveals how individual masons are reinventing tradition and professional identities in response to shifting sets of constraints and opportunities.*

Résumé : *Sur la base de travaux sur le terrain avec les maçons de Djenné, cette communication explore la relation entre les savoirs locaux, l'architecture vernaculaire et le monde en évolution. Le caractère spécifique de Djenné perdure grâce à la transmission dynamique et adaptée des savoirs spécialisés d'une génération de bâtisseurs à l'autre. Les artisans acquièrent à la fois des compétences techniques, des secrets du métier, une connaissance culturelle et du devoir social leur permettant de répondre aux besoins et aspirations actuels de leurs clients. Les maîtres maçons intègrent habilement le changement et l'innovation au discours sur la continuité et la tradition. Finalement, une étude de cas montre comment différents maçons réinventent la tradition et les identités professionnelles en réponse aux contraintes et aux opportunités en évolution.*

During ethnographic fieldwork with masons in the West African town of Djenné (Mali), I worked as a laborer on building sites in order to *learn about learning* in a firsthand,

embodied manner. Two seasons of constructing, repairing, and plastering mud houses and subsequent visits with my mason colleagues have allowed me to carefully consider the intricate weave of handiwork with social knowledge and the ways in which craft expertise is communicated on-site and across generations (Marchand 2009a). This paper explores the fundamental yet fragile relationship between local knowledge and vernacular mud architecture and the ways in which notions of tradition and authenticity are challenged, negotiated, and transformed in practice.

In Djenné, the mason's work has been recognized as a distinct profession for centuries, and the organization and hierarchy within the trade community are reproduced largely by the guildlike alliance of the *barey ton*, or masons' association. The association is presided over by a chief, or *barey bumo*, who is elected by its senior members to direct meetings and supervise collaborative events such as the annual replastering of the town's monumental mosque. Each household in Djenné is contractually bound to a particular mason or family of masons, and these ties of patronage extend back over generations. When a mason retires or dies, he may pass client-patrons on to sons, nephews, or selected disciples who apprenticed under his tutelage (Marchand 2003a) (fig. 1).

Through long apprenticeship, masons not only gain technical proficiency in building with mud brick but, importantly, also acquire worldviews, social skills, trade secrets, and a sense of professional duty. Mastery of these various forms of practical and propositional knowledge enables masons to competently negotiate the boundaries of "tradition" and to construct meaningful living environments. Djenné's masons have responded dynamically to the changing needs, aspirations, and lifestyle choices of the town's inhabitants while



FIGURE 1 Gathering of the *barey ton* masons' association to make communal benedictions after the annual replastering of Djenné's mosque. Photo: T. H. J. Marchand

continuing to produce buildings that are rooted in a dialogue with history and place.

For nearly four decades, however, a taxing combination of drought, emigration, and an unstable economy has menaced Djenné's mud architecture. More recently, the construction of a dam on the upper reaches of the Bani River poses latent threats to the livelihoods of Djenné's resident fishermen and farmers; and the control of seasonal flooding on surrounding plains may disrupt supplies of alluvial silts from which good-quality bricks and plasters are made (Gallier 2002). Also, since the turn of the twenty-first century, new information technologies are plugging Djenné into a global economy of ideas and commodities. An already tenuous balance between local tradition and imported modernity is being put to the test by the rapid influx of alternative lifestyle choices and consumer goods, including construction materials. In addition, a nationwide expansion of formal schooling is reorienting young people's ambitions toward careers in business, science, and the civil service, as opposed to the more traditional crafts, thereby demoting the status of on-site apprenticeships (Marchand, Sidibé, and Vogel 2007). Presumably, this will have adverse effects on the quality of future recruits to the building trades and on the long-term prestige of the masons' association.

It must be emphasized that Djenné's distinctive mud architecture has been successfully safeguarded to date not through the rigid enforcement of conservation rules and regulations but rather via the dynamic and responsive transmis-

sion of skilled knowledge from one generation of builders to the next. Effectively it is this "tradition as process," as instituted in the apprenticeship system, that needs to be (re)valued (Marchand 2003b, 2005). I thus reason that the masons' control over their training needs to remain central to conservation initiatives for the town, and their skill-based knowledge and professional position must be accorded their due status. My core argument is applicable to the conservation of vernacular mud architecture worldwide and aims to renew appreciation for on-site learning that engenders not merely technical ability but also necessary cultural understanding and social responsibility.

A Mason's Apprenticeship

At the start of a mason's traditional apprenticeship, boys as young as six and seven years old may follow fathers, uncles, and older siblings to building sites for their first exposure to the trade. Between play, they are delegated simple tasks such as scraping caked mud from the tools, carrying small loads of building materials, and fetching glasses of sugar-saturated tea for the workers. In these early years, young boys mainly watch, and some attempt to emulate their tutors by laying bricks or smoothing plaster with bare hands. As they grow older, they are delegated increasing responsibility, and they are expected to work closely at the mason's side, formally learning the skills of the trade as an apprentice, or *dyenté idyé*. That privileged position on the work site allows regulated access to the mason's drawstring sack of essential tools: crowbar (*sasiré*), plumb line (*guru karfo*), tape measure (Fr. *mètre*), string level, and two types of trowels. The larger and sturdier of the trowels, the *trouèl courou bibi* (black-skin trowel), is manufactured by local blacksmiths; the smaller, finely pointed *trouèl français* is imported for delicate plasterwork and sculpting architectural decorations in soft mud.

By assisting, observing, engaging in careful mimesis, and repeated practice, the new apprentice hones his tool-wielding techniques and measured judgment. By listening to the mason's stories about the houses and inhabitants of the quarters where they work, the young man gradually becomes versed in the lore of Djenné's urban environment. He is audience to tales about the historic feats performed by legendary master builders, and he is witness to repeated ethnic claims about the Bozo people's historic domination of the trade in towns and villages throughout the region (Marchand 2003c). Now and again, the apprentice tags along to meetings with clients and suppliers, where he watches skilled negotiations

over budgets and scheduling. On-site, he observes his master's management of his labor force, and he is periodically exposed to politically charged interactions between competing masons (see fig. 3).

Masons teach trusted apprentices to recite benedictions that protect the building team and work sites from harm and that ward off dangerous spells cast by powerful mason adversaries. Their benedictions and spells consist of a mix of "white" Qur'anic-based knowledge (*bai quaré*) and "black African" animist knowledge (*bai bibi*); and they sometimes employ blessed objects and amulets in the laying of foundations and the construction of walls. Over the course of his career, a capable mason accumulates a cache of secret rites performed to exorcise the land and buildings of evil djinn and to guarantee the structural integrity of the edifices he erects (Marchand 2007). In combination, masonry techniques, urban and ethnic lore, business skills, and magic slowly forge the apprentice's practice and his identity as a member of the corporate community.

Typically, the apprentice's first major test is to construct a brick wall. He must demonstrate the necessary skills for erecting a perfectly vertical and well-supported structure. If there are flaws the wall is dismantled, and he begins anew. If he succeeds, and can do so repeatedly, the mason presents his apprentice with a plumb line. This elementary tool heralds the young man's rising status. But he is not promoted to the rank of mason until some time later. Final judgment ultimately rests with his master. When the apprentice is deemed fully qualified to oversee duties autonomously, the master announces his decision at a *barey ton* meeting. He can confidently anticipate that the association members will accept his judgment without objection. In fact, the decision concerning the young man's qualifications has been a shared one. As an apprentice circulates between projects and masons during his training, the members of this close-knit trade become familiar with the young man's skills and conduct, and, in effect, they contribute collectively to his formation. Therefore, learning and personal formation are not encapsulated in a one-on-one master-pupil relation; rather, apprenticeship is distributed across the broader community of practitioners (figs. 2-4).

Innovating Tradition

Though the overall appearance of Djenné's architecture has remained remarkably congruous over the past century and longer, the building tradition itself is by no means static. An apprentice's long acquaintance with his restricted palette of



FIGURE 2 Portrait of a laborer at a Djenné building site. Photo: T. H. J. Marchand



FIGURE 3 Masons and apprentices constructing the monumental parapet of a Djenné house. Photo by T. H. J. Marchand



FIGURE 4 Masons constructing a brick wall.
Photo: T. H. J. Marchand

tools and materials serves to inculcate practical knowledge of possibilities and limitations that guides his structural experimentation. His introduction to client negotiations concerning design and budget, as well as his immersion in the array of current masonry methods and practices, serves to shape his aesthetic sensibilities and his judgment of quality, proportion, and composition. Ultimately, master status depends on one's ability to conceive of a project holistically—from design and planning to construction—and to coordinate all the resources and activities necessary for its realization. The combination of structural and aesthetic principles, together with an accretion of practical experience, enables trade masters to creatively expand the existing repertoire of built forms and decorations in a way that is deemed both traditional and innovative by their colleagues and the public (Marchand 2009b) (fig. 5).

But the rank of master—accompanied by the license to innovate—is premised not only on technical accomplishment but also on social aptitude. The latter includes one's ability to procure the esteem of other masons and perform eloquently at the *barey ton* meetings, to gather a prestigious clientele and oversee notable commissions, and to become a respected member of the town's Islamic religious community and comport oneself with appropriate social graces. In sum, it requires the ability to strategically negotiate one's social identity while simultaneously promoting one's professional ideas and ascertaining legitimacy for one's creative practices.

It is common for younger, rising masons to attribute any innovative design solutions they may have to senior colleagues with already established authority, or even to deceased mas-



FIGURE 5 A Djenné resident standing in the front door of his new house. The house features new materials, including glazed ceramic tile surfaces, cemented floors, and an Italianate balustrade along the roofline. Photo: T. H. J. Marchand

ters. This act of transference may be construed as a strategy to locate their own novel practices within an existing canon. By pointing to already-validated persons, younger or lesser-known practitioners effectively absolve themselves from having to negotiate approval and professional accreditation within the conservative patriarchal order of their trade community. They instead seek endorsement as mere reproducers of an established practice or form, though this may not be entirely the case.

In my opinion, the true identity of a creative author is not of utmost concern. More salient to my argument is that there exists in the trade both recognition and appreciation for creative improvisation and innovation. This creativity is not one that reacts against or surpasses Djenné's characteristic architectural style but rather one that remains responsive to it. It expands and embellishes the repertoire of possible expression by producing its own articulation within the existing discursive bounds of "traditional architecture and practice." Such creative ingenuity grasps tradition as a responsive and

FIGURE 6 Reconstruction of a Djenné-style monumental arch in plywood sheeting on a main road in Bamako. Photo: T. H. J. Marchand



dynamic resource, not as a static code of predetermined rules. Figures of creative genius, real or imaginary, are integral to the machinery that produces and reproduces the trade's history, strengthening its roots and fortifying its regional and global reputation.

Among the Djenné masons I worked with, one particular individual has carved a unique space within the discourse and representation of the town's architecture. He and a small circle of trusted colleagues have strategically sidestepped the regulated order of the *barey ton* by nurturing close relations with foreign scholars, conservators, and the handful of European residents of Djenné. They have consequently secured a number of prestigious building contracts both at home and abroad. These include several commissions from foreigners residing in Mali for substantial dwellings with monumental facades in the so-called Tukolor and Moroccan styles and a grand house in the western city of Kayes for a prominent politician. Assignments for overseas projects have included most notably a Djenné-style gateway erected on the Mall in Washington, D.C., for the 2003 Smithsonian Folklife Festival; a scale reconstruction of the Djenné Mosque raised beneath the dome of the ultramodern Clayarch Gimhae Museum in South Korea; and an exhibition of monumental Djenné house facades constructed during the "African Perspectives" symposium hosted at the Technical University in Delft. In recent months, negotiations have gotten under way to build a Djenné-style house for a client in northern Ghana. Djenné's Sudanese style—so

called by French administrators and promoted at turn-of-the-century colonial exhibitions (Prussin 1986)—is set to infiltrate Anglophone regions of West Africa (fig. 6).

The figure at the center of these efforts to export Djenné's mud architecture has steadily fashioned himself as a building contractor and consultant rather than a "mere" mason. As a young builder with a comparatively high level of formal schooling and fluency in French, he established lasting relations with a number of Dutch scholars in the early 1980s and was later entrusted to be a key player in the Dutch-Malian restoration project of Djenné's historic houses (1996–2002) (for a detailed description of the project, see Bedaux et al. 2000). As a contractor, he oversees several projects in parallel with a corps of mason-cousins and loyal laborers under his command and only selectively engages in the muddy work of laying bricks. To my knowledge, there is no precedent for this transformation of roles among Djenné's mud masons. As a consequence, his status among the broader corporate community cannot be easily categorized. To a considerable degree, he operates autonomously from the local trade structure; many commissions are derived from new and foreign clients as differentiated from those typically inherited from former masters; and his relative youth means that his rank and authority are vulnerable to contestations from the trade's gerontocracy.

Although becoming a master (*barey amir*) is traditionally the outcome of lengthy social and political negotiations beyond technical ability, this mason has attempted to

reconfigure the criteria, with a degree of success. He boldly stakes out his expertise on questions of “authenticity” and the “correct” representation of Djenné’s traditional buildings; and, through his foreign contacts and projects, he has maneuvered himself into serving as an international spokesman of sorts, exceeding the local bounds of discourse perpetuated by the *barey ton* association. Not only is he fluent in a Western language in addition to the several African ones he speaks, but he is also conversant in his craft at multiple levels, enabling him to both efficiently direct building sites and laborers and persuade scholarly audiences of his intellectual expertise.

In sum, such recent exchanges and collaborations between foreign scholars/conservators and exceptional masons, like the one I have portrayed, introduce a fascinating dimension for ongoing studies of the changing representations (and reproductions) of Djenné’s architecture at both the regional and global levels.

Conclusion

Djenné is a living, changing town. Citizens and masons take pride in its World Heritage status, but a host of obstructions continue to frustrate full-fledged conservation efforts. Weak government and local leadership, abetted by fragile economics and conflicting development initiatives, has impeded long-term planning for conserving the mud-brick houses and staunching the pillage of treasures from nearby Djenné-Djeno. But equally, Djenné’s population has courted outside intervention cautiously, and they have tactically resisted the imposition of rules and regulations on their living environment. The residents, masons included, struggle to participate in Mali’s national project for progress and in the global arena of information. More than perhaps any other town in the country, Djenné maintains a strong sense of continuity, but tradition and continuity, as in any place, are necessarily couched in a relation with modernity and change. My study of the masons champions the argument that the tradition most worthy of support and conservation is the apprenticeship system itself. This rounded education endows young men with the complex set of skills to innovatively reproduce an urban landscape meaningful to their fellow residents. Ultimately, ownership of Djenné’s architectural heritage must be entrusted to those who make its buildings and keep it a living place.

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Lessons Learned from the Earthen Conservation Projects in Mopti and Timbuktu: A Joint DNPC/AKTC Initiative

Francesco Siravo and Klessigué Sanogo

Abstract: *The first part of this paper discusses the joint conservation activities of the Malian Direction nationale du Patrimoine culturel (DNPC) and the Historic Cities Programme (HCP) of the Aga Khan Trust for Culture (AKTC) in Mopti and Timbuktu. The second part touches on four aspects that are crucial for the protection of the country's earthen heritage: (1) establishment of a countrywide inventory of significant earthen buildings; (2) establishment of a mechanism for the annual maintenance of restored buildings; (3) training; and (4) introduction of legislation, guidelines, and technical improvements for the rehabilitation of traditional settlements and domestic earthen buildings.*

Résumé : *La première partie de cette présentation évoque les activités de conservation conjointes de la Direction nationale du Patrimoine culturel (DNPC) du Mali et le Programme pour les Cités historiques du Trust Aga Khan pour la Culture à Mopti et Tombouctou. La deuxième partie traite des quatre aspects essentiels pour la protection future du patrimoine bâti en terre : 1) l'établissement d'un inventaire national des constructions importantes en terre ; 2) la mise en place d'un mécanisme pour l'entretien annuel des constructions restaurées ; 3) la formation ; et 4) l'adoption d'une législation, de directives et d'amélioration techniques pour la réhabilitation des quartiers traditionnels et des bâtiments domestiques en terre.*

We welcome the opportunity to present the joint conservation activities carried out in Mali by the Direction nationale du Patrimoine culturel (DNPC) of the Ministry of Culture and the Historic Cities Programme (HCP) of the Aga Khan Trust for Culture (AKTC). This paper discusses first our work in Mopti

and Timbuktu, which includes the conservation of the Mopti mosque, completed in June 2006, the current infrastructure improvements in the neighborhood surrounding the mosque, and the ongoing restoration of the Mosque of Djingareyber in Timbuktu. It then discusses the main issues related to the long-term preservation of Mali's earthen heritage.

Let us start with Mopti. The decision to begin work in the country with the restoration of the Great Mosque of Mopti was determined by what we felt was a practical and immediate necessity. During a countrywide mission in 2004, this was the monument that we found at greatest risk. In 1978 and again in 2003, the entire upper register of the building had been rebuilt with fired bricks and cement, adding considerable loads to the structure. This intervention brought about a series of structural cracks and the infiltration of water in the lower, earthen part of the building. Urgent intervention was justified on structural grounds. But it also served a more general purpose: to discourage the introduction of alien construction materials. Rather than eliminating the need for maintenance, they aggravate problems and require more substantial and costlier interventions at a later stage. It is far better to use traditional materials and methods and, if needed, improve their performance, and ensure regular maintenance over time.

The Great Mosque of Mopti, also known as the Komoguel mosque, is a relatively late structure built between 1936 and 1943 on the site of a previous mosque. It is modeled after the Great Mosque of Djenné, built in 1907. It is a symmetrical, rectangular structure supported by massive pillars. The exterior is defined by slender pillars topped by pinnacles and two symmetrical minarets flanked by two lower towers on each side (fig. 1). The minaret on the eastern facade corresponds to the interior prayer niche. Restoration work started in October



FIGURE 1 Aerial view of the restored Great Mosque of Mopti in late 2006. Photo: AKDN, Bamako

2004 and ended in June 2006. This work included the removal of the cement and reconstruction of the upper part of the building; replacement of the structural timber and roof slab; renovation of the earthen brick walls, minarets, and towers; and the reintegration of the protective plaster. Inside the building, the cement flooring and woodwork were replaced, together with the electrical and speaker systems (fig. 2).

The restoration was complemented by a training program aimed at transferring traditional knowledge from the older to a younger generation of builders. In 2005, while its restoration was in progress, the mosque was officially listed on Mali's national register of monuments.

The restoration is the centerpiece of a broader involvement in the Komoguel neighborhood surrounding the mosque. The long-term objective is to improve the standard of living through better access to water and sanitation, better health care, vocational training, and microcredit services. In the longer term, we envisage the construction of a protective embankment or dyke and the creation of a visitor and community center, as well as greater involvement in the rehabilitation of housing.

At the end of 2006, following the work on the Great Mosque of Mopti, the DNPC and AKTC started comprehensive rehabilitation work in Timbuktu's Djingareyber mosque. Founded in the fourteenth century, it is the oldest earthen structure in sub-Saharan Africa. It is listed on the national register of historic buildings and in 1988 was listed as a UNESCO

World Heritage Site. The form, building materials, and finishes of the Djingareyber mosque are quite different from those of the Great Mosque of Mopti. Mosques in Timbuktu have low, massive walls. Their distinguishing feature is an imposing minaret, shaped like a truncated pyramid. Their walls are made of stone (*alhore*) instead of mud bricks, and the nature and composition of the earthen plaster are quite different from what is found in Mopti.

Also at the Djingareyber mosque, lack of maintenance and the harsh climatic conditions have taken a toll, especially with regard to poor masonry bonding and water infiltration. Moreover, building work carried out in the late 1960s introduced exterior stone cladding in parts of the building that is not only alien to the character of the monument but also compromises its structural integrity. We have now completed the initial phase of the work in the southern section of the mosque. Also in this case, the intervention will be comprehensive: the exterior facades, interior columns, and minaret need consolidation; the roof slab has to be replaced; and the entire drainage system around the monument has to be overhauled (figs. 3, 4). Work in the interior includes conservation of the prayer halls and decorated niche, as well as improvements to the ventilation and electrical and sound systems. As was the case in Mopti, training is an essential and fully integrated component of the project.

With regard to the modalities of implementation, in both Mopti and Timbuktu the project team is in charge of



FIGURE 2 The south entrance of the Mopti mosque before and after restoration. Note the damage caused by the cement structure constructed on top of the building prior to restoration of the structure. Photos: AKTC, G. Devreux and G. Taxil



FIGURE 3 View of the Djingareyber mosque under restoration.
Photo: AKTC, L. Blanco



FIGURE 4 Installation of the ceiling made of *goettes* arranged in a geometric pattern, part of the work on the roof of the Djingareyber mosque. Photo: AKTC, M. Sy

the development of the restoration work, providing technical advice and acting as the main contractor. Accordingly, the team is responsible for planning and scheduling the work, coordinating labor and procurement, and monitoring the quality of the results achieved. Direct recruitment of experienced craftsmen has been crucial in reintroducing traditional methods and training a new generation of builders.

* * *

Here we want to move away from individual buildings and broaden our discussion to themes that have a general relevance to the preservation of Mali's earthen heritage: (1) the establishment of a countrywide inventory of significant earthen buildings; (2) the creation of a system for the annual maintenance of restored as well as endangered structures; (3) the training of skilled workers and specialized professionals; and (4) the establishment of local legislation and the reintroduction of traditional building practices for vernacular earthen buildings and settlements.

These are complex issues, and we can only touch briefly on each. The first important point is the establishment of a countrywide inventory. Our ability to protect and intervene in Mali's earthen heritage can only be as good as the information we have. And here we suffer from huge gaps, both in terms of the quantity and scope of information and in terms of the type and use of data. For example, we know a fair amount about the

large congregational mosques but very little about neighborhood mosques and even less about the small rural mosques, a rich heritage where one can still observe the persistence of earlier forms and techniques (fig. 5). We must also acknowledge that our documentation of chiefs' residences, tombs, communal and meeting houses (*saho*), utilitarian structures, and fortifications, as well as urban and village settlements, is fragmentary and incomplete.

Moreover, we need to consider the significance and future use of the information. Architectural and aesthetic criteria may not be the only reasons to document the existing heritage. Other factors, such as historical associations, important lineages, social significance, rarity, community value, and risk, may be equally important.

Our experience indicates that inventories also need to take into account the materials and techniques specific to each region. Learning from experienced and master masons is one way to reintroduce traditional know-how, but this information needs to be cross-referenced with the evidence incorporated in the old buildings themselves, as well as the geographic provenance of the construction materials. Ideally, over the long term, we should work toward the preparation of region-specific manuals of traditional construction and conservation. Any future inventory must include the definition of the different levels of risk. Paramount in this respect is to ascertain whether a maintenance system is being implemented.



FIGURE 5 The mosque of Nando, in a small village near Mopti, is one of many traditional earthen structures that need to be inventoried, listed, and protected. Photo: AKTC, G. Taxil

This brings us to the second important issue. While regular maintenance is important for the preservation of old buildings anywhere, in the case of earthen structures it is vital, a question of life or death for a building. The Mopti mosque is a good case in point. The technical parameters and cost of annual maintenance are well understood, and the project has established an excellent team capable of carrying out the work (fig. 6). But a clear apportionment of responsibilities, a funding mechanism, and a protocol for implementation still need to be put in place. Where the traditional systems of in-kind *corvées* and community participation have disappeared, a viable alternative has yet to be found. Is maintenance still the responsibility of the community? Or should the state intervene, especially in cases where, as in Mopti, the building has been listed? And, in either case, where should the money come from? Donations? Government funds? Revenue from tourism? These are some of the alternatives that are being discussed at present and for which answers are urgently needed.

But even in cases where community participation in the maintenance of the structures is still viable, as in Djenné, is it really working? Or have the social and economic transformations of recent years seriously undermined its effectiveness? Also in this case, there is a need for new answers and better technical supervision by local masons' associations and more effective monitoring by local and national institutions.

This last point is closely related to the third issue we would like to raise, that of training. Our direct experience shows that there is a need to transfer traditional know-how from the older to the younger generation. This can be done very successfully within the framework of a restoration site, which can also serve as a training opportunity. More than thirty young masons and specialists have been trained on the job during the Mopti restoration, and a similar effort is now under way in Timbuktu (fig. 7).

We have had similar positive experiences with other trades, such as carpentry, metalwork, and pottery making; the very existence of a demand for traditional crafts can be a powerful incentive for the revitalization of many disappearing trades. But our window of opportunity is limited. Many of the repositories of this traditional knowledge are craftsmen who are advanced in age. This is the time to ensure that training opportunities are established throughout the country and that the baton is passed to the next generation.



FIGURE 6 The first yearly *crépissage* in the Mopti mosque following restoration of the building in 2006. Periodic maintenance is of paramount importance for extending the life of earthen structures. Photo: AKTC, G. Taxil



FIGURE 7 Graduation ceremony on completion of site activities in Mopti. More than thirty young masons and specialists were trained on the job during the restoration of the Mopti mosque. Photo: AKDN, Bamako, S. Chitalia

But there is another aspect of training that needs urgent and sustained attention. To date, it has been difficult to find young professionals who are knowledgeable about traditional construction and conservation and willing to take on site supervision and documentation responsibilities on a full-time basis on our sites. And yet this is what the country needs so badly if its national heritage is to be effectively protected and managed.

We have no immediate answers, except to recommend that this type of training be established in existing schools and that the idea of a specialized center for earthen conservation and traditional construction, such as the one proposed in Ségou, be revived. It is essential to establish a solid link between architectural studies and the building trades.

We hope to be able to stimulate wider interest in earthen architecture and its related crafts in Mali, also through the implementation of future urban improvement initiatives. And this is the final issue we wish to raise: the need to introduce rehabilitation policies and legislation for the protection and upgrading of vernacular buildings and traditional settlements. By and large, these are the greater part of the country's earthen heritage, as well as the inseparable context of the important monuments discussed earlier.

Even a cursory walk through the historic settlements, such as Mopti, Djenné, or Timbuktu, shows that a process of rapid transformation is under way. Here, the greatest threat to the survival of an earthen building tradition is represented

by imported construction systems, often expensive, out of character, and not suited to the local climate. The principal reason for their success is that they are new and are associated with affluence, whereas earthen buildings continue to be linked with poverty and neglect. But it need not be so. One need only demonstrate that living conditions in houses and vernacular earthen structures can be greatly improved and at a reasonable cost.

But where do we begin? A first step is the rehabilitation project in the neighborhood around the restored Mopti mosque. The rationale for the initiative is that in order to improve this traditional neighborhood and its earthen buildings, the place to start is with the drainage and sewage systems. The program includes overhauling the public infrastructure and repaving the streets, as well as establishing individual connections to the sewage and water networks. The latter in particular will have an immediate effect, improving living conditions and reducing water infiltration into the structures themselves, thus eliminating one of the principal causes of building deterioration. The cost of this simple improvement is quite modest, but it can have a considerable impact on the longevity of the buildings themselves. Other basic interventions could follow this pilot project, perhaps through a housing credit scheme or revolving fund.

Together with these physical improvements, effective legislation for urban areas and settlements needs to be introduced. The DNPC has already developed draft guidelines for Mopti. Another excellent set of guidelines has been proposed for Gao, but they have not yet been translated into statutory town plans. This legal passage, however, is quite important: experience in other parts of the world shows that in order to be effective, these guidelines need to be integrated into the local planning and building bylaws under the control of the local government authorities. Further, implementation of conservation actions and the reintroduction of traditional building practices should become part of the day-to-day responsibility of local planning offices (fig. 8).

In closing, we hope that by addressing forcefully these key issues, it will be possible to better protect the national cultural heritage and better promote earthen construction systems and technologies in the country. No extraordinary measures and no massive infusion of funds are required. The real challenge ahead is to manage Mali's rich earthen heritage day after day, year in and year out, by knowing what is there, instituting regular maintenance, providing practical on-the-job training, and improving the traditional built environment for the communities concerned.



FIGURE 8 The proposed visitor and community center in Mopti will introduce the use of traditional earthen technologies in new construction, as well as provide a community space and source of revenue for the maintenance of the nearby mosque. The project is part of the rehabilitation of the Komoguel neighborhood in Mopti. Photo: AKTC. Design: F. Siravo. Rendering: E. Trapani

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The office of the Aga Khan Development Network in Bamako, led by its resident representative, Ferid Nandjee, provided logistical support throughout the development of the joint initiative. Klessigué Sanogo coordinates the project on behalf of the DNPC. Francesco Siravo has been responsible

on behalf of AKTC for the project's development and technical coordination from 2004 to March 2008, a role recently handed over to Christophe Bouleau. Jurjen van der Tas, HCP deputy director, is responsible for the social development and infrastructure rehabilitation activities in Mopti. The international consultants and national experts who have been or are currently engaged in the initiative are listed below.

Mopti Mosque Restoration Team (2004–2006)

Gisèle Taxil, site architect and earthen construction specialist

Wilfredo Carazas, Lucia Blanco Canales, and Mariam Sy, architects and earthen construction specialists

Guy Devreux, conservator

Laurino Saccucci, Alphamoi Touré, and Moussa Yena, master masons

Luigi Branchetti, Mamadou Sagara, and Moussa Togola, joinery and woodwork

Casimir Kéita, Sékou Timbinné, and Seyba Touré, electrical and sound systems

Kadidia Niantao, ceramist

Djingareyber Restoration Team (2007–present)

Gautier Bicheron, site architect

Lucia Blanco Canales, site architect, January–June 2007

Wilfredo Carazas, Mariam Sy, and Gisèle Taxil, architects and earthen construction specialists

Josephine D'Ilario, conservator

Baba Djité, Mohamed Mahalmane, Ibrahim Mahalmane, and Laurino Saccucci, master masons

Many other people, too many to be named here, have contributed to the development of the joint DNPC/AKTC restoration projects in Mopti and Timbuktu. The authors wish to express their most sincere appreciation to each and every one but especially to the site workers and craftsmen who day by day have brought these buildings back to life.

PART TWO

Conservation of Living Sites

Conservation des sites vivants

Adobe Cities of Libya: Unique World Heritage Architecture at Risk

Abdulgader Abufayed, Amer Rghei, and Abubaker A. Aboufayed

Abstract: *Libya has many cities constructed of adobe strategically located across its vast area. Constructed with full consideration of local environmental and socioeconomic factors, these cities combine attractiveness, simplicity, and sophistication with affordability, functionality, and sustainability. They are facing serious challenges, however, stemming from depopulation, poor maintenance, and encroachment of or even displacement by new “concrete” cities. The objective of this paper is to highlight the significance of adobe cities of Libya, the challenges they face, and the measures needed to safeguard them through a case study of the city of Ghadames.*

Résumé : *La Libye possède de nombreuses villes construites en adobe, implantées stratégiquement sur son vaste territoire. Construites en tenant compte des facteurs environnementaux et socio-économiques locaux, ces villes sont à la fois agréables, simples, sophistiquées, peu coûteuses, fonctionnelles et durables. Elles sont cependant confrontées à de sérieux défis liés à la dépopulation, au manque d’entretien et à l’envahissement par les nouvelles villes de « béton » qui les concurrencent, voire les remplacent. Le but de cette communication est de souligner l’importance des villes en adobe de Libye, les problèmes qui leur sont posés et les mesures de sauvegarde envisagées, à travers l’étude de cas de la ville de Ghadamès.*

Libya is a large, sparsely populated country strategically located on the southern coast of the Mediterranean Sea. It is this location that made Libya the cradle and crossroad of the world’s oldest and greatest civilizations. The prehistoric carvings and Garamantes, Phoenician, Greek, Roman, and Arab-Islamic cities spanning the country are living proof of the contributions Libyans have made to the advancement of

human culture. These contributions are best reflected in the earthen architecture, which exhibits diversity and sophistication characteristic of place and time. Adobe cities warrant special attention because of their unique, sustainable architecture, their large number, their important role until only a few decades ago, and their significance as World Heritage Sites as part of a large adobe corridor extending across the Sahara Desert from the Atlantic states of Morocco, Mauritania, and Senegal to the Arabian Gulf states and beyond. These cities face the common threat of abandonment and replacement by new “concrete” cities with modern amenities.

This paper highlights the significance of the adobe architecture of Libya by identifying its major features, values, and benefits, with special reference to the case of the historic city of Ghadames. Subsequently, it elaborates the major challenges facing earthen cities, their prospects, and the strategies to be adopted for safeguarding and promoting their use in the twenty-first century. These features are further demonstrated through a comparison of adobe cities and the modern cities that are constructed “opposite” them.

Geophysical Features

Libya’s earthen architecture is a response to the country’s geophysical features: a long coastline (1,900 km), mountain ranges on the east and west with altitudes approaching 700 meters above sea level and a mountain range (Tibesti) to the south exceeding 1,000 meters in altitude, two fertile plains (Jefara and Marj), and an overwhelmingly barren desert covering more than 95 percent of the country.

Libya is characterized by three subclimatic zones, namely, the mild Mediterranean subzone, the semiarid and

mountain zone, and the arid zone. Rainfall is modest; it is highest in the coastal and mountainous zones and decreases abruptly southward, with more than 90 percent of the country receiving less than 10 millimeters per year. Expectedly, relative humidity is low in most of the country. Temperatures are generally high, with extreme lows reaching -6°C and extreme highs exceeding 50°C .

Although it lacks natural sources of surface water, Libya has immense groundwater reserves, especially in the south. The availability and quality of water have always dictated the location of cities and towns. Most of the population resides along the coastal corridor; the remainder is found in the many oases scattered in the desert.

Earthen Architectural Heritage of Libya

Practically, all adobe cities are located at or near the desert oases, which possess naturally flowing springs and high water table aquifers. Being the most valuable resource, water was used very efficiently under an advanced management system. Consequently, agriculture flourished, ensuring food and sufficiency and providing building materials as well as an aesthetic landscape. Sustainability and prosperity were thus ensured in these remote cities with their highly skilled and industrious populations.

It is the harsh, hot climatic conditions, along with the availability of adobe materials and their low cost, among other factors, that made adobe the favored building material in most regions of Libya. Other complementary materials included stone, gypsum, lime, and load-bearing wood products.

Rich in groundwater, the many adobe cities of Libya were constructed with full consideration of the physical environmental constraints, socioeconomic factors, and harsh climatic conditions. Adobe architecture employed local building materials and simple building techniques; it was human driven, labor intensive, and time-consuming. This architecture combined attractiveness, simplicity, and sophistication with affordability, functionality, and sustainability. Moreover, earthen architecture constituted a valuable asset for local communities as it provided shelter to large numbers of citizens, offered job opportunities, and symbolized cultural heritage and national pride.

Adobe settlements (villages, towns, and cities) have been linked by a network of routes used extensively by trade and pilgrim caravans. These routes, in use as recently as the 1950s, extended from Morocco to Mecca and from Tripoli/Tunis to Kano and Khartoum. Cultural and commercial contacts

enforced and shaped by Islam contributed to the uniqueness of Libyan/Saharan earthen architecture. These settlements show an overall urban style of unity and homogeneity in their planning and methods of construction. Their form is compact, and they have covered streets and are surrounded by green belts. The buildings have thick adobe walls, with no windows open to the outside.

Like their sister vernacular cities worldwide, Libyan adobe cities were designed, executed, and maintained by their residents directly, that is, through full community participation. Consequently, they met their modest but high-quality standards:

- security within well-defined borders as these cities were enclosed within fences;
- a close-knit society with strong doctrines and traditions, making the community crime-free;
- protection from the harsh environment, being within or near an evergreen oasis and having narrow and, sometimes, covered streets;
- social and spatial closeness as houses were wall-to-wall with areas allocated among tribes or families;
- cost-effective housing using abundant local materials;
- equality and modesty of residents as houses are quite similar in terms of materials, design, appearance, and so on; and
- a beautiful land- and cityscape compatible with the surroundings.

Experience and research findings over the past forty years have demonstrated the superiority of adobe cities to their new “concrete-constructed” rivals (EzZway and EzZway 2002). Adobe cities are more comfortable in winter and summer, with natural attenuation due to design and material selection and therefore significantly lower energy requirements. Socially, the new cities suffer from alienation and loose relationships, resulting in a less-than-ideal social fabric.

Ghadames: Epitome of Libya’s Earthen Architectural Heritage

The number of earthen cities and buildings still in existence in Libya exceeds six hundred. Of these sites, Ghadames is perhaps the best known and most illustrative of Libya’s earthen architecture (Abufayed 2003). It is one of Islam’s oldest cities (Youshaa 2002). In 1986 it was inscribed on UNESCO’s World

Heritage List in recognition of its outstanding features and threatened sustainability.

Ghadames is situated about 600 kilometers southwest of Tripoli, Libya's capital, and only a few kilometers from Tunisia and Algeria. Enclosed within an oasis surrounded by barren desert and located strategically on the axis of a major trans-Saharan caravan route, it has been one of the Sahara's most important cities.

The City Form

Ghadames was built on an area of about 7.5 hectares. It was planned, designed, and constructed to have a very compact form with a definite hierarchy in the city's elements. Spaces are located, organized and classified, and sized based on order and function. There are seven semi-independent neighborhoods that can be isolated completely by means of external and internal gates, or entrances. Each neighborhood has a main street, public buildings (squares, mosques, *zawias*, schools, etc.), commercial buildings, and private houses, the latter constituting the majority of buildings. Streets decrease in size and length, from the public main street to semipublic alleys to private passageways or cul-de-sacs.

Streets are lined with benches spaced according to age groups; those closest to mosques are reserved for seniors, those farthest from the mosque for children. Streets open onto partially covered or open squares (*maydan*) reserved for sitting and for socioreligious occasions.

To overcome the harsh climate, streets are narrow, winding, and covered completely except for lighting and ventilation openings spaced almost regularly along them (fig. 1). Consequently, the city's buildings form an extensive monolithic structure with one large roof. This roof is used exclusively by women and children for socializing and trade during the daytime. Moreover, it optimizes adaptations to the harsh environment by minimizing exposed areas and maximizing the area per unit volume. This feature, along with proper selection of isolating local building materials, gives houses in Ghadames superior thermal qualities.

The two-tiered streets have an almost uniform height of about 10 meters, slightly lower than the maximum heights of palm trees so as to ensure protection from the frequent sandstorms and to minimize loss of agricultural land area. Having more than fifteen hundred buildings, Ghadames sustained a high population density of over a thousand persons per hectare. The city's architecture is characterized by its unique, organic form, morphology, covered streets, and unique arches (see fig. 1).



FIGURE 1 Unique architectural features of Ghadames: arches and covered streets. Photos: A. Abufayed

House Design and Form

The city's compactness is the result of the compactness of its houses. To maximize utilization of very limited arable land, house areas had to be as small as possible (20–80 m²), with vertical expansion as a means for increased area. Houses have a uniform “standard” courtyard-type design; each house consists of three levels assigned different functions. The entrance opens directly onto a covered passageway on the ground floor that was used for storage of farm tools (or commercial goods). Stairs lead from the entrance lobby to the first floor, where the most important “living room” area is located. This area was essentially a courtyard, which was covered for protection from the hostile environment; it was directly lit and ventilated by a small, 75-by-75-centimeter opening in the ceiling. This living space is surrounded by bedrooms and leads to food storage and sleeping rooms, a few steps higher.

The central living room is the most important space in the home. The floor is covered with colorful, locally handmade rugs and mats. The walls are whitewashed and decorated—solely by the housewife—with bright red painted motifs, hanging mirrors, brass utensils, baskets, and brass jars. There are cupboards and niches in the walls at different levels for keeping valuables, as well as food.

The terrace/top floor, reached by a staircase, houses the kitchen and sometimes a small room. It was reserved for women's activities such as cooking, washing, trading, and entertaining female guests. Since all houses are linked at an upper street level (which covered the lower streets), women could move freely at this upper level without contravening the traditional separation of the sexes. Another advantage of the street system in the old city of Ghadames was that in the event of attack,

street openings could be covered and kept in complete darkness as a means of defense. All terraces are surrounded by small walls to ensure privacy.

Doors of the houses in Ghadames were constructed of segments of palm trunks. They were seldom decorated, except for those whose owners had made the pilgrimage to Mecca.

Indigenous Building Practices

Building practices have evolved over many centuries relying totally on local skills and materials (Abufayed and ElAzhari 2003). Adobe (Arabic for “sun-dried brick”) is the main material of construction of Ghadamsi buildings, along with palm tree trunks, fronds, and leaf stems. Stones, gypsum, and lime were also employed. This use of traditional technology enabled the builders to provide a shelter well adapted to the conditions of the Saharan environment and readily affordable by the residents.

Adobe bricks were made of a mixture of white and black soils soaked in water, mixed and formed in rectangular wooden molds. Local stone was used to build foundations; dried bricks were used for building walls, while gypsum and coral stone were used to construct arches and vaults. Mud “adobe” mortar bonded the layers of the bricks.

Palm tree trunks, fronds, and leaf stems were the main components in roof construction. Trunk beams were covered with a mat of stems and a thin layer of palm fronds and topped with a 20- to 30-centimeter-thick slab of adobe mortar. The roof was finished with a thin layer of gypsum plaster topped with a lime wash.

The Current Situation

For decades, earthen architecture in general and adobe architecture in particular have been facing serious challenges that threaten their very survival. These challenges stem mainly from the interruption of routine maintenance, adverse environmental conditions, depopulation or transient immigrant populations, the improper introduction of “modern” amenities, and the encroachment of “modern” architecture, industry, and agriculture. The inherent nature of the construction materials and their susceptibility, if not properly maintained, to deterioration have contributed to the seriousness of these challenges. Other challenges include the following:

- Poor understanding and improper valuing of earthen architecture;
- Lack of technical data needed to conserve earthen architecture;

- High costs associated with rehabilitating a large number of sites;
- Diverging approaches and interests of stakeholders, ranging from conservative do-nothing advocates to liberal advocates with opposing practices;
- Urgency of addressing challenges versus time needed for proficiency and provision of resources;
- Need for “amenities” versus their associated potentially adverse impacts;
- Limited resources and strong competition by other equally urgent priorities;
- Lack of skills and technical literature on rehabilitation and reuse;
- Detachment of the new “concrete” generation and lack of interest in rehabilitating adobe cities;
- Rigidity and inability to adapt to dynamically changing lifestyles and to integrate with modern architecture; and
- Sweeping support of modern architecture, especially by the younger generation.

All this means that Libya’s cities are in different states of disintegration, depending on the intensity of efforts to safeguard them (fig. 2). Where nothing has been done, irreparable damage has occurred, and the cities have all but disappeared. Some cities met the same fate when they were simply demolished to make way for new, “modern” cities. The majority of adobe cities in Libya have ceased to exist. Those that remain have suffered serious but repairable damage, among them Derj, Ghadames, Tunin, AlBerket, and Jadida, as well as many individual historic buildings.

Efforts toward Safeguarding Libya’s Earthen Architecture

Increased national awareness of the value of earthen architecture in concert with community pressures and state support for cultural conservation has led to public and private actions toward safeguarding the nation’s earthen architecture. Significant steps in this direction include the following:

- Establishment of the Authority for Management of Historic Cities;
- Comprehensive inventory of historic cities and buildings;
- Initiation of classification of sites and cities surveyed;



FIGURE 2 Deterioration of adobe structures in Ghadames. Photo: A Abufayed



FIGURE 3 Project for the rehabilitation of Ghadames Tylawaan school (a) before and (b) after. Photo: A. Abufayed

- Implementation of several rehabilitation projects by the Authority, including Ghadames (fig. 3) and Ghat;
- Implementation of several rehabilitation projects by NGOs, including those in Derj, Jalu, and Houn;
- Provision of financial and technical support by the Authority for rehabilitation of individual houses by owners;
- Preservation of local knowledge and skills through training; and
- Organization of a national symposium on developing a national strategy for safeguarding historic cities.

Future Prospects

Adobe architecture in Libya is facing serious challenges caused by natural factors and human interventions or lack of interventions. Urgent action is therefore needed by decision makers and all stakeholders to safeguard this architecture for its cultural and socioeconomic values and as a source of inspiration for the planning and building of modern “traditional” settlements that are optimized socially, economically,

and environmentally. Moreover, this architecture is a common world heritage. Actions proposed in this direction include the following:

- Updating the inventory and assessment of the current state of adobe cities/buildings;
- Learning from past lessons associated with preservation experiences;
- Extending the merits of the architecture of adobe cities to modern cities and the modernizing of adobe cities;
- Funding research and development in the field of earthen architecture to provide a technical approach to the understanding and upgrading of adobe architecture;
- Sharing knowledge and experience with others nationally and internationally;
- Adopting a national preservation strategy while saving all that can be saved immediately;
- Developing the necessary legislation for the preservation of earthen architectural heritage;

- Engaging all stakeholders in all preservation processes to ensure success of the strategy;
- Transforming depopulated cities into living cities with adaptive reuse (a heritage city is not a museum);
- Creating a viable mechanism for preservation and building on successes;
- Making preservation sustainable by ensuring that it is planned and managed by the people and that they benefit from it directly (shelter, jobs, recycling, energy, preservation of heritage); and
- Networking with international organizations, NGOs, and learning centers.

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Un plan de gestion pour retirer un bien de la Liste du patrimoine mondial en péril : Le cas des Palais royaux d'Abomey

Léonard Ahonon et Thierry Joffroy

Résumé : Les Palais royaux d'Abomey, inscrits sur la Liste du patrimoine mondial en 1985 et sur la Liste du patrimoine mondial en péril la même année, ont obtenu la mobilisation des autorités béninoises et de la communauté internationale. Pourtant, des actions trop ponctuelles ou centrées seulement sur la zone muséale, le manque de suivi du plan de conservation élaboré en 1998, ou encore les investissements répartis sur un nombre seulement limité de structures ont engendré des pertes parfois irréversibles. En 2004, la mission d'évaluation de l'ICOMOS a constaté la pertinence du plan de gestion qui a pu être réhabilité. Les retards ont depuis été rattrapés par le gestionnaire du site qui a privilégié la prévention des risques et les résultats visibles. Ces avancées ont été évaluées et, grâce à l'engagement des parties prenantes, le plan de gestion a été révisé en 2007, ce qui a permis de retirer le site de la Liste du patrimoine mondial en péril.

Abstract: The royal palaces of Abomey, inscribed on the World Heritage List in 1985 and on the List of World Heritage in Danger in the same year, have mobilized the Benin authorities and the international community. Yet the piecemeal activities, or activities focused only on the museum area, the lack of follow-up on a conservation plan drawn up in 1998, and investments allocated to a limited number of structures have often led to irreversible losses. In 2004 an ICOMOS evaluation mission confirmed the relevance of the management plan, which was revisited. The site manager was able to catch up on lost time, giving priority to risk prevention with visible results. This progress was assessed, and due to the commitment of stakeholders the management plan was revised in 2007, thus enabling the site to be removed from the List of World Heritage in Danger in July 2007.

La République du Bénin, pays de l'Afrique de l'Ouest, comprend plusieurs groupes socioculturels. Ce peuple mixte a fait preuve d'ingéniosité pour produire les moyens nécessaires à son existence et a su notamment créer un habitat qui prend en compte l'environnement tout en s'enrichissant graduellement des échanges culturels et économiques qu'a connu le pays au cours de son histoire.

Selon l'aire géographique, chaque groupe socioculturel a établi un mode de gestion qui lui est propre, conformément à des règles étudiées, conçues et instaurées pour faciliter cette gestion.

Le plateau d'Abomey, sur lequel s'est établi le siège d'un vaste royaume n'est pas resté en marge de ce développement, comme en témoignent aujourd'hui encore les impressionnants Palais royaux d'Abomey.

Le 6 décembre 1985, les Palais royaux d'Abomey ont été inscrits sur la Liste du patrimoine mondial de l'UNESCO, sur la base des critères (iii) et (iv). Étant donné l'état précaire de conservation des composantes de ce bien, le Comité du patrimoine mondial a jugé utile de l'inscrire sur la Liste du patrimoine mondial en péril la même année.

Cette communication abordera la présentation des Palais royaux d'Abomey, les actions menées jusqu'en 2005, les évolutions connues par le site et les actions menées entre 2006 et 2007 pour atteindre les résultats ayant permis de retirer le site de la Liste du patrimoine mondial en péril le 25 juin 2007.

Présentation des Palais royaux d'Abomey

Le site des Palais royaux d'Abomey s'étend sur 47 ha et comprend 184 bâtiments construits en terre. Il constitue le centre

de décision du pouvoir traditionnel du royaume de Danxome qui se développa dans la région à partir du milieu du XVII^e siècle. Désormais, le site demeure le témoin matériel essentiel de ce royaume bâti selon le précepte énoncé par son fondateur, Hwegbaja, « que le royaume soit toujours plus grand ». Onze palais privés lui sont associés, chaque roi ayant construit son palais de fonction à côté de celui de son prédécesseur, de même que son palais privé à l'extérieur de l'*agbodo*, le fossé défensif qui ceinture la ville royale. Cette disposition des palais les uns par rapport aux autres illustre bien cette volonté initiale du fondateur du royaume.

Les palais sont organisés sous forme d'une succession de cours très hiérarchisées, l'accès de l'une à l'autre étant assuré par des portails bâtis à cheval sur les murs d'enceinte principaux. Cette disposition se retrouve aussi pour les bâtiments principaux (*adjalala*). L'organisation spatiale du site est

parfaitement structurée, chaque espace ayant un usage bien précis et réglementé par la tradition. Les composantes (les *honnuwa*, le *djononxo*, le *lègèdèxo*, le *tassinonxo*, le *logodo*, l'*adjalala*, le *djexo*, l'*adoxo*, le *boxo*, l'*adanjexo*, le *dosseme* et autres) ont chacune une fonction qui les caractérise.

Les résidents sont orientés dans ces espaces en fonction de leur rôle au sein du palais. De même, la circulation du visiteur est conditionnée par l'objet de sa visite et par son rang social, depuis la devanture d'un palais jusqu'à la salle où le roi tient conseil et reçoit ses hôtes de marque (fig. 1).

Le site possède nombre de points symboliques et lieux de culte, plus ou moins visibles. Si certains sont marqués par des arbres ou des autels, d'autres sont simplement des lieux ou des buttes de terre quasiment imperceptibles, mais bel et bien présents. C'est le cas de la place *singbodji / houéhondji*, dernière place à avoir effectivement été utilisée pour les ren-

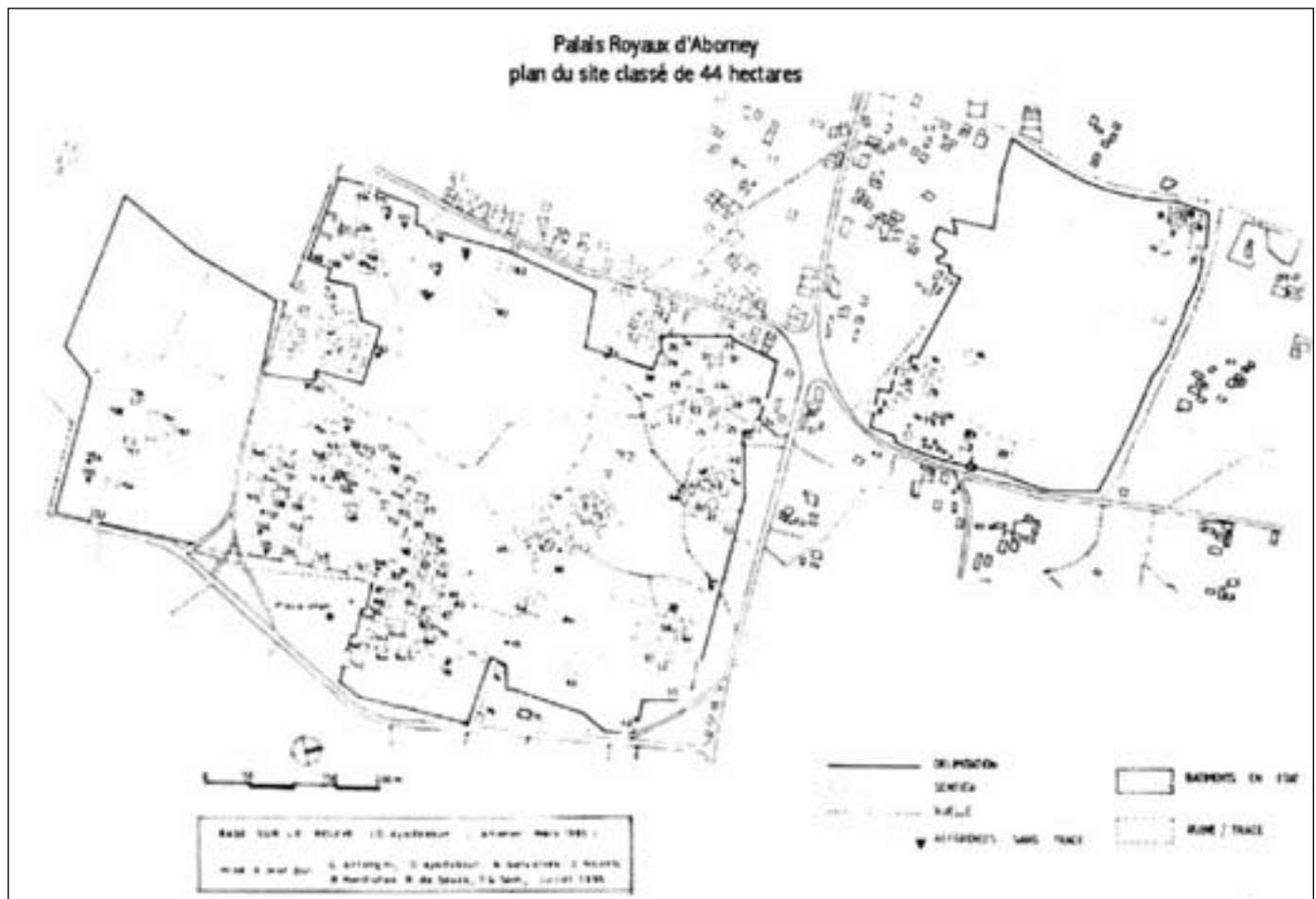


FIGURE 1 Plan du site des Palais royaux d'Abomey.

contres entre le roi et son peuple. C'est un lieu où l'on célèbre de nos jours les deux grandes cérémonies annuelles liées respectivement à la récolte des céréales et au droit de consommer l'igname, et où sont aussi organisées les intronisations des rois, princes, princesses et dignitaires.

Si les palais ne sont plus habités aujourd'hui, une des cours reste en activité, celle de *dossémé*, où résident les *dadasi*, femmes incarnées aux rois, qui participent aux cérémonies commémoratives. Quelques tombes sont aussi entretenues et surveillées en permanence par leurs gardiennes.

Le site classé des Palais royaux d'Abomey demeure le témoin vivant de la puissance du royaume de Danxomé, et de la civilisation qui lui est associée dont la communauté internationale s'accorde à reconnaître les valeurs exprimées par les détenteurs naturels (familles royales d'Abomey) et les différentes parties prenantes, notamment les chercheurs. Ces valeurs sont de plusieurs ordres :

- valeurs historiques et archéologiques ;
- valeurs immatérielles ;
- valeurs esthétiques, scientifiques et techniques ;
- valeurs économiques et sociales ;
- valeurs symboliques.

Le nombre de visiteurs augmente chaque année jusqu'à atteindre plus de 23 000, ce qui contribue pour une large part au développement de cette ville qui voit se multiplier le nombre des infrastructures hôtelières.

Le bien a disposé d'un premier plan de conservation et de gestion pour la période 1998-2003. Sa mise en œuvre a été évaluée, ce qui a permis l'élaboration d'un nouveau plan de conservation, de gestion et de mise en valeur pour la période de 2007 à 2011.

Considéré comme une institution de l'État et placé sous la tutelle de la Direction du patrimoine culturel du Bénin, le site des Palais royaux d'Abomey dispose d'un conseil de gestion, d'un comité technique de gestion et d'une administration composée d'un gestionnaire de site ayant sous sa tutelle un responsable de la muséographie, un conservateur de site et un responsable des ressources humaines, matérielles et financières.

Activités menées jusqu'en 2005

Plusieurs activités ont été menées depuis l'inscription du bien sur la Liste du patrimoine mondial le 06 décembre 1985 et parmi lesquelles il importe de souligner principalement :

Les travaux de restauration des palais Guézo-Glélé

Ces travaux faits dans le respect des savoirs et savoir-faire traditionnels ont concerné les murs d'enceinte, les coiffes sur murs d'enceinte et les enduits peints au kaolin ou à la chaux et le *colta*, ainsi que les charpentes de toitures et les plafonds.

La réorganisation des collections du musée

Les Palais royaux d'Abomey sont à la fois un musée de site et un musée de collections. Les attributs royaux, les parures, les vêtements, les objets cérémoniels, les armes et autres des différents rois qui se sont succédé dans le royaume de Danxomé sont en grande partie conservés sur le site, dans les réserves ou dans les lieux d'expositions ouverts au public.

De plus, la rénovation de l'exposition permanente du musée réalisée en trois phases permet désormais de présenter l'histoire du royaume de Danxomé depuis sa création jusqu'à la conquête coloniale.

À la suite de la formation des techniciens du musée aux techniques de conservation préventive, une campagne de désinfestation par fumigation, d'entretien et de documentation des collections a eu lieu. Des structures de rangement ont aussi été aménagées et une nouvelle réserve permettant de sécuriser les objets a été créée.

Enfin, la restauration des bas-reliefs découpés de l'*ad-jalala* du roi Glele est une intervention qui a non seulement permis de sauver ces objets en les rendant déplaçables pour être exposés au public, mais aussi de former des techniciens en conservation des bas-reliefs *in situ*.

L'animation du musée

Le renforcement des capacités professionnelles s'est étendu à la formation des guides qui présentent aux visiteurs le musée de site ou le musée de collections, le parcours étant inversé.

Outre ces actions fondées sur le principe des visites traditionnellement offertes au public, certaines activités d'animation ont été développées, notamment « Noël au musée », les activités du groupe « Jeunesse Initiative » du musée et les enregistrements spécifiques.

Il reste à souligner que le site des Palais royaux d'Abomey reste vivant. Les familles royales peuvent en effet continuer à organiser des cérémonies, dans la continuité de ce qui avait lieu au palais au temps des rois.

Un point d'aboutissement de tous ces efforts a été la conférence internationale sur le thème « Passé, présent et futur des Palais royaux d'Abomey » organisée en 1997 à Abomey, grâce au soutien de l'ICCROM et de l'Institut Getty de Conservation (fig. 2).



FIGURE 2 Vue de la cour extérieure du palais Guézo, qui fait partie du Musée Historique d'Abomey. Photographie : Francesca Piqué, 1995



FIGURE 3 Palais de Béhanzin, restauré en 2003. Photographie : Francesca Piqué, 2006

La restauration de Dowome

Dowome, palais du roi Béhanzin, n'a jamais été achevé à cause de la guerre, le suzerain ayant passé quatre ans à défendre l'intégrité de son royaume contre les colonisateurs. L'effort entrepris par les familles royales n'a pu aboutir, faute de moyens, le palais faisant plus de huit hectares. Finalement, grâce à l'aide du gouvernement japonais et de l'UNESCO, ce palais construit en terre a été restauré (fig. 3).

Le renforcement des capacités professionnelles

Le site des Palais royaux d'Abomey a bénéficié de plusieurs opportunités de formation des ressources humaines en restauration et conservation du bâti et en maîtrise des techniques de muséographie.

Activités menées en 2006–2007

L'ensemble des activités décrites ci-dessus concerne une étendue d'environ 10 hectares seulement sur les 47 hectares que compte le site, ne permettant pas de retirer le site de la Liste du patrimoine en péril. En effet, malgré certains efforts, toutes les activités prévues dans le cadre de la mise

en œuvre du plan de conservation 1998-2002 n'ont pu être réalisées, ce qui a révélé certaines faiblesses du système de gestion en vigueur.

Un travail important a été réalisé entre 2006 et 2007 pour corriger toutes les insuffisances constatées. Pour cela, des subventions de la communauté internationale, obtenues grâce au Centre du patrimoine mondial, et l'apport de l'État béninois à travers le Programme d'investissements publics (PIP), jumelés avec les ressources propres générées par le site, ont permis d'affirmer sans ambiguïté le statut patrimonial du site et de sauvegarder les principaux éléments structurant des différentes aires royales. Les principales activités menées sont :

Le renforcement administratif et juridique

Sur le plan administratif, suite à la décision 28 COM 15A.14 du Comité du patrimoine mondial, le site des Palais royaux d'Abomey a fait l'objet d'un intérêt particulier de la part des autorités béninoises. L'administration de gestion du site a été restructurée avec la création du poste de gestionnaire du site ayant sous sa tutelle un conservateur des bâtiments et espaces, un conservateur du musée et un comptable. De plus,

un poste budgétaire destiné uniquement à la sauvegarde des autres composantes du site a été créé et est passé de 20 % environ des recettes du site en 2005 à 40 % en 2006.

Sur le plan juridique, le site des Palais royaux d'Abomey est considéré comme un secteur sauvegardé bénéficiant de mesures de protection particulière dans le projet de loi sur la protection du patrimoine culturel voté à l'Assemblée nationale, et dont la promulgation est attendue à la Présidence de la République. Un levé topographique a permis la délimitation du site et la détermination de sa superficie de 47,6 ha, et la zone tampon a été clairement définie. Celle-ci est constituée de trois zones spécifiques à différents niveaux de restriction qui ont été officiellement instituées par l'arrêté municipal 2006-N°4/013/MCA/SG/-SAG du 5 juillet 2006 portant règlement d'Urbanisme (fig. 4).

Les mesures de conservation préventive et de maintenance

Sur le plan physique et technique, les mesures de conservation préventives en cours sont strictement respectées et appliquées sur l'ensemble des 47 ha. Le site bénéficie chaque jour de deux types d'inspections :

La première consiste à inspecter chaque matin toutes les composantes du site pour détecter les dégradations (fissures, lacunes, trous laissés par le passage d'animaux déprédateurs, galeries de termites, mauvais fonctionnement du drainage par endroits, regain de mauvaises herbes sur les murs ou murailles, etc.) et à s'assurer du bon fonctionnement des fermetures et des toitures. Les résultats sont consignés dans une fiche d'inspection et d'identification et les solutions de traitement appropriées sont mises en œuvre. Deux jeunes ouvriers formés en conséquence sont commis à cette tâche ;

La deuxième concerne l'inspection générale effectuée trois fois par semaine par le conservateur des bâtiments et espaces pour vérifier l'intégrité du site, détecter les actions anthropiques préjudiciables à l'intégrité et à la conservation du site. Des actions sont engagées pour résoudre les problèmes. Cette inspection s'étend à la vérification du respect des prescriptions relatives à la zone tampon.

De même, une méthode de maintenance régulière et systématique a été élaborée. Toutes les cours sont balayées trois fois par semaine et un sarclage éventuel des herbes en saison des pluies est effectué deux fois par semaine. Toutes les composantes, à savoir les bâtiments, les murs d'enceinte et murailles, sont entretenues à la base sur une bande de trois mètres grâce à des allées aménagées sur tout le tour

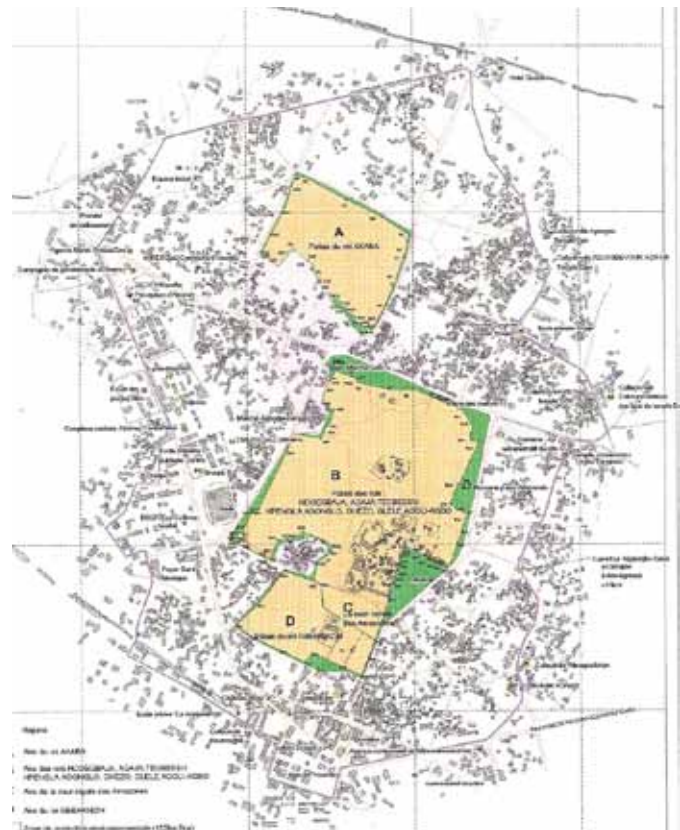


FIGURE 4 Zone de protection du site.

permettant d'y accéder et empêchant les petits animaux de créer leurs habitats à la base des murs. L'ensemble du site reçoit, conformément au plan de conservation, de gestion et de mise en valeur, une coupe à ras des herbes facilitant ainsi la lisibilité et la visibilité de toutes les composantes du site. L'entretien des abords immédiats du site qui jouxtent les voies publiques est assuré périodiquement par la Mairie. Enfin, à la fin de chaque mois, une campagne générale d'entretien de toutes les salles d'exposition et de l'intérieur de toutes les composantes du site est réalisée pour mettre les collections à l'abri des poussières et de tous les dépôts nuisibles.

Le drainage du site

L'une des causes de dégradation des composantes du site est la remontée capillaire accompagnée du transport de sels dans la base des murs, ce qui occasionne non seulement la dégradation des enduits, mais aussi de la fondation. De ce fait,

la stabilité des murs se trouve fragilisée puisqu'ils s'amincissent à la base et peuvent tomber d'un jour à l'autre.

Une attention particulière est donc portée à ce phénomène et, à titre préventif, un drainage de toutes les cours est assuré de façon à ce que dès qu'il pleut l'eau soit systématiquement évacuée de la base des murs et renvoyée vers l'extérieur, en dehors des aires royales.

Cette évacuation engendre parfois la diminution du niveau du sol, ce qui nécessite d'effectuer un rechargement périodique pour maintenir les pentes d'évacuation.

Le renforcement de la sécurité

La sécurité de jour et de nuit est assurée par une équipe installée à cet effet, de façon discrète ou apparente, selon le cas.

La valorisation des aspects intangibles du site

Les aspects intangibles du site sont surtout mis en valeur à travers l'organisation des différentes cérémonies qui ont lieu depuis le temps des rois. Il s'agit notamment de *djahouhou*, *kablaba*, *tédoudou* (cérémonies de prémisses d'igname), *gbé-biobio*, intronisations de dignitaires, etc., que les familles royales sont chargées d'organiser périodiquement et à une date précise.

Aperçu du plan de conservation, de gestion et de mise en valeur du site

L'évaluation de la mise en œuvre du plan de conservation du site 1998-2002 et la réalisation de la délimitation de la zone tampon ont conduit au lancement de l'élaboration du nouveau plan de conservation, de gestion et de mise en valeur des Palais royaux d'Abomey.

Le processus utilisé est essentiellement fondé sur l'évaluation des actions réalisées, de celles qui restent à faire et des facteurs ayant bloqué la réalisation des objectifs fixés dans le précédent plan de conservation.

Pour y parvenir, il a été utile de faire un exercice de compréhension du bien, en révisant les documents de synthèses sur la présentation historique du site, la situation actuelle, la déclaration de valeur, son statut, son authenticité et intégrité, les menaces et les contraintes qui pèsent sur lui, ses potentiels ainsi que ses opportunités.

La méthode a essentiellement reposé sur l'approche participative de toutes les parties prenantes du site. Elle a permis de déboucher sur une vision claire formulée comme suit : « Que le site des Palais royaux d'Abomey, témoin essentiel

et toujours bien vivant du valeureux royaume du *Danxomé*, joue pleinement son rôle en tant que patrimoine mondial de l'humanité et contribue à la dynamique de développement de la ville d'Abomey ! ».

Ce qui a permis de se fixer les objectifs généraux suivants :

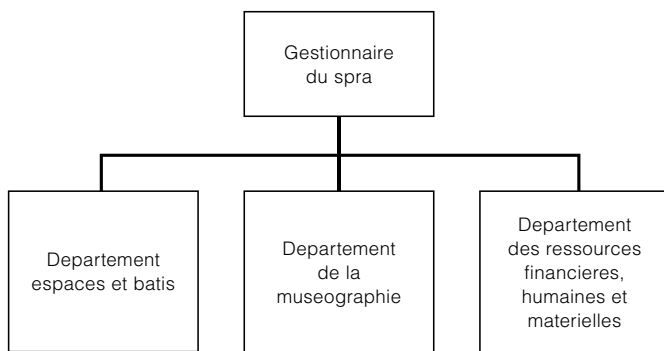
- Poursuivre et formaliser les acquis en matière de conservation et de gestion du site ;
- Renforcer les capacités d'intervention sur l'ensemble du site ;
- Améliorer la connaissance des aspects tangibles et intangibles du site ;
- Poursuivre l'amélioration progressive de l'état de conservation du site et des services offerts.

La formulation des indicateurs et des sources de vérification précis, permettant de réaliser une évaluation à mi-parcours et à la fin des cinq ans prévus pour la mise en œuvre du plan de gestion, a été clairement définie.

Les points les plus importants sur lesquels repose ce plan de gestion concernent :

- La gestion, le suivi et l'évaluation ;
- L'entretien et les réparations préventives ;
- La formalisation des procédures ;
- Le partenariat, le personnel et les moyens techniques ;
- Les revenus financiers ;
- La promotion ;
- La recherche fondamentale ;
- La recherche appliquée ;
- La formation ;
- La remise en fonction du bloc administratif ;
- L'amélioration progressive du site des Palais Royaux d'Abomey ;
- Les visites ;
- L'animation et l'éducation.

La formalisation de la gestion passera par l'établissement d'un statut spécifique pour le site, avec la définition claire des activités des différents départements autonomes, mais avec une obligation de résultat, tout ceci renforcé par le fonctionnement correct du Conseil de gestion et du Comité technique de gestion.



Perspectives d'avenir et atouts du site

Au terme du plan de gestion en cours, en 2011, on attend les résultats suivants :

- Présence d'une équipe de professionnels formés, en mesure d'élaborer et de conduire les travaux de restauration dans le respect des normes internationales de conservation ;
- Connaissance approfondie et maîtrise des circonstances et des processus de dégradation des édifices et des pans de murs et murailles ;



FIGURE 5 Une vue avec le roi Dedjanlangni Agoli-Agbo avec sa cour et la délégation CPM-ICOMOS.

- Appropriation de technologies expérimentées sur la conservation des édifices, des bas-reliefs et des collections etc. ;
- Existence d'un Conseil de gestion très impliqué dans le suivi des activités de conservation et de gestion ;
- Mise en œuvre des activités spécifiques prévues dans le plan de conservation, de gestion et de mise en valeur du site 2007-11.

Conclusion

Le nouveau plan de gestion a été présenté au Comité du patrimoine mondial lors de sa 31^e session à Christchurch, Nouvelle-Zélande. Le Comité a particulièrement apprécié l'effort de collecte des informations concernant les interventions successives faites sur le site par le Gouvernement béninois et ses partenaires, en matière de conservation et de gestion. Il a jugé particulièrement pertinentes la méthode participative et l'élaboration de la vision commune avec les parties prenantes, et a apprécié la proposition de programme de travail suggéré, et l'engagement du Gouvernement béninois pour le mettre en œuvre (figs. 5, 6).

Sur ces bases, le Comité du patrimoine mondial a enfin pu prendre la décision tant attendue par le Gouvernement



FIGURE 6 Une vue avec le roi Houédogni Béhanzin avec sa cour et la délégation CPM-ICOMOS.

bénois de retirer les Palais royaux d'Abomey de la Liste du patrimoine mondial en péril.

La situation des palais n'en demeure pas moins fragile et le gestionnaire du site devra constamment veiller à ce que le plan de conservation, de gestion et de mise en valeur du site soit bien appliqué (fig. 7). Le Comité du patrimoine mondial devra régulièrement évaluer les avancées réalisées. Quant au Gouvernement du Bénin, il devra rester mobilisé et poursuivre son effort de financement régulier.

Enfin, le plan de conservation, de gestion et de mise en valeur du site est sur cinq ans. Sa révision complète – à la lumière d'avancées concrètes – devra donc être réalisée en 2008, en prévision d'un troisième plan pour 2010–14.



FIGURE 7 Mur vestige de la case à étage du roi Akaba, un des seuls éléments complètement authentique des palais, dont il faut donc prendre le plus grand soin.

Références

- Loi 2007–20 portant protection du patrimoine culturel et du patrimoine naturel à caractère culturel en République du Bénin.
- Plan de conservation, de gestion et de mise en valeur du site des palais royaux d'Abomey (2007–11).
- Rapport de suivi réactif de l'UNESCO d'évaluation de l'état de conservation du site des palais royaux d'Abomey, 2007.
- Rapport de suivi réactif de l'UNESCO sur l'état de conservation du site des palais royaux d'Abomey, 2004.
- Rapport du séminaire au Musée Historique d'Abomey, Bénin, du 12 au 15 mai 1997, sur la conservation du patrimoine bâti.

Conserver les villes historiques en terre du patrimoine mondial : Protéger les valeurs et comprendre les menaces

Francesco Bandarin et Lazare Eloundou Assomo

Résumé : *Les centres urbains historiques s'adaptent en permanence aux dynamiques sociales et posent d'importants problèmes de conservation du patrimoine, surtout, lorsqu'il s'agit de villes construites en terre, particulièrement sensibles à la modernisation, au développement et aux changements climatiques. Les auteurs soulignent qu'aucun accord international sur la préservation des villes historiques ne concerne directement ce type de patrimoine et demandent que les efforts pour la conservation de ces architectures de terre se concentrent à la fois sur la définition des valeurs intrinsèques et sur l'anticipation des menaces. Ils se réfèrent aux appels du Comité du patrimoine mondial qui, depuis 2001, souhaite la mise en place de directives internationales spécifiques aux villes construites en terre.*

Abstract: *Historic city centers must constantly adapt to the dynamics of society and are a particular challenge for sustainable heritage conservation. This is especially the case for earthen cities, which are very sensitive to modernization, development, and climate change. The authors point out that no international agreements on the preservation of historic cities have directly addressed this type of heritage and argue that conservation efforts for earthen architecture should focus on both intrinsic values and threats. They refer to the approaches of the World Heritage Committee, which since 2001 has recommended the development of international guidelines applicable to cities built of earth.*

Depuis 2001, le Centre du patrimoine mondial a lancé une réflexion sur la protection des valeurs et la compréhension des menaces qui pèsent sur les villes historiques, bâties en partie ou en totalité en terre, et plus particulièrement sur celles

inscrites sur la Liste du patrimoine mondial de l'UNESCO. Cette réflexion n'a de sens que parce qu'elle s'inscrit dans un contexte plus large de conservation de la totalité des villes historiques du patrimoine mondial¹.

Cette communication tente, dans un premier temps, de faire le point sur l'état de la réflexion à ce jour, d'abord en rappelant quelques faits marquants qui ont permis de définir les méthodes et approches actuelles en faveur des villes historiques, et en présentant les récents efforts du Centre du patrimoine mondial dans ce domaine particulier de conservation. La deuxième partie, elle, traite des principales valeurs des centres historiques bâtis en terre, ainsi que des menaces auxquelles ils sont de plus en plus confrontés ; cela dans une perspective de leur conservation durable, et dans le cadre de la mise en œuvre du Programme du patrimoine mondial sur l'architecture de terre adoptée par le Comité du patrimoine mondial en 2007.

Considérations préliminaires

La Liste du patrimoine mondial de l'UNESCO compte à ce jour, en février 2008, 851 biens dont 660 biens culturels, 166 naturels et 25 mixtes répartis dans 141 États parties à la Convention du patrimoine mondial. Sur l'ensemble de ces 660 biens culturels, près de 200 concernent en partie ou en totalité des villes historiques.

De manière générale, la question de la conservation des centres historiques est antérieure à l'adoption de la Convention du patrimoine mondial, même si celle-ci est la première qui intègre de façon très claire, cette catégorie comme patrimoine culturel². Déjà en 1931, la Charte d'Athènes, en mentionnant la nécessité de « respecter la physio-

nomie des villes »³, a contribué à lancer la dynamique qui a permis de nourrir la réflexion sur la conservation des centres historiques. Cette dynamique se traduit aujourd'hui par une importante production de chartes et déclarations spécifiques dont on pourrait retenir :

- La Recommandation de Nairobi concernant la sauvegarde des ensembles historiques ou traditionnels et leur rôle dans la vie contemporaine, en 1976⁴ ;
- La Charte ICOMOS de Washington sur la sauvegarde des villes historiques, en 1987 ;
- La Déclaration de Québec sur la sauvegarde des villes du patrimoine mondial, en 1991 ;
- La Charte de Fès de l'Organisation des villes du patrimoine mondial, en 1993 ;
- La Déclaration interaméricaine sur la sauvegarde des villes historiques des Amériques, en 2001 ;
- La Déclaration de Puebla sur les mesures de prévention et de protection pour les villes du patrimoine mondial en cas de désastre, en 2001 ; et
- La Déclaration de Montréal sur la préservation des villes historiques, en 2003.

Une rapide étude de l'ensemble de ces chartes et déclarations nous révèle qu'il n'y a pas eu, à ce jour, d'orientations spécifiques internationales sur les villes historiques bâties en terre, permettant au Comité du patrimoine mondial de mieux examiner leur état de conservation. Or, il ne fait pas de doute que la production intellectuelle est immense. En témoignent les publications faites à l'issue des conférences Terra depuis 36 ans et les résultats de nombreux projets de conservations conduits de par le monde, ainsi que les recommandations de réunions permettant d'engager une compilation de recommandations possibles.

De même, ces ensembles urbains témoignent de l'intelligence avec laquelle les peuples de ce monde les ont bâtis, et rappellent qu'ils sont indéniablement la meilleure expression de la relation entre l'homme et son environnement. Ils méritent alors que des directives particulières leur soient appliquées. En effet, les villes historiques en terre n'ont de sens que parce qu'elles sont habitées, donc vivantes, et que cette dynamique humaine a toujours été la garantie de leur préservation grâce aux pratiques d'entretien traditionnel et à l'organisation sociale et économique qui les caractérisaient.

Les centres historiques en architecture de terre du patrimoine mondial

Un récent pré-inventaire estime à environ 106 le nombre de biens de la Liste du patrimoine mondial construits en totalité ou en partie en terre, soit près de 16 % de l'ensemble de ceux-ci. Si l'on analyse ce pré-inventaire⁵, près de la moitié de ces biens en terre sont des centres historiques habités. Ils se répartissent de manière inégale dans les régions du monde, avec une forte représentation en Amérique latine (22 en Amérique latine, 9 en Europe et 9 dans les États arabes, 4 en Afrique, 2 en Asie). Ce pourcentage très significatif et cette disparité, traduisent deux choses fondamentales : premièrement, l'intérêt qu'il faudrait accorder à leur identification et leur gestion et conservation –notamment en Afrique –, tant ces centres historiques sont porteurs de valeurs historiques, immatérielles et architecturales uniques ; deuxièmement, les difficultés auxquelles ils sont confrontés parce qu'exposés à des menaces sérieuses dont les plus importantes sont étudiées dans les paragraphes qui suivent.

Dans la Convention du patrimoine mondial, l'un des premiers paragraphes introductifs, porte sur la nécessité « pour l'équilibre de l'homme et son épanouissement, de lui conserver un cadre de vie à sa dimension où il reste en contact avec la nature et les témoignages de civilisation laissés par les générations passées »⁶.

Cette justification pourrait sans doute s'appliquer aux villes historiques bâties en terre. La question de leur conservation se situe inévitablement dans la recherche de l'équilibre entre le besoin de leur conservation et celui de l'adapter aux besoins contemporains, sans mettre en péril ses valeurs et son intégrité. Cette approche est encore plus importante aujourd'hui, compte tenu de la difficulté qu'elles ont à exister en tant que témoignages du passé face aux exigences du monde moderne.

Dans le passé, le Comité du patrimoine mondial, en inscrivant les villes historiques d'architecture en terre, a le plus souvent mis l'accent sur le caractère monumental des édifices, sur le milieu environnemental et sur leur dimension territoriale. Dans très peu de cas, il s'est agi de valoriser l'intelligence d'une tradition de construction exceptionnelle. Cela tient au fait que le Comité du patrimoine mondial, dans son approche des ensembles urbains, ne souhaitait pas différencier les villes historiques selon le type de matériau de construction.

Cette approche se justifie au regard des Orientations⁷ qui lui servent à examiner la valeur universelle exceptionnelle.

En effet, comme toute autre ville historique du monde, les villes bâties en terre connaissent un constant besoin d'amélioration ou de développement des infrastructures, des logements et des services. Elles exigent également une politique d'aménagement et une gestion qui fassent de la protection le point-clé de la conservation. C'est cette approche globale qui caractérise le « Mémoire de Vienne » de 2005, document qui définit des règles permettant de guider les pays dans leurs actions⁸.

Mais comment accommoder les besoins d'adaptation des centres historiques en terre au monde moderne sans compromettre leur caractère historique ou/ni leur identité ? Là est la véritable question.

Une approche appropriée pourrait être la réponse à cette question, mais elle devrait s'appuyer sur deux nécessités, notamment de :

- toujours rechercher, en priorité, des solutions techniques adaptées, que ce soit au niveau de l'aménagement urbain, ou à celui des interventions sur l'habitat et sur les infrastructures ;
- privilégier les savoir-faire traditionnels locaux qui continuent d'être les meilleures recettes grâce auxquelles ces trésors urbains ont pu être préservés jusqu'à ce jour.

Menaces pour les villes historiques en terre du patrimoine mondial

Parmi les menaces auxquelles sont confrontées les villes historiques en terre du patrimoine mondial, on pourrait en retenir notamment plusieurs : les pressions de développement conduisant à des mutations de l'environnement bâti, l'action des services publics certes nécessaire mais le plus souvent inadaptée à la réalité de l'architecture de terre, l'absence de politiques de conservation permettant de répondre aux fortes pressions urbaines de développement, et les phénomènes naturels le plus souvent dus aux forces climatiques (inondations, tremblements de terre, tempêtes de sable et autres).

Les pressions de développement sont le plus souvent la conséquence des aspirations à une meilleure qualité de vie. Ces centres historiques sont sujets à des initiatives (Bandarin 2003), calculées ou non, qui modifient dramatiquement leurs structures physiques et sociales. Celles-ci peuvent être guidées par la spéculation foncière, le développement des activités commerciales, ou encore les besoins de transformation de l'habitat pour y introduire des éléments de confort moderne.

Malheureusement, ces volontés qui entraînent des mutations importantes au niveau du bâti et du non-bâti, ont amené de nombreux centres historiques en terre à perdre leur identité, voire à disparaître. Il faut également ajouter le changement des fonctions initiales des villes en terre, grâce auxquelles des logiques de gestion et d'entretien permettaient d'assurer leur conservation durable. Avec la disparition de ces fonctions initiales, on assiste à des effondrements des dynamiques socio-économiques, qui se traduisent par l'abandon des métiers de construction et conservation traditionnelle, l'abandon des habitations, la modification de la structure urbaine, l'apparition des nouveaux matériaux de construction souvent inadaptés. Il y a enfin l'inclusion des architectures contemporaines, qui si elles ne se conçoivent pas dans un esprit de respect du lieu, affectent son intégrité et son authenticité.

Certains aménagements urbains réalisés dans les villes historiques bâties en terre constituent aussi des menaces. Il s'agit par exemple de systèmes techniques d'adduction d'eau, certes nécessaires, mais qui posent deux questions majeures :

- la question de la gestion des eaux usées dans l'ensemble de la ville et notamment de leur évacuation ;
- la question de l'installation et de l'usage adéquat de ces nouveaux équipements (robinetterie dans les habitations).

Ces systèmes techniques sont le plus souvent des modèles standards à regards, et ont non seulement un impact visuel négatif, mais peuvent être la source de problèmes structurels graves par le fait de stagnation d'eau due à de mauvais écoulements, et même de problèmes d'hygiène.

Afin d'illustrer les propos précédents, il convient de s'arrêter quelques instants sur le cas de la ville ancienne de Djenné, au Mali. Djenné est à ce jour, la seule ville historique en terre du patrimoine mondial dans laquelle près de 95 % des structures physiques sont des structures bâties en terre (fig. 1).

Pourtant, des changements commencent progressivement à prendre place aussi bien dans le tissu urbain qu'au sein des bâtiments. Ces changements pourraient sérieusement altérer cette « perle de l'Afrique » si des dispositions appropriées ne sont pas prises pour endiguer la pression du développement urbanistique que connaît la ville depuis une vingtaine d'années et qui entraîne la dégradation de l'architecture. Visiblement, c'est avant tout la conséquence de pressions intenses résultant des exigences de mobilité urbaine, des besoins d'inadaptation des habitations aux nouveaux

standards de confort et à la restructuration de la famille, qui font que le nombre de maisons en ruine a augmenté à une allure vertigineuse. Les matériaux et techniques modernes gagnent du terrain et sont de plus en plus utilisés lors des rénovations. On voit aujourd'hui apparaître sur certaines façades, des revêtements en briques de terre cuite rouges ou de carreaux de céramique, ou encore du ciment pour solidifier les ornements, ce qui fragilise les murs en terre.

Tous ces changements sont amplifiés par les difficultés de gestion urbaine apparues notamment du fait de l'absence d'une répartition claire des rôles respectifs de l'État et de la collectivité locale.

Les facteurs naturels, le plus souvent dus aux changements climatiques⁹, sont également des menaces importantes pour la conservation des centres historiques bâtis en terre. On pourrait à titre d'exemple citer entre autres les catastrophes naturelles comme les inondations survenues à Tombouctou (Mali), en 2003, suite à de fortes pluies torrentielles qui ont causé la destruction de nombreux îlots d'habitation dans la vieille ville ; ou encore le séisme à Bam (Iran), toujours en 2003, dont les conséquences ont été dramatiques, notamment pour la citadelle.

Comment pallier l'absence d'orientations claires ? Nouvelles approches définies par le Centre du patrimoine mondial

Jusqu'en 2003, les questions de pressions de développement et autres défis, non pris en compte dans le corpus de documents existants sur la conservation des villes historiques, n'avaient pas été suffisamment traitées par le Comité du patrimoine mondial. L'attention portée par le Comité, tient particulièrement de la nécessité d'adapter les politiques de conservation facilitant une utilisation durable des éléments patrimoniaux, dans un contexte où la population vivant dans les villes historiques et leurs périphéries, ne cessera de croître dans les années à venir.

C'est lors de sa 27^e session, en 2003, que le Comité a finalement décidé d'un colloque pour discuter des moyens de réguler efficacement les besoins de modernisation des environnements urbains historiques, tout en préservant leurs valeurs historiques, en particulier celles des villes inscrites sur la Liste du patrimoine mondial. C'est ainsi que le Centre du patrimoine mondial, en coopération avec l'ICOMOS et la Ville de Vienne, ont organisé à Vienne (Autriche), en 2005, la conférence internationale « Patrimoine mondial et architecture contemporaine – Gestion du paysage urbain his-



FIGURE 1 La Vieille Ville de Djenné. Photo : Lazare Eloundou Assomo. © L. Eloundou, UNESCO

torique ». Lors de ce colloque, une première ébauche de principes et de directives a été adoptée : le « Mémoire de Vienne ». Ce document encourage à une approche intégrée de l'architecture contemporaine, du développement urbain et des questions d'intégrité du paysage urbain historique.

Ce Mémoire est aujourd'hui considéré comme un précieux document historique de notre temps. Il s'agit d'un document de transition qui laisse entrevoir une vision de l'écologie humaine indiquant une évolution vers le développement durable et une conception plus large de l'espace urbain. De l'avis de tous les spécialistes, la voie à suivre pour une meilleure gestion des villes historiques semble passer par l'appropriation du concept de « paysage » ou de « territoire », non dans le sens des paysages conçus qui sont familiers à la plupart des spécialistes de la conservation, mais plutôt des paysages associatifs. En effet, l'importance de ce concept réside dans sa capacité à favoriser un dialogue entre de larges secteurs de la communauté sur la question de l'évolution contemporaine dans les villes historiques. Le dialogue est, en fait, la véritable recommandation prônée par le Mémoire de Vienne. Et cela s'applique indéniablement pour ce qui concerne les villes historiques en terre.

Le Centre du patrimoine mondial a poursuivi ses consultations régionales sur ce sujet, avec trois réunions régionales organisées à Jérusalem (Israël, juin 2006), Saint-Petersbourg (Russie, janvier 2007), et Olinda (Brésil, novembre 2007). Ces consultations ont conduit à la nécessité de réexaminer certains documents normatifs et en particulier

la « Recommandation de Nairobi » de 1976. Cette remise en question se justifie par les conclusions issues des réunions régionales qui montrent qu'un nombre de questions fondamentales ont profondément changé la discipline et la pratique de la conservation du patrimoine urbain. La question porte sur :

- l'importance du concept de « territoire », perçu comme une stratification de la dynamique urbaine ancienne et actuelle, et qui prend en compte l'interaction entre l'environnement naturel et l'environnement construit ;
- le rôle de l'architecture contemporaine ;
- le rôle évolutif et économique des villes, qui amène à mettre l'accent sur les processus non locaux tels que le tourisme et le développement urbain, et qui associe des acteurs extérieurs du changement.

Le Comité du patrimoine mondial considère donc que les nouvelles dynamiques apparues dans l'architecture et le développement urbain, qui ont entraîné de nouveaux défis de conservation et de gestion du patrimoine urbain, exigent de nouvelles approches et un examen critique des normes et directives élaborées il y a trois décennies. Par conséquent, la Recommandation de 1976 concernant la sauvegarde des ensembles historiques sera revue par un groupe de travail mis en place par le Comité.

La révision de cet important document est une chance pour la prise en compte des spécificités liées à la conservation et la gestion des villes historiques bâties en terre. En effet, les questions liées à l'adaptation des habitations aux besoins de confort moderne, l'introduction des infrastructures et équipements modernes, l'appréciation des questions d'intégrité et d'authenticité pourraient être clarifiées dans ce nouveau document.

Notes

- 1 <http://whc.unesco.org/fr/liste>.
- 2 UNESCO, Convention pour la protection du patrimoine mondial, culturel et naturel, 1972.
- 3 La Charte d'Athènes, chap. III, 1931.
- 4 Proposition pour la préparation d'une nouvelle recommandation concernant les paysages urbains historiques, Document WHC-08/32.COM/7.2, 2008.
- 5 <http://terre.grenoble.archi.fr/patrimoine/listepatrimoine2007.pdf>.
- 6 UNESCO, Convention pour la protection du patrimoine mondial, culturel et naturel, 1.
- 7 UNESCO, Orientations devant guider la mise en œuvre de la Convention du patrimoine mondial, 2005.
- 8 UNESCO, Mémoire de Vienne, 2005.
- 9 UNESCO, *Case Studies on Climate Change and World Heritage*, 2007.

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Documenting and Representing the Historic City of Tarim, Yemen

James Conlon and Pamela Jerome

Abstract: *Since 2000 the Tarimi Mansions Preservation Project (TMPP) has documented and stabilized several mud-brick villas in Tarim, Yemen. Conservation programs in historic cities always work with a diverse group of stakeholders—from professionals like ourselves to myriad local actors. As part of the larger conservation process, it has been our objective to use the documentation process as a catalyst for the development of a conservation master plan for Tarim’s historic core that would include a full range of informed participants. Documentation must function as more than a record of the state of significant built fabric or of the information in archival histories; it is a form of representation that aims to bridge the gap between multiple stakeholders in a complex urban environment.*

Résumé : *Depuis 2000, le Projet de Préservation des Maisons de Tarim (TMPP) a documenté et stabilisé plusieurs maisons en briques de terre à Tarim, Yémen. Les programmes de conservation dans les villes historiques réunissent toujours un groupe diversifié de parties prenantes – depuis les professionnels comme nous jusqu’aux multiples acteurs locaux. Dans le cadre d’un processus de conservation plus étendu, notre objectif était d’utiliser le processus de documentation comme catalyseur pour l’élaboration d’un plan directeur pour la conservation du centre historique de Tarim qui comprendrait un large panel de participants informés. La documentation est appelée à être plus qu’un constat de l’état de conservation d’un bâti significatif ou qu’une information pour les archives historiques : elle constitue une forme de représentation visant à réduire l’écart entre les multiples acteurs dans un environnement urbain complexe.*

Heritage conservation involves a broad spectrum of actors. As conservation professionals, we are expected to articulate our objectives to an increasingly diverse group of specialists as well as local stakeholders. Capturing and representing information in the contemporary milieu has taken on a critical position in the conservation of significant places. This complexity only increases in urban environments of significance. Documents such as the Ename Charter have established professional guidelines.¹ At the heart of the charter’s recommendations is the recognition of the four-way relationship among object represented, designer, audience, and medium of representation (Mitchell 1995). Each of these four areas takes on greater import depending on our objectives and the social context of the interpretive program. In different situations, we may emphasize one area over another to balance the interpretive program. Likewise, overemphasizing the role of a give area may deprive the interpretive program of balance. In documenting and interpreting the historic city of Tarim (fig. 1), we searched for that balance in the cultural context of contemporary Yemen.

An Urban Question

How does one document and represent a city? Heritage conservators begin with the idea of significance,² but there are characteristics of cities that set them apart from other heritage places. In the view of Walter Benjamin, cities offer unique opportunities for engaging the past. They are labyrinths where layers of artifacts and the material remnants of memory wait to be discovered by the urban wanderer. Much of Benjamin’s perspective depends on his critique of the historical method



FIGURE 1 General view of Tarim looking northwest. Photo: James Conlon. Courtesy of the Visual Media Center, Columbia University

and instrumental rationalism: the recovery of a place's significance hinges on the activation of our memory through the experience of physical discovery rather than an intentional, intellectual process (see esp. Benjamin 1979, 2002; for a critical introduction to these points, see Savage 2000). Depicting a day in the life of the metropolis through a series of unnarrated montages, Walter Ruttmann's *Berlin: Symphony of a Great City* exemplifies how one might represent Benjamin's perspective.³ But cities are also systems of built signifiers, meant to explicitly codify, communicate, and reproduce social behavior. The urban environment transmits meaning through intentional, learned systems of knowledge as much as through passive discovery. We may consider cultural specificity as well. Urban environments may share characteristics, but they are shaped by the unique social perspectives of their inhabitants. This side of the coin is perhaps best presented in historical narrative rather than a film like Ruttmann's. Our challenge as conservators is to tap in to the materiality behind these different positions to communicate narratives past and present so as to best manage change in our shared urban heritage.

Historic Tarim

The unique challenges of urbanism are present in Tarim, Yemen, a city of 100,000 in Yemen's Hadhramaut Valley. The valley has been linked to the Indian Ocean basin for most of its

history through dense social and economic networks (fig. 2). During the nineteenth and early twentieth centuries, Yemeni movements between South Asia, Southeast Asia, East Africa, and the Middle East intensified with the first wave of globalization under British and Dutch imperial hegemony (Bayly 1999). At different instances in this period, as much as 40 percent of the male population of some Hadhrami villages were working overseas (Boxberger 2002). Some Hadhramis abroad were simple laborers; others traveled to academic centers in pursuit of knowledge.

Some families became extremely wealthy through their landholdings across the region, even building international trading companies. The al-Kafs were an especially prominent family (fig. 3). 'Abd al-Rahman al-Kaf (d. 1863–64) established a business in Singapore, which his family expanded until the holding company's value was second only to that of the city port. The family used their wealth on infrastructure development in Tarim, on their home, and also on social projects. 'Abd al-Rahman (d. 1950) became a major patron of reform-minded youth organizations in Southeast Asia. Another al-Kaf built the first regional hospital in Tarim. 'Alawi Abu Bakr (d. unknown), an engineer by training, fancied himself a gentleman architect and gathered pattern books while abroad and sketched the buildings he encountered (Freitag 1997; Modini-Kesheh 1999). His designs are likely the inspirations for many of the villas in Tarim. These individuals have unique biographies, but they had one thing in common: after making their fortunes in Singapore, they returned to Tarim, built villas for their extended families, and invested in the urban infrastructure.



FIGURE 2 The world of the Indian Ocean in the late nineteenth and early twentieth century. Courtesy of the Visual Media Center, Columbia University



FIGURE 3 The al-Kaf family in Singapore. Photo: Personal collection of Muhammad al-Juneid. Courtesy of the Visual Media Center, Columbia University

The al-Kafs tell us of one side of this world, but they represent only part of Tarim's significance. On the African coast of the Indian Ocean, in the city of Lamu, we find Sheikh 'Abdallah b. Muhammad b. Salim Ba Kathir al-Kindi (d. 1927) (see fig. 2). Ba Kathir was in fact born in Lamu (in present-day Kenya) in the late nineteenth century, though he traced his lineage to the Hadhramaut through his father. Lamu was then the academic center of East Africa, and Ba Kathir became a scholar and ascetic of some renown. He went on to study in Mecca, served as a teacher for a Hadhrami expatriate community in Java, arbitrated disputes among Muslims in Cape Town and Uganda, and eventually opened a school in Zanzibar. He traveled to the Hadhramaut as well, publishing a travelogue of his experiences in the 1920s. It was important for scholars of Hadhrami descent to return to the valley, meet with noted individuals, and interact with the Tarim sayyids (descendants of the Prophet Muhammad). Already a recognized scholar, Ba Kathir nonetheless had to legitimate his position among the transnational Hadhrami community by making a pilgrimage to the valley (Hartwig 2001; see also Ho 2008; Pouwels 1987).

These stories tell us of Tarim's significance as both a socioeconomic and a spiritual center. One may trace the transnational culture of the al-Kafs through the hybrid architectural fabric of Tarim. Hadhrami masons and lime-plaster craftsmen were highly skilled and flexible (fig. 4). They incorporated the architectural languages of Neoclassicism, Rococo, Mughal,

Art Nouveau, and Art Deco in 'Alawi's drawings into their tradition of earthen construction (Damluji 1992). Likewise, Tarim was an idealized center to another strata of Hadhramis abroad. With its mosques, tombs, and shrines, Tarim and the entire valley functioned as the sacred space for a community of scholars and the Prophet's descendants. The tombs and houses of pious individuals monumentalize this significance. In this way the architecture of Tarim, like its broader history, represents a dialogue between cultures both within and outside contemporary Yemen.



FIGURE 4 Traditional builders applying a coat of mud plaster. Photo: Pamela Jerome. Courtesy of the Visual Media Center, Columbia University



FIGURE 5 Qasr 'Abd al-Rahman bin Sheikh al-Kaf, 2003. Photo: Rene Fan. Courtesy of the Visual Media Center, Columbia University

Community and the Built Environment: The Columbia University Documentation Project

The significance of Tarim as an urban heritage site lies in a full range of cultural phenomena. Whether contemporary or traditional, cities are complex cultural-ecological systems. In these dynamic environments, conservation is the challenge to manage change to ensure that the past has a role in the future. We may understand Tarim as a system spreading far beyond the town limits, across the Hadhramaut Valley, and beyond into the Indian Ocean to the east, south, and west. Beginning with the material fabric of individual buildings and the traces of master craftsmen and informal designers, we move on to unique urban topographies, the broader cultural and historical sphere of the Indian Ocean, and the individual narratives of the early modern era. The key, then, is to uncover the artifacts of this broader milieu as they appear in the urban environment, as Benjamin would, and reproduce that moment of discovery in our documentation and interpretation schemes. At the same time, we must also represent the logic of place through its monuments and history as an explicit cultural system.

In order to fully document the rich layering of Tarim, the Tarimi Mansions Preservation Project (TMPP) established a working group⁴ and a comprehensive and integrated system of documentation. The efforts of our working group began as a documentation-training program with the aim of catalyzing local and international support to establish institutions to

conserve the historic fabric of Tarim. The TMPP started with a review of the city's merchant villas to identify significance, conditions, ownership context, and adaptive reuse potential. Twelve of the more than fifty significant villas were expropriated during the Marxist era, resulting in their abandonment. Our work resulted in the listing of the ensemble on the World Monuments Fund 100 Most Endangered Sites List for two consecutive two-year periods, from 2000 to 2004. A preliminary feasibility study was also conducted in 2000 (Jerome and Al-Radi 2001) and later updated and expanded in 2004 (Jerome 2004). Since 2002 we have documented six of the abandoned mansions: Qasr al-'Ishshah, Dar al-Salam, Hamtut, al-Riyadh, Qasr Abd al-Rahman bin Sheikh al-Kaf, and Qasr al-Fijr (figs. 5, 6).⁵

Through documentation, we intended to develop a language that would express Tarim's significance and urge people to contribute to the long-term sustainability of its historic area (Conlon, Jerome, and Al-Radi 2003). We have turned to video documentation, conventional and spherical photography, computer-aided design and animation, and database technologies to organize and interpret Tarim's rich history.⁶ Layering multimedia objects by means of a geographic metaphor has proved both cost- and time-effective. Moreover, the type of navigation we created through the use of a geographic meta-

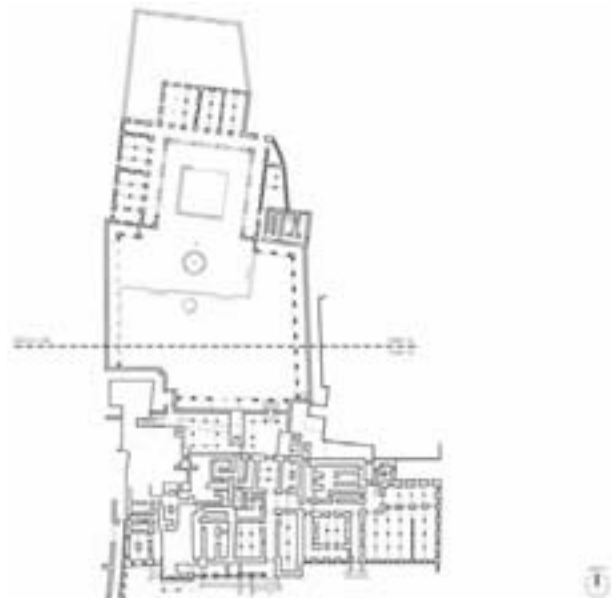


FIGURE 6 Qasr 'Abd al-Rahman bin Sheikh al-Kaf. Plan drawn by Sara Lardinois. Courtesy of the Visual Media Center, Columbia University

phor enabled us to reproduce the sense of discovery articulated by Benjamin while also layering conventional texts and organizational strategies in a manner more in line with traditional interpretive objectives of the conservator's or historian's discipline.

Balancing Media, Message, and Audience: Expediency beyond Theory

While the choice to use new media was clear to us, it presented some serious questions concerning the Yemeni public's ability to gain access to our materials. In fact, the statistics on the average Yemeni's access to information technology would lead us to believe that digitization of knowledge is in effect an act of controlling and, in turn, locking away knowledge. The World Bank statistics on information and communications technologies (ICT) for Yemen are not encouraging. Based on figures from 2001, personal computing and Internet use are rare and expensive in Yemen. Of Yemen's population of 18 million, only 1.9 per every 1,000 people have a personal computer. Yemen has only 17,000 Internet users, and the average monthly off-peak service charge for access to the World Wide Web is \$44.50—more expensive than in the United States.⁷ The final consideration is language. Even as Arabic becomes more prevalent on the Web, the literacy rate in Yemen is around 40 percent.

Why, then, use Web-based media at all? To return to the four-part system of representation we opened with, the medium seems to be overshadowing our audience. But as Lev Manovich (2001) has pointed out, "Just as there is no 'innocent eye,' there is no 'pure computer.'" New media technologies have become so ubiquitous to us that we forget the distance we ourselves have from our computers. Interactions with our machines mostly occur at an end stage of selections and compositions. The programmer works directly with binary code, but most of us have become adept at manipulating drop-down menus and selecting options from an extensive, albeit finite, library. Our personal history of computing occurs through a long process of mediation, drawing on a wealth of social metaphors. Individual acumen and creativity come as much in our presentation as in our adaptation of software to particular social contexts. May not something similar happen in the Yemeni context? If we are prudent enough to work with the limited infrastructure in Yemen, we may use new media to enhance the way we express the significance of heritage in the appropriate social contexts and cultural metaphors of the country (Manovich 2001). Limited infrastructure is a prob-

lem but not the end of the story; limited computer skills are a problem but again not the end; inserting what we have into the appropriate social contexts is a promising strategy.

With this in mind, we sought to design primarily visually oriented resources that would complement oral presentations and group-oriented learning. Emphasizing visual over textual content also helps us work through the language issue. This approach better complements traditional narrative techniques, as well as the general local emphasis on oral transmission of knowledge. It empowers local stakeholders, needing only one person familiar with computers and English to reach a larger audience. We use Arabic in the navigation; the majority of the English-language content covers information of more import to American students and academics. We also keep resources scalable: chunks of media embedded in other media may be moved and isolated according to the situation at hand, making it easier to respond to different perspectives.

We pay special attention to social spaces of presentation, again, for both practical and intellectual, even symbolic reasons. Many of the merchant villas were built as powerful urban monuments signifying the affluence of a new elite.⁸ Qasr al-'Ishshah, one of the more significant al-Kaf villas, has been adapted into a cultural heritage center. We have in turn targeted this building to disseminate our interpretive materials, attempting to reassert its monumentality while bolstering its new life as an educational center. Although we take advantage of Flash Animation and databases to present and store our material online, there is no reason why our virtual Indian Ocean cannot sit on an average hard drive. One of the reuse strategies for al-'Ishshah is a children's education center. They have access to computers here, so our partners distribute our resource off-line in their small computer lab. This allows us to take advantage of the pedagogical mission of the center, the availability of local expertise, and the inherent monumentality of the space to perform history. Likewise, we use our own educational programs and other cultural events in this way (fig. 7).

There are, then, many practical considerations at work, but one should also keep in mind that visual perception is not a passive recording of information but an active element of conceptualization that exercises selective, abstract, and creative acts of intellectual formation (Arnheim 1969). Marshall McLuhan (1964) argued that the medium, independent of content, has its own intrinsic effects. It is this essence that ultimately shapes a medium's unique message, even beyond its literal content. "The medium is the message" because it is the "medium that shapes and controls the scale and form of human association and action" (McLuhan



FIGURE 7 Celebrating the masons of the Hadhramaut with a visit from the German Nobel Laureate Günter Grass (Qasr Hamtut in the background). Photo: James Conlon. Courtesy of the Visual Media Center, Columbia University

1964). Much has been written on the effects of new media technologies on society (Castells 2001; Conlon 2004; Gere 2002; Heidegger 1977; Manovich 2001; McLuhan 1964), and these technologies will undoubtedly shape Yemeni society for generations to come. McLuhan's work, for this reason, is revolutionary. At the same time, no culture is a passive object. Different people engage technologies, reshaping them just as they themselves are transformed by the technological experience. We are still in the early stages of our project to document and interpret Tarim, but new media technologies may complement the nascent social and cultural elements at work to conserve the historic city and celebrate the world of the Indian Ocean.

Postscript: The Changing Urban Landscape

A growing conservation movement is forming among local stakeholders, and the national government and local and international nongovernmental organizations are taking an interest in the program. The Social Fund for Development, a local quasi-nongovernmental organization (QUANGO), and the U.S. State Department Ambassador's Fund for Cultural Preservation have supported a pilot project to stabilize and restore Qasr al-'Ishshah, one of the most significant merchant villas. More projects are in the works.

Nonetheless, the cultural sphere that defined the significance of Tarim has changed dramatically since the inception of the former People's Democratic Republic of Yemen (South Yemen) in 1969. As the nations of the Indian Ocean region gained their independence, the open flow of people and money through the area decreased dramatically (Freitag and Clarence-Smith 2003). The Communist regime in South Yemen did not help matters: in some cases they appropriated the land and assets of the affluent, driving them from the country. The natural growth and innovation of Tarim's urban fabric gave way to centralized, bureaucratic planning. Considering this legacy alongside the demographic changes taking place in contemporary Yemen, there is great pressure on unique urban settings in Hadhrami cities such as Tarim (fig. 8). Yemen's entire population had reached about 18.5 million people by 2003. This number in itself is not alarming, but Yemen's growth rate is between 2.7 percent and 3.5 percent per year, a high rate for any country. Of Yemen's population, only about one million live in the Hadhramaut Governorate, where Tarim is located. The Yemeni government sees the quiet, open spaces of the region as ripe for expansion. Development efforts focus on road construction into sparsely populated regions such as the Hadhramaut and the Tihama in the hope of opening new opportunities to citizens in the more crowded north.⁹ If the Yemeni population continues to increase at the current rate and unplanned construction continues as well, we will soon witness a full demographic explosion in Tarim and other historic cities of the Hadhramaut Valley.¹⁰ This is already happening in Sey'un, the largest city in the valley, and the shape of Shibam, al-Qatn, and Tarim is changing under the earliest effects of these shifts. More changes will follow the expansion of new roads, although there are few statistics at this point. The pressures may not reach the proportions of global megacities in our lifetime, but the patterns of change tell a troubling story for heritage conservation.¹¹

Although our first pilot project has produced results, the need remains for a citywide, perhaps regional, conservation plan. Our working group has collaborated with Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) with this in mind, using components of its highly successful Shibam model, a winner of the 2007 Aga Khan Award for Architecture. In the meantime, our partners and we act as a conduit between the Yemeni government, funding organizations, and regional stakeholders. Documentation and interpretation have been essential tools in our efforts, but only sustainable heritage management through the actions of local stakeholders will preserve the built environment.



FIGURE 8 Unsympathetic concrete construction in front of Dar al-Salam. The building in question is a much-needed hospital, so conservation becomes the challenge of managing change to ensure that the past has a role in the future while not hindering access to needed services. Photo: James Conlon. Courtesy of the Visual Media Center, Columbia University

Notes

- 1 ICOMOS Ename Charter for the Interpretation of Cultural Heritage Sites, as ratified at the 16th General Assembly in October 2008.
- 2 See *Revised Burra Charter*, Australia ICOMOS, 1999.
- 3 Walter Ruttmann, dir., *Berlin: Die Symphonie der Großstadt* (DVD, Image Entertainment, Germany, September 23, 1927 [May 4, 1999]).
- 4 This group includes Columbia University, the American Institute for Yemeni Studies, Yemen's Social Fund for Development, Yemen's General Organization of Antiquities and Museums, the Tarim branch of the Yemeni Society for History and Heritage Protection, and the Tarim Assembly for Heritage Preservation.

- 5 "Community and the Built Environment," Columbia University, Visual Media Center. Available at www.learn.columbia.edu/tarim, no date.
- 6 See the project Web site: www.learn.columbia.edu/tarim.
- 7 <http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/MENAEXT/YEMENEXTN/0,,contentMDK:20185670~pagePK:141137~piPK:217854~theSitePK:310165,00.html>.
- 8 Damluji discusses this idea extensively, and Boxberger also covers the increase in the performance of affluence in the nineteenth and twentieth centuries.
- 9 From the World Bank country indicators: <http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/MENAEXT/YEMENEXTN/0,,menuPK:310174~pagePK:141132~piPK:141107~theSitePK:310165,00.html>. The Ministry of Public Health and Population estimated a 2001 population of 18,862,999. See also Abdullah Al-Asil, "Population Growth Is the Yemeni Government's Real Challenge," *Yemen Times*, December 10, 2007.
- 10 In fact, we have seen the rezoning map of Tarim proposed by the Ministry of Public Works, wherein vast areas of the date palm groves surrounding and integral to Tarim have been gridded into building lots for future expansion.
- 11 We are indebted to Omar Abdalaziz al-Hallaj, director of the Shibam Urban Development Project, and Lamiya Khalidi, director of the Zabid Documentation Training Program, for their information on these demographic changes.

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Recent Work in Earthen Architecture

Edward Crocker

Abstract: *This paper reviews projects undertaken in the recent past by the author and his associates that demonstrate advances in the field of earthen architectural conservation. Among the issues discussed are the conservation of a pitched earthen roof, remediation of design flaws in two buildings of the same era but in different geographic locations, seismic monitoring of the oldest public building the United States, and the strapping and “caging” of historic earthen structures.*

Résumé : *Cette communication passe en revue les projets mis en œuvre récemment par l’auteur et ses associés qui témoignent d’avancées dans le domaine de la conservation de l’architecture de terre. Les sujets abordés traitent notamment de la conservation d’un toit pentu en terre, de la correction des défauts de conception dans deux bâtiments de la même époque mais de régions différentes, de la surveillance sismique du plus ancien bâtiment public des États-Unis, et du lattage et « cerclage » des structures historiques en terre.*

Separated at Birth? The Costilla County Courthouse and the Otto Franc Homestead

The Costilla County Courthouse (1886) in San Luis, Colorado, is an adobe structure on a fieldstone footing laid up using portland cement mortar. This was a rare occurrence because portland cement was not manufactured anywhere in the region until well into the next century, and transport costs would have made it very expensive to use.

The adobes in the courthouse were laid using mud mortar but are not the usual size for this area; instead of the norm, 10 by 14 by 4 inches, they are the approximate size of a stan-

dard fired brick. And they are laid in Common Bond, with intermittent headers (bricks laid across the long axis of the wall) punctuating the stringers (those laid along the axis). This is also nonconforming to the region and the time. The builders continued their iconoclasm by eliminating the usual wooden headers over the windows in favor of arches using fired bricks in lime mortar and by rendering the exterior with a thin and very friable portland mix scored to look like ashlar masonry.

The mixing of dissimilar materials, like mismatching tissue in an organ transplant, leads to rejection of the offending component or failure of the entire system. An early photo indeed shows the plaster coming off in sheets. How, in this case, do we respect the original materials and the technologies employed by the builders while knowing full well that this may not be the best thing for the structure?

Our solution was to contrive a lathing system that is reversible without damaging the adobe walls. We used 4-by-10-foot sheets of expanded metal lath attached using quarter-inch through bolts and low-profile nuts. The interior will be plastered with earth for permeability, and the exterior, reflecting the desires of the builders 120 years ago, will have a thin coat of thoroughly modern portland cement.

In a rather remarkable turn of events, we had not yet finished with the first phase on the Costilla County Courthouse when we were confronted by its apparent prototype in northwestern Wyoming. Aside from the unlikely presence of an adobe ranch house in northern Wyoming, there was an uncanny resemblance between the adobe masonry style in the Otto Franc von Lichtenstein homestead (1878) and the Costilla County Courthouse. Again, the walls are on fieldstone footings, the size and proportions of the adobes are more akin



(a)



(b)

FIGURE 1 Costilla County Courthouse, San Luis, Colorado (a), and Otto Franc House, Pitchfork Ranch, Meteetsee, Wyoming (b). Photos: Edward Crocker

to those of the fired bricks one would find in the midwestern United States during the same era, and in both buildings the masonry units were laid in identical Common Bond.

The clincher was the treatment of the windows. In the slightly later Costilla County Courthouse the shallow arches over the openings are constructed of fired brick; the feature is identical in the Franc house, except that the masonry units are adobe (fig. 1). In both cases, the design flaw later became a problem, but the point here is that it seems clear that masons familiar with brick were imported to construct these two amazing structures.

Could they have been the same masons? Could the illustrious Baron von Lichtenstein have brought in the masons to build his ranch house and on completion of the job sent them to another project needing their skills in southern Colorado?

The Hutmakers and the Hopi

When I arrived at the Hutmacher Farm in North Dakota (built in 1928), I simply had to stand in amazement and ponder the temerity of a family of German immigrants building a pitched mud roof in the Great Plains, where the onslaught of wind, rain, snow, sleet, and hail made for incessant maintenance.

Naturally, there were reasons the Hutmakers built as they did. First, they were limited by the natural resources available to them. Second, and more profoundly, they were replicating a traditional architectural form that has its roots in the Black Sea region of the Ukraine and was brought to North Dakota by people of German-Russian descent. The building tradition they carried to the Great Plains called for building with pitched roofs, but the tradition did not prescribe the



FIGURE 2 Hutmacher Farm, Killdeer, North Dakota. Photo: Edward Crocker

means and methods to do so half a world away from the archetypes in the Caucasus.

The result was that the Hutmachers, using what was at hand, piled a thick layer of rich clay over an underlayment of straw and brush at about a 30-degree angle. It was (to quote two granddaughters of the builder) “a maintenance problem.” The house is essentially buried on one side from the cascading clay.

The present owners of the farm readily concede that they cannot afford the maintenance cycle demanded by the original materials. At the same time, they are completely averse to abandoning the essentials of an earthen roof. When an inquiry came my way, I was intrigued, never having heard of a pitched earthen roof, to say nothing of trying to restore one. But, as I began to ponder the challenge, I postulated that the problem might be solved by borrowing an idea, a solid technology really, from the ancient Hopi village of Oraibi in Arizona.

Years ago, at the request of the owner, I “excavated” a flat earthen roof on a building that probably had not been maintained for at least half a century. What I found was quite remarkable. Earthen roofs are not simple constructs; on the contrary, the successful ones have a carefully thought-out stratigraphy. Essentially, there are varying components of well-draining sandy clays, absorptive clay, and virtually impermeable clays cleverly layered over the brush mat.

I am hopeful that by using that model and modifying it to include a lime- and gravel-rich coat exposed to the weather (fig. 2), we have lengthened the maintenance cycle to something the owners can live with while not abandoning either

the spirit or the specifics of the original. It will be very satisfying if a venerable Hopi technology provides a solution to the dilemma at Hutmacher.

Responding to Basket Cases

Monitoring historic buildings is a crucial aspect of their preservation, especially when a specific site is—or is perceived to be—in imminent danger. In fall 2003 we were contracted to stabilize the north wall of the Palace of the Governors in Santa Fe, New Mexico (fig. 3), and subsequently to monitor the entire Palace complex as a nearby building was demolished.

We proposed and installed a series of three seismographs and sixteen crack monitors in strategic locations throughout the Palace/History Library complex. Then, weeks before the demolition began, we took daily readings of both sets of indicators to establish the baseline data. The monitoring allowed us to judge when to halt work and when to recommend a different approach. The system worked admirably, and the Palace survived unscathed. But what if the monitoring, or another event, requires a response?

One of the more challenging aspects of dealing with historic adobe and stone buildings is deriving a method of structurally underpinning while being true to the preservation tenets of minimal intervention and reversibility. We have developed hardware to underpin even the most difficult situation. Perhaps the most innovative approach is the use of “adobe baskets.” These are steel elements, engineered to specific



FIGURE 3 Palace of the Governors, Santa Fe, New Mexico. Photo: Edward Crocker



(a)



(b)

FIGURE 4 Installation of adobe baskets.

Photos: Edward Crocker

jobs, that are installed in segments and supported on helical piers. The piers are installed adjacent to the wall being treated, and then short sections of the wall are undermined and the basket slipped in (fig. 4a). Once the basket is in place, the wall is rebuilt (fig. 4b) and the basket is mechanically lifted up (fig. 4c) to provide positive support of the wall. The baskets can be welded into a continuous grade beam. They are designed to break capillarity through the use of a gravel layer at the bottom of the basket. Should the occasion ever arise, both the piers and baskets can be removed or replaced—a distinct advantage over a concrete grade beam.

Caging Adobes

Recently we were called on to stabilize a two-story adobe building. It was January, there was snow on the ground, and the structure we were to treat was sitting in a puddle. The contractor had peeled off some of the cement plaster and discovered, to his horror, that the walls at the base were mere pedestals, having lost nearly half their thickness over time. Fortunately, though they were only single wythe walls 14 inches thick, they were completely frozen and thus still capable of bearing the loads if everyone remained light-footed and prayed fervently for bad weather.

My son, who is not known for piety, seemed to receive a nearly divine enlightenment when he came up with “adobe cages” to tame this beast. Essentially, he welded 1-inch channel iron into frames with sufficient bracing to make them rigid,



(c)

then welded a heavy-gauge expanded metal over the frames. The dimensions of the frames fit sections of the wall and were intended to encase the bottom 3 feet. By mixing a lime-rich mud and piling it into the damaged wall and filling the low-profile cage with the same material, he could through-bolt two cages together, one inside and the other outside, with minimal interference to the original wall. The resulting sandwich served the purpose brilliantly: it was structural, reversible if necessary, completely vapor permeable because of the expanded metal, and of such low profile that we could later plaster directly over the cages.

Stabilizing Los Luceros Hacienda

Counterintuitive as it may seem, the process of maintenance and repair can itself be deleterious. The buildings that pose

the most difficult conservation problems are those that are old enough to have undergone several restoration and repair campaigns. Such a situation presented itself when, during reconstruction, a large section of wall collapsed at Los Luceros Hacienda (ca. 1865) in northern New Mexico.

The serious issues, and the real challenges from a technical viewpoint, arose in areas where there had been an active attempt at repairs and renovations, mostly during the past fifty years. In some areas coved or weathered adobe had been replaced with concrete, brick, stone, and, more recently, stabilized adobes.

Because the walls of the building had been so compromised by “maintenance,” collapses had already occurred, and some very large and threatening cracks had appeared. We recommended and designed a system to bind the walls together. In keeping with the principles of reversibility and minimal intervention, we specified the use of polyester strapping to wrap the entire structure at several levels (fig. 5). The strapping is 3 inches wide and about one-eighth of an inch thick and has a test strength of 30,000 pounds. Importantly, it will only stretch about 5 percent before reaching its limit, which is why we use polyester over nylon, which can stretch up to 30 percent before failing.

The strapping was run in one piece around the full circumference of the building at window and door lintel height and again at the wooden bond beam separating the stories, hitting as much exposed wood as possible. Grommet holes were melted in and brass decking screws with washers were used to affix it to the wood as well as to the adobe. The strapping was pulled taut mechanically before it was screwed to the walls.



FIGURE 5 Polyester strapping in place at Los Luceros Hacienda, Alcalde, New Mexico. Photo: Edward Crocker

Interior walls were treated as well, with the strapping installed in such a manner as to bind them to the peripheral walls.

The architect on the project also asked us to design and inject a lightweight grout into the many voids (mostly caused by capillary rise and rodents in the wall base) and cracks (occurring mostly at the junctures of dissimilar materials). Experimentation with the local adobes led us to a mix that pumped and flowed easily, bonded well, and remained durable and vapor permeable when set. For a base we used a moderately hydraulic lime (St. Astier NHL 3.5), and for aggregate, hollow ceramic X-61 microspheres manufactured by the 3M Company.

La problématique de la conservation du bâti au Koutammakou

Nayondjoua Djanguenane

Résumé : Les Batammariba ont développé sur leur territoire, le Koutammakou, une architecture de terre très originale. Les sikièn, parsèment l'espace aménagé et demeurent l'épicentre de la vie sociale, culturelle et religieuse des Batammariba. Aujourd'hui, les sikièn jouissent d'un cadre traditionnel adapté à la conservation. Cependant, dans un monde en mutation qui suscite de nouveaux besoins, des menaces apparaissent et pourraient mettre en péril l'intégrité du site : introduction d'autres modèles de construction, raréfaction des matériaux locaux, disparition des savoir-faire, et autres. La communication propose des approches de réponses établies en conformité avec le plan de conservation et de gestion du site.

Abstract: The Batammariba have developed an original form of earthen architecture, sikien, in their territory of the Koutammakou. The sikien are scattered around the built area and remain at the center of the social, cultural, and religious life of the Batammariba. Today there is an appropriate traditional approach to their conservation. However, in a changing world, with new needs appearing, threats are emerging that may prove detrimental to the integrity of the site: the introduction of other building types, the scarcity of local materials, the loss of skills, and so on. This paper suggests possible responses developed in keeping with the site conservation and management plan.

Le toponyme *Koutammakou* signifie littéralement « le territoire où l'on bâtit avec la terre » et le nom *batammariba*, « ceux qui façonnent la terre », « les maçons de terre » ou encore « ceux qui construisent avec la terre » (fig. 1).

En effet, la capacité à sélectionner l'emplacement, à concevoir, à bâtir puis habiter la *takienta* ou maison tra-



FIGURE 1 Une *takienta* et ses autels extérieurs. Photo : CRATerre-ENSAG, Joffroy, Thierry

ditionnelle est une spécificité de ce peuple aussi appelé au Togo et au Bénin *batammaliba*, *bétammaliba*, *bétammaribè*, *b'tammariba*, *tammariba*, *tammaliba*, *batammaba* (fig. 2). Ces désignations rappelant leur spécialisation en construction en terre les distinguent de nombreuses autres ethnies pourtant linguistiquement et culturellement très proches.

Les *sikièn* (pluriel de *takienta*), ces habitats fortifiés à étage, parsèment le territoire savamment aménagé et demeurent jusqu'à ce jour, l'épicentre de la vie sociale, culturelle et religieuse des Batammariba. Ils ont conservé et perpétué cette technique constructive, les savoir-faire y afférents et les différents usages de ce bâti. Les valeurs ainsi transmises et protégées ont permis le classement au patrimoine mondial de l'UNESCO de l'ensemble du site comme paysage culturel.

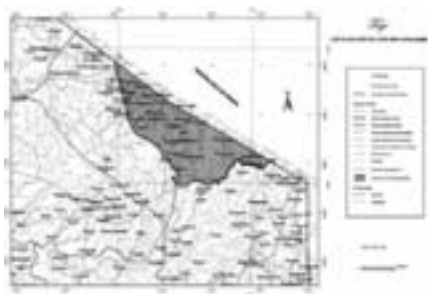


FIGURE 2 Localisation du Koutammakou, Togo. Carte :
Direction du patrimoine culturel du Togo

Certes, une partie importante du site, cadre de vie des Batammariba, garde encore son authenticité et son intégrité mais elle n'est nullement à l'abri des menaces dont les premiers effets apparaissent çà et là et qui pourraient, dans un futur proche, entamer la dégradation, voire la disparition totale de ce type d'habitat.

Cette communication centrée sur la conservation de ce bâti abordera le sujet en trois parties : présentation de la *takienta*, problèmes et menaces, et perspectives de conservation durable.

Présentation de la *takienta*

Le pays et les hommes

Le Koutammakou du Togo est situé au nord-est de la préfecture de la Kéran, à environ 500 km de Lomé, la capitale. Il couvre une superficie de 50 000 hectares et s'étend entre la rivière Kéran et la République du Bénin. Du côté du Bénin, ce territoire est plus vaste et abrite près de 200 000 âmes. Les Batammariba qui ont investi ce territoire entre le XVI^e et le XVIII^e siècle se réclament de plusieurs origines :

- Ils seraient descendus du ciel (mythe de l'autochtonie développé par Tcham (1997) probablement à Tayakou (Bénin), où l'on peut encore voir la *takienta* primordiale (fig. 3) ;
- Ils seraient des enfants de *fawaafa*, le serpent sacré et souterrain qui aurait couvé ses œufs d'où sortirent leurs ancêtres (Séwane 1999) ;
- Les Batammariba affirment aussi qu'ils viennent de *Dinaba*, un lieu mythique proche du Mogho Naba, au Burkina Faso.

La takienta et ses multiples fonctions

La *takienta*, élément le plus représentatif et le plus significatif du paysage culturel *otammari* est un microcosme à l'intérieur duquel le Batammariba naît, vit et meurt. Tout se passe dans et autour de cette maison originale aux multiples fonctions. Sa conservation à travers des siècles se justifie par une série de fonctions qu'elle assume.

- Habitat fortifié et structuré inspiré par Kuyé : Selon les Batammariba, Kuyé (Dieu) créa leurs ancêtres et les fit descendre du ciel munis de la maquette de l'habitat dont ils disposent depuis des siècles. Les éléments constitutifs de base de la maison-bloc sont la terre, la paille et le bois – matériaux locaux prélevés dans les environs et savamment utilisés grâce à l'ingéniosité des maçons locaux. Toutes les parties de l'habitat ont des fonctions utilitaires ou sacrées. Du rez-de-chaussée à l'étage, on chemine par l'étable, le poulailler, les autels intérieurs, le moulin, le mortier, la cuisine, la terrasse, les chambres à coucher, les greniers, la terrasse, les toilettes, etc. Maison-refuge, elle était aussi un habitat défensif en période de guerre, de razzia ou de toute attaque étrangère ou extérieure. La *takienta* est aussi un temple, épicerie de la vie et des croyances du Batammariba. Le rez-de-chaussée est l'espace des ancêtres et des morts et abrite de ce fait leurs autels. Les autels intérieurs, d'une taille inférieure à celle des autels extérieurs,



FIGURE 3 Tayakou au Bénin, *takienta* primordiale.
Photo : Direction du patrimoine culturel du Togo



FIGURE 4 Autels intérieurs contenant des potions magiques.
Photo : CRATerre-ENSAG, Joffroy, Thierry

représentent les esprits des ancêtres et des défunts de la famille qui continuent d'intervenir dans la vie du Batammariba. C'est par ces autels que le contact s'établit entre les vivants et les morts. Au-dessus des autels, sont accrochés au mur, dans le vestibule, des trophées de chasse coutumière et les reliques des fauves tués qui interviennent dans les cérémonies du *tibenti* des grands chasseurs. Les autels extérieurs situés de part et d'autre de l'unique entrée du complexe constituent des réceptacles des divinités protectrices contenant des potions magiques médicamenteuses et du matériel d'initiation (fig. 4).

- Construction et conservation de la *takienta* : Tout un savoir-faire traditionnel entoure la construction de la *takienta*. L'exécution du gros œuvre revient aux maçons aidés dans cette tâche par des apprentis et les autres membres de la communauté. Les femmes se chargent des travaux de finition : le crépissage et la décoration des murs, le damage du plancher, l'aménagement des espaces féminins tels que la cuisine, les toilettes, la terrasse, les greniers, le mortier, le moulin et autres.

La *takienta*, cadre de vie de cette population, reste un modèle d'actualité. Partout, les constructions, les reconstructions et les consolidations se poursuivent en saison sèche et confèrent à tout le *Koutammakou*, son caractère vivant et évolutif.

La conservation de la *takienta* est motivée par plusieurs raisons :

- Les fondements mythiques et culturels : Selon les Batammariba, la maquette de l'habitat inspirée par *Kuyé* est et reste le seul lieu de vie. En dehors de la *takienta* il n'y a point de salut. Sans *takienta*, le Batammariba s'écarte des prescriptions existentielles de Dieu. Sans *tata*, le monde s'effondre! Car la culture et toutes les valeurs immatérielles qui se développent autour de la *takienta* s'étioleront et disparaîtront faisant ainsi de l'espace *otammari*, un monde sans identité et donc sans vie.
- Les raisons religieuses : Il est inconcevable dans l'espace *otammari* de bâtir une *takienta* sans autels intérieurs ni extérieurs. Le faire relèverait d'un sacrilège ou d'une dénégation à son identité, car *Kuyé* n'a pas seulement conçu cette maison pour les hommes mais également pour les ancêtres et les divinités. C'est à cet endroit que les vivants et les morts entrent en communion avec Dieu.
- Les raisons initiatiques : Les Batammariba, fortement attachés à leur culture, perpétuent de façon spectaculaire leurs rites initiatiques malgré l'influence des autres religions et certains effets pervers du modernisme.

Quatre grandes cérémonies initiatiques rythment l'existence du Batammariba (figs. 5, 6) : le *difuani* des jeunes garçons, le *dikuntri* des jeunes filles, le *tibenti* à la mort des adultes porteurs de vie, et *itanwin*, une cérémonie de flagellation et d'endurance des hommes.

Au centre de toutes ces pratiques, on note la permanence incontestable et manifeste de la *takienta*. Unique cadre de ces cérémonies, la *takienta* demeure l'élément le plus important du parcours initiatique qui se déroule dans la grande maison de cérémonies (une *takienta*), au cimetière et à l'autel de *fawaafa*.

- Les raisons identitaires et esthétiques : Depuis près d'un siècle, les Batammariba se sont rendus à l'évidence que leur habitat génère un intérêt aussi bien



FIGURE 5 Le *difuani* des jeunes garçons. Photo : Direction du patrimoine culturel du Togo



FIGURE 6 *Itanwin*, une cérémonie de flagellation et d'endurance des hommes en pays Tamberma. Photo : CRATerre-ENSAG, Joffroy, Thierry

au plan national qu'international. Ceci les conforte dans leur volonté de le conserver de manière durable. En définitive, le bâti au Koutammakou se conserve encore conformément aux normes édictées depuis les temps immémoriaux. Il est l'objet d'un entretien régulier après les quatre mois de pluie. Hommes, femmes et jeunes s'y adonnent selon les compétences de chacun. L'entretien des autels coïncide souvent avec les fêtes des moissons et se fait agréablement accompagné de bière de mil et de repas cuisinés avec la volaille et les animaux sacrifiés.

Malgré un état assez satisfaisant de conservation de la *takienta* et un engouement encore perceptible à multiplier les modèles originaux, cette architecture présente des problèmes et des indices de menaces pouvant nuire à court, moyen et long terme à son intégrité et à son authenticité.

Problèmes et menaces

L'architecture traditionnelle du Koutammakou conserve ses caractéristiques physiques et socioculturelles propres. Elle n'est cependant pas à l'abri des effets anthropiques, des aléas climatiques et d'autres facteurs induits du changement social qui pourraient provoquer sa stagnation ou sa disparition. On note déjà des problèmes et des menaces concernant l'édification et la conservation de la *takienta*.

Problèmes

- Raréfaction des bois d'œuvre. *Prosopis africana*, qui offre un bois dur et inattaquable par les termites pour la charpente et la toiture-terrasse disparaît presque complètement. Les autres essences utilisées telles qu'*Anogeissus leiocarpus*, *Butyrospermum Parkii*, *Kaya senegalensis* et *Diospyros mespiliformis* sont essentiellement des espèces fruitières ou médicinales et ne sauraient offrir du bois d'œuvre sans créer un déséquilibre alimentaire et sanitaire.
- Déboisement accéléré des abords du fleuve Kéran. Ces berges ont subi des effets anthropiques depuis 1990 où la population s'était vengée de la politique non concertée de création des réserves de faune au détriment de l'homme. Ce bois d'œuvre prélevé sert à la fabrication du charbon de bois, très prisé dans les villes.
- Coût élevé de la construction (achat de bois, de paille, coût de la main-d'œuvre des maçons et des manœuvres, des pourvoyeuses d'eau et autres).
- Entretien récurrent et saisonnier (réparation, reconstruction des parties effondrées pendant la saison pluvieuse, renforcement de l'étanchéité, consolidation).
- Non-formalisation de l'apprentissage des techniques du bâti et savoir-faire y afférents. Aujourd'hui, certains jeunes intéressés par le métier hésitent car aucun diplôme ne sanctionne l'apprentissage

traditionnel, contrairement à l'apprentissage formel qui offre des garanties d'obtention de diplômes et d'exercice du métier hors de l'espace *otammari*.

Menaces

Les Batammariba, comme tous les peuples, aspirent en ce début du XXI^e siècle à un mieux-être et à un certain développement. Certains jeunes s'inscrivent dans la logique des anciens : se développer sans perdre son âme. D'autres, par contre, voudraient voir le Koutammakou ressembler à cette grande ville urbanisée aux immeubles scintillants des temps modernes, qui à leurs yeux, confère valeur et importance à l'homme. Une troisième catégorie voudrait répondre à ce besoin, par exemple disposer d'espace pour le mobilier moderne et avoir tout le confort. Ces besoins sont réels mais leur satisfaction non contrôlée constitue des menaces.

- La principale menace afférente à la *takienta* réside dans l'abandon de plus en plus visible de son édification. Sur le site, cinq situations se présentent (fig. 7) :
 - construction de simples cases rondes à côté des *tatas* familiaux,
 - mutation de la structure circulaire en forme carrée ou rectangulaire avec substitution de la tôle à la paille,
 - développement des agglomérations et de petits centres urbains avec des constructions modernes,
 - construction de la *takienta* en parpaings de ciment (fig. 8),



FIGURE 7 Une *takienta* abandonnée. Photo : Direction du patrimoine culturel du Togo



FIGURE 8 Une *takienta* en parpaings de ciment. Photo : Direction du patrimoine culturel du Togo

- construction d'équipements modernes de l'administration (école, dispensaire, centre culturel et autres) sans harmonie avec l'environnement.
- En dehors de cette menace, on observe les pathologies suivantes :
 - tassement d'une partie du bâti en cas de fortes pluies accompagnées de tornades,
 - utilisation de matériaux périssables du fait de l'infestation et de la corruption de leurs éléments constitutifs (termites, puces, charançons des bois et des céréales),
 - effets dus aux intempéries (fissures, craquelures, remontées capillaires),
 - dénigrement et intolérance des prosélytes des nouvelles religions à visée iconoclaste percevant la structure complète comme une œuvre surannée et démoniaque.

Quelles stratégies adopter alors pour conserver et mettre en valeur ce patrimoine qui revêt un intérêt pour la communauté locale et pour toute l'humanité ?

Les perspectives de conservation durable

Dans un monde en pleine mutation, le problème de survie de la *takienta* se posera à moyen et long terme si des mesures conservatoires ne sont pas prises à temps. Si dans les villages du Koutammakou, la *takienta* se maintient beaucoup plus, elle disparaît par contre dans les petits centres urbains, en emportant toutes les valeurs générées au fil des siècles.

C'est dans cette perspective que le plan de conservation et de gestion qui accompagne le dossier de nomination du site vise trois objectifs principaux, à savoir :

- la mise en place d'une protection juridique et d'un mécanisme de gestion efficace pour la conservation et la promotion du site,
- la valorisation de la culture *otammari* et la promotion d'un tourisme respectueux des valeurs intrinsèques du site,
- la contribution à l'amélioration des conditions de vie des Batammariba.

Ce dernier objectif, qui se décline en plusieurs objectifs spécifiques, comporte ceux exclusivement centrés sur le bâti, dont le renouvellement des essences utilisables pour la construction de la *takienta*, et des recherches pour l'amélioration globale de l'habitat.

Des actions en deux étapes ont été prévues : dans un premier temps et à court terme, remédier au manque de bois par le développement des pépinières des essences de *Prosopis africana*, teck, eucalyptus, *Anogeissus leiocarpus*, caïlcédrat, en reboisant les espaces peu propices à l'agriculture. Dans cette optique, chaque famille pourra disposer d'un petit bois pour son utilisation.

On procédera par ailleurs à l'extension des forêts sacrées en renforçant les interdits de coupe d'arbres. Toutefois, des cérémonies d'abattage d'arbres pourraient être instaurées tous les cinq ans pour permettre la régénération des forêts.

Dans un second temps, il conviendra d'engager, à moyen et long terme, des recherches pour l'amélioration de l'habitat par :

- l'identification des maçons, des prêtres, des chefs de terre et des devins afin d'étudier avec eux la possibilité d'améliorer la structure et la technique constructive de la *takienta* sans profaner le panthéon,
- la réalisation d'une étude sur le mode de production et d'entretien de l'habitat et leur évolution,
- la réalisation d'une étude sur les nouveaux besoins et souhaits en matière de logement,
- l'élaboration des propositions diversifiées d'amélioration de l'habitat,
- la construction des prototypes,
- l'évaluation de la qualité des diverses réponses proposées,

- l'établissement des partenariats pour la construction d'habitations,
- la réalisation d'une étude de faisabilité pour déterminer les possibilités de diffusion des innovations ayant prouvé leur pertinence.

Depuis la fin de 2004, le Service de conservation et de promotion mis en place est chargé de coordonner toutes ces actions, de veiller à l'application de toutes les mesures de conservation et de protection modernes qui accompagnent la pratique traditionnelle et de conseiller les populations sur la nécessité de conserver les valeurs du site.

Conclusion

Le bâti au Koutammakou est dans un très bon état de conservation et les acteurs de cette performance continuent à y veiller. Les Batammariba sont très fiers du classement de leur site sur la Liste du patrimoine mondial. Par contre, les anciens s'inquiètent de l'avenir de cette œuvre originale à laquelle s'identifie leur ethnie. Certes, les Batammariba s'investissent encore dans la pérennisation de la *takienta*, mais le temps et l'évolution des mœurs, la mondialisation avec son corollaire d'uniformisation et de phagocytose peuvent sonner le glas de cette belle architecture vernaculaire qui sert d'inspiration à nombre d'architectes. En appui aux efforts de la Direction du patrimoine, l'UNESCO, le Programme Africa 2009, CRA Terre-ENSAG et l'association les Amis du patrimoine sont intervenus en pionniers pour la mise en œuvre du plan de gestion 2002-12. Un appel est lancé à toutes les bonnes volontés pour aider ces institutions déjà impliquées à intervenir davantage sur le site. Il revient aussi à l'État togolais de renforcer ses efforts de mobilisation des moyens nécessaires pour continuer à assurer la mise en œuvre du plan de gestion.

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The Conservation of Earthen Architectural Landscapes: A Preliminary Reflection and Review of Concepts

Maria Isabel Kanan, Mariana Correia, and John Hurd

Abstract: *Earthen architectural landscape is an area of study that has experienced increased interest due to the rising awareness of the broader field of cultural landscapes. This paper reviews recent literature on the topic and attempts to identify specific matters as well as concepts that have not been adequately researched. The goal is to spur research and action concerning their protection and conservation.*

Résumé : *Le paysage d'architecture en terre est une discipline de recherche qui a bénéficié d'un formidable regain d'intérêt après la sensibilisation naissante au domaine plus large des paysages culturels. Cette communication passe en revue la documentation récente sur ce sujet et tente de définir des questions précises et des notions qui n'ont pas encore fait l'objet de suffisamment de recherche. Elle vise à favoriser une meilleure prise de conscience des paysages d'architecture en terre, car la recherche et l'action sont actuellement insuffisantes pour en assurer la protection et la conservation.*

The conservation of earthen architectural landscapes is a multi-dimensional concept that needs to be better defined and understood. Recently there has been rising awareness and interest in the study of earthen cultural landscapes. The aim of this paper is to examine and reflect on the concept of cultural landscape, in particular, how it is being defined and what it means when applied to the study and conservation of earthen architecture. Our preliminary research has identified issues, concerns, and interrelated concepts that need to be investigated for more appropriate and frequent use of the concept of cultural landscapes in the protection and conservation of earthen architecture.

Through a review of the literature on the study and conservation of earthen architecture, it is possible to better define this concept as applied to earthen architectural heritage and to generate discussion and a clearer understanding of the issues. It is expected that this type of literature review and research will bring together the missions of the ICOMOS International Scientific Committee on Earthen Architectural Heritage (ISCEAH) and the needs of the international community to protect and conserve valuable earthen architectural landscapes that are not yet recognized.

Reasons to Discuss the Topic of Cultural Landscapes as It Applies to Earthen Architectural Heritage

Ancestral Significance of Built Heritage Attached to the Landscape

Since ancient times earth has been used to build urban and rural palaces, monasteries, temples, city walls, and forts, as well as simple dwellings. Earth is an exceptional building material because it is always sourced locally. The techniques have been transported by tradesmen, connecting different cultures (Schroeder et al. 2003) (fig. 1).

High Proportion and Evident Stock of Earthen Built Heritage

The stock of earthen heritage constitutes a huge proportion of our cultural heritage. Earthen landscapes are clearly seen in Iran, Morocco, Ladakh, Tibet, Mali, Mexico, Peru, Egypt, and Yemen, just to name a few of the places with earthen sites (fig. 2). Almost half of all the built World Heritage Sites contain some earth elements.



FIGURE 1 Chan Chan, one of the largest pre-Hispanic cities in the Americas. Photo: M. Isabel Kanan



FIGURE 2 Ksar of Ait Ben Haddou, Morocco. Photo: Mariana Correia

Intangible Meanings and Continuously Changing Living Culture

Earthen sites are commonly linked to intangible forces that drive a living, organic, and dynamic culture with continuously changing landscapes. In this type of environment the “cycling and recycling” techniques that are subject to replacement and maintenance from time to time are usually filled with immaterial significance and tradition. According to Prosper

(2007: 119), “Such spatial practices and performances transform largely unmodified wilderness into meaningful cultural spaces symbolizing a collective consciousness that is inextricably associated with a geographical territory.”

Lack of Proper Protection and Conservation Levels and Standards

Today, even with much effort from the scientific community and professionals and the support of international organizations, significant parts of earthen settlements are being irreparably damaged and lost.

Brief Historical Background of the Concept of Cultural Landscapes

According to Fowler (2003: 16–17), “The conceptual origins lie in the writings of German historians and French geographers in the mid- to late nineteenth century and then improved in the beginning of the twentieth century, but it was only in the 1990s that the term *cultural landscape* came into accepted professional use in conservation circles. Over the last decade, the World Heritage Committee has been a pioneer in applying, in a practical way, such an intellectual concept.” According to the World Heritage Convention (1992), *cultural landscape* embraces a diversity of manifestations of interaction between humankind and its natural environment and often reflects special combined qualities and significance.

Important Issues Based on Relevant Examples in the Literature

We examined papers from previous Terra international conferences and organized them by relevant topics, as follows.

Character of Earthen Remains and Traces in the Landscape

Bewley and Everson (2000) presented an article concerning “earthworks”—traces left by past societies—which the UK is very rich in, that are visible on the land surface and in the landscape. Similarly, Chadburn and Batchelor (2000) describe the earthen monuments in the area of Stonehenge.

Castellanos and Hoyle (2000) highlight the complexity of Chan Chan, the large expanse of the site, and the remains of the buildings, palaces, and agricultural and rural zones. Recognition of these cities, settlements, farming, fields, and so on, as cultural landscapes is an important part of protecting the overall character of these sites.

Specific Physical-Spatial Organization and Adaptive Use of Earth

Mohammadi (2003) emphasizes the physical-spatial aspect of the urban form of the desert city of Yazd, where the street landscape and the relationship between culture and physical structure are specific to place (fig. 3).

Jayhani and Omrani (2003) write about the use of adobe architecture in central regions of Iran. Adobe responds well to the climatic needs and structural demands; furthermore, it is capable of changing with a culture's organic and dynamic developments.

Schijns (2000) presents the case of Dakhleh Oasis in Egypt, where defensible villages are built at the top of the hill. The versatility of earthen construction in adapting to the topographic and geographic conditions gives a special landscape character to the earthen sites.

Ahmed (1993) describes earthen construction in the extremely wet conditions of Bangladesh. When the sites were built they were adapted to the topography, climate, availability of materials, and social conditions.

Synchronic Attachment to the Natural Context and Continued Use

Gupta (2003) writes about the cultural landscape of Ladakh in the western Himalayas, which is under continuous threat, resulting in the alteration of its significance. Ladakh is a living culture. Traditional systems were developed based on the availability of raw material, and the villages have a close link with the context.

Pandit (2003) writes about Ladakh's harmony with nature. Its villages and buildings are in fine ecological balance with their environment and add an element of interest to the landscape. Rituals and ceremonies dictate spatial requirements for particular types of structures and determine to some extent the buildings' site plan, layout, and construction methods.

Chaudhry (2003) describes the thousand-year-old architectural heritage of the western Himalayan regions: Ladakh, Nubra, Zaskar, Lahaul, Spiti, and Kinnaur. In Ladakh prominent landscape features are adopted into the landscape as part of the magical and philosophical system (fig. 4). Specially positioned sites (for defense, etc.) can be seen. Mud walls that cross the landscape often manifest their religious and practical meanings. The settlements, whose historic structures made of mud, timber, and stone are still inhabited today, and the intangible heritage that they represent are unique (fig. 5). This can be seen in the villages, monasteries, forts, palaces, and



FIGURE 3 The landscape of the city of Meybod from the Narin Castle, Iran. Photo: M. Isabel Kanan



FIGURE 4 Stupas (Chorten) near Basgo, Upper Indus Valley, Ladakh. Photo: John Hurd

regional structures that are associated with the harsh landscape (fig. 6); the cultural, social, and economic relationship of the settlements to nature; the unique architectural style; and the rituals of traditional life. All these aspects contribute to a rich cultural heritage connected with the geographic context of the Himalayan and Karakoram ranges and the Buddhist religion. Together they are a specific and exceptional cultural landscape.

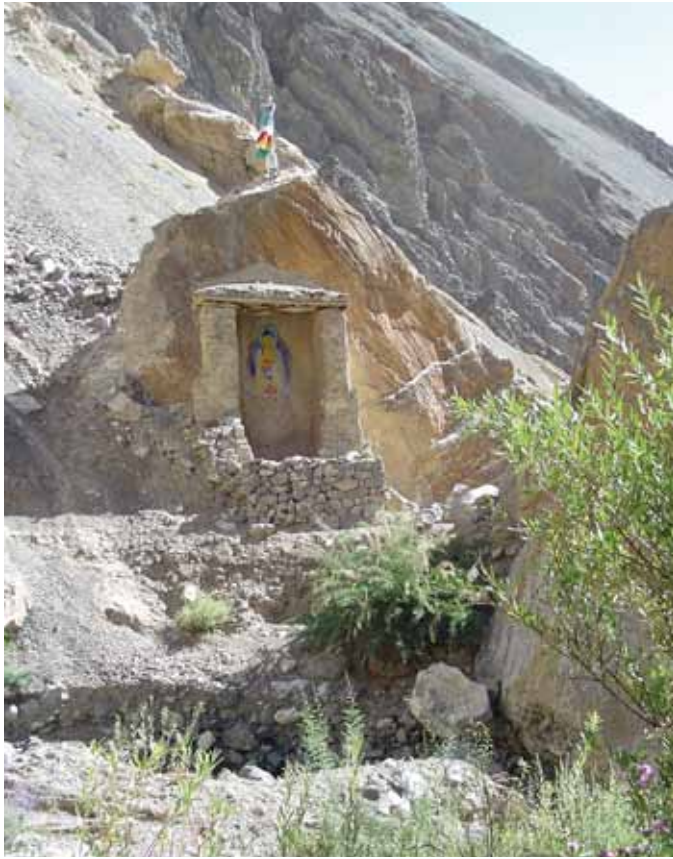


FIGURE 5 Sacred place, Upper Indus Valley, close to Ladakh.
Photo: John Hurd



FIGURE 6 A hill village and monastery with a high Himalayan mountain in the background. Photo: John Hurd

Universal Values / World Heritage

Schmidt et al. (2007) refer to the archaeological and ethnological interest of Bandiagara, together with the natural environment of the plateau, which creates a unique cultural landscape (fig. 7). Bedaux et al. (2002) explain that the dense urban structure of Djenné, which exhibits continuity and uniformity of style in its earth-brick structures, together with the daily use of the city and its integration with the fertile inland Niger Delta, led UNESCO to accept the city and the surrounding archaeological sites as a World Monument in 1988. It is crucial to declare the rest of the city a protected townscape (fig. 8).

Talebian (2003) writes about the earth-brick site of Chogha Zanbil, listed as a UNESCO World Heritage Site in 1997. He argues that this huge cultural landscape is undergoing change and recommends recognition of different aspects of the authenticity of this historical-cultural domain. He calls attention to recent concern about vernacular cultures and cultural landscapes, the need to conserve the spatial totality and to understand the authenticity of a property, and to preserving the authenticity of components and their integrity in relation to the whole. Further, especially regarding the cultural landscape, he acknowledges that the essence of a place is that it is changeable and that balance between change and integrity is highly significant.

Malisius (1993) presents an outstanding example of earthen architecture through the historic town of Ghadames in the northern Sahara: cube-shaped houses designed around



FIGURE 7 Dogon Country, Mali. Photo: M. Isabel Kanan



FIGURE 8 Djenné mosque, Mali. Photo: Mariana Correia

a central living room perfectly adapted to the rough desert climate, interwoven structures presenting integration of built environment with lifestyle, economical use of local resources, and recycling of limited natural resources.

Proposal for Applying the Concept of Cultural Landscape to Earthen Heritage

Earthen settlements are a particular type of cultural landscape that have a unique expression. This expression is due in part to the fact that earth can often be used in its natural, unmodified state for architectural and agricultural purposes. Our use of earth, however, becomes more efficient as we increase our empirical understanding of the material and its performance over time and in different environmental conditions. Often the high maintenance that is required for earthen buildings and agricultural lands can be achieved cooperatively, through traditional and religious observances throughout the year.

Earthen structures can respond and adapt to changing conditions while having little impact on the overall continuity of the surrounding landscape. Earthen structures often reflect the shapes and forms of the local landscape. This process creates cultural landscapes that are often magical in terms of their spirit of place. Earthen settlements generally have a strong connection with the natural environment and landscape. When they are part of a living culture, the whole ensemble is a cultural landscape.

We propose to use the term *earthen cultural landscape* to refer to built heritage based on the technology of earthen materials and techniques that result in a unique form of expression and interaction with nature (synchronic, balanced, and adapted form). Integral to this landscape is a complex and specific system of values, tangible and intangible heritage, and historic continuity of planning and intent.

Conclusion: Looking Forward

Cultural landscape is a vital concept for the preservation of earthen settlements. Conservation and respect of the historic *hierarchy* is fundamental. Many earthen settlements have evolved over time and are still alive and relevant. Conservation should not inhibit growth and evolution within the settlements. We encourage the preservation of earthen heritage as cultural landscape and recommend finding measures to accomplish this. Work at this level requires an interdisciplinary focus, to which the ISCEAH of ICOMOS can contribute greatly.

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Raising Awareness of the Value of Earthen Architecture for Living and Working in the Nile Valley, Egypt

Hossam Mahdy

Abstract: *This paper aims to find a way to reverse or slow down the fast pace of demolition and hasty changes to the vernacular built environment of the Nile Valley in Egypt. Observations and analysis of the situation since Hassan Fathy's attempts in the late 1940s are presented. Lack of awareness is an obvious cause for unsympathetic attitudes on the part of both the official and unofficial sectors. A strategy for raising awareness is developed on the basis of establishing a significance statement involving all stakeholders. Objectives are defined for implementing the proposed strategy.*

Résumé : *La communication vise à définir le moyen d'inverser ou de ralentir le rythme accéléré des démolitions et des modifications hâtives du bâti vernaculaire dans la Vallée du Nil en Égypte. La situation est observée et analysée depuis les tentatives d'Hassan Fathy, à la fin des années 40. L'absence de prise de conscience explique l'attitude négative des secteurs officiels et non officiels. Une stratégie de sensibilisation est donc établie, à partir d'une déclaration de valeur impliquant tous les partenaires concernés, avec définition des objectifs de mise en œuvre de la stratégie proposée.*

Values

Mud houses, pigeon towers, mosques, churches, and other village earthen architecture, together with water wheels, irrigation canal networks, fields, trees, and, of course, the Nile, formed the Egyptian rural landscape (Henein 1988). The beauty and harmony of the Nile Valley landscape attracted the attention of many geographers, historians, travelers, and artists (Manley and Abdel-Hakim 2004). Murals and carvings on ancient Egyptian monuments show that very little change occurred to the landscape and lifestyle of the Egyptian fellah,

or peasant, up to the 1970s. When politicians talk of the “true Egypt” they refer to the Nile Valley and its peasants (Ayrout 2005). The place of the fellah and village life within the identity of Egypt is reflected in the works of Egyptian painters, sculptors, musicians, novelists, poets, and other artists. Rural traditional mud buildings have identity value as an essential part of the integrity of the Nile Valley, which is significant as a world-class cultural route and cultural landscape.

Threats

Mud buildings are culturally significant as vernacular heritage and as an essential part of the lifestyle and rich intangible heritage in the Nile Valley. An example of the importance of mud in the life of the fellah is the tradition carried out on the birth of a child. Upon giving birth, a woman (fellaha) swallows a handful of moist earth. The afterbirth is buried in earth inside the home, and the umbilical cord, together with a few grains of corn, is wrapped in a cloth and buried in the family's field. In addition, the first time a fellah's child gets his hair cut, the hair is rolled into a ball of mud; and mourning women daub their heads and arms with mud. In his important book *The Egyptian Peasant* (2005), Ayrout writes, “The water and mud of the Nile enter into, and in a large part explain, the whole life of the fellah, his work and his home, his body and his temperament, and lend him both their qualities and their defects.”

The economic and functional values of traditional mud buildings are obvious: high environmental performance, high aesthetic values, and low cost. These values are in addition to the buildings' heritage and identity values.

Modernization and development efforts in Egypt started as early as the first half of the nineteenth century. “Combating poverty, ignorance and disease” was the aim of most reform

programs (Johnson 2004). Although considerable progress has been made in Cairo and other cities, this aim is still valid in rural Egypt. Most villages in the Nile Valley have inadequate education, health, and social services. They also lack many essential services, such as running water, sewage networks, electricity, and garbage collection systems. The great increase in population is aggravating the problem as the fertile land of the Nile Valley is limited to a narrow strip along the river (Weyland 1993).

Formal and informal efforts to overcome development problems are the major threats to the safeguarding of earthen architecture in the Nile Valley. The formal efforts, by planners, decision makers, and local authorities, are devoted to producing comprehensive plans for all Egyptian villages. The National Program for Rural Development started in 1995 with the aim of “developing” all Egyptian villages by the year 2017 (Al Qutb 1990), according to the following criteria:

1. Safeguarding the agricultural land and preventing construction on fertile soil;
2. Upgrading the urban environment of the villages and improving living standards;
3. Improving services and securing the requirements for expected future expansions;
4. Controlling urban expansion by preventing horizontal expansion and allowing vertical expansion to protect agricultural land.

Obviously, these criteria mean “throwing out the baby with the bathwater.” The results can already be seen in many villages. They are beginning to look like the informal housing areas on the edges of big cities in Egypt: reinforced concrete multistory buildings with no identity, aesthetic, environmental, or functional values.

Buildings such as health clinics, schools, police stations, and local branches of governmental departments constitute another threat to the earthen environment. They are usually built with high-tech materials and techniques and stand in the midst of the organic earthen village environment like ships from outer space, without any relevance to their context. They undermine the identity and aesthetic values of the rural cultural landscape.

Unfortunately, informal efforts by peasants to improve their living standards are heavily influenced by formal attitudes. A sign of a fellah’s prosperity is the replacement of his mud house with a reinforced concrete block house with glass and aluminum windows.

Many other factors have contributed to the threat to the traditional lifestyle of the Nile Valley, such as the return of migrant workers from oil-rich countries with different value systems, the spread of consumption values as a result of the influence of mass media, and rural-to-urban migration (Hopkins and Westergaard 1998).

Another threat is the shift in the field of construction and maintenance from traditional to modern materials and techniques. It is becoming more and more difficult to find someone to build a mud house, weave a reed mat, fix a waterwheel, or maintain a pigeon tower. It is becoming the industry standard to build with reinforced concrete, fix a kerosene-powered water pump, and use chemical fertilizers and plastic mats.

Perhaps the gravest threat facing the acceptance of the value of earthen architecture is the psychological, sociological, and cultural dimensions. Although all agree that the “true Egypt” is in the villages and that most city dwellers in Egypt today are of recent rural origins, middle-class urban Egyptians are continuing the long colonial traditions of undermining the fellah and mocking his traditional dress, house, and lifestyle. In fact, *fellah* is often used in current Egyptian dialect as a synonym for an ignorant, retarded, poor, and helpless person. I use the word here as a reminder of this threat.

Awareness

The shortage of cement, steel, and timber after World War II led the Egyptian architect Hassan Fathy to search for an alternative building material. Mud was not as obvious a solution as it may seem to us today. Fathy explained:

The peasant built his house out of mud, or mud bricks, which he dug out of the ground and dried in the sun. And here, in every hovel in Egypt, was the answer to my problem. Here, for years, for centuries, the peasant had been wisely and quietly exploiting the obvious building materials, while we, with our modern school-learned ideas, never dreamed of using such a ludicrous substance as mud for so serious a creation as a house. (1973)

He discovered building with mud, not only as a material and technique of building, but also, more important, as a philosophy of interaction between man and his environment (fig. 1).

Fathy is probably the most important advocate of the value of earthen architecture for living and working in modern times (Steele 1988) (fig. 2). He practiced what he preached (fig. 3). In 1948 he built the New Gurna village on the West



FIGURE 1 A traditional mud house in Gournat Mar'i studied by Hassan Fathy. Photo: Hassan Fathy. © Rare Books and Special Collections Library, The American University in Cairo

Bank of Luxor as a pioneering demonstration of the appropriateness and aesthetics of building with mud. Although his philosophy and work were appreciated all over the world, he was fiercely rejected in his own country. It is very sad to say that sixty years later, in the Egypt of 2008, there is still a pressing need for raising awareness on all levels—from the local peasantry to national decision makers.

Most inhabitants of New Gourna have neglected their mud buildings or replaced them with reinforced concrete block buildings (fig. 4). Authorities on the local, regional, and national levels have turned a blind eye to the gradual loss of these architectural masterpieces. Furthermore, many of the traditional houses in the old village of Gourna were bulldozed in 2006 to gain access to the archaeological layer of ancient tombs (fig. 5). Some of the demolished houses were fine examples of vernacular heritage of the Nile Valley. They also were important for the integrity of Thebes, a World Heritage Site.

The state of old and New Gourna is a manifestation of the lack of awareness of the value of earthen architecture, traditional and modern, vernacular and architect designed. There is an urgent need to raise awareness of both the val-



FIGURE 2 Hassan Fathy in New Gourna village, which he designed and built. © Rare Books and Special Collections Library, The American University in Cairo

ues of earthen architecture and the threats that are facing its preservation.



FIGURE 3 Hassan Fathy instructing traditional builders who worked with him in the construction of New Gourna. © Rare Books and Special Collections Library, The American University in Cairo



FIGURE 4 A view of part of New Gournna from the minaret of the mosque in 2008. Mud buildings that were built by Hassan Fathy are in a bad state of conservation. Many buildings were replaced by new reinforced concrete blocks. Photo: Hossam Mahdy

Toward a Significance Statement

A significance statement should be drafted. However, it will remain a draft until all stakeholders contribute to its final formation. Earthen architecture has the following sets of values (Avrami, Mason, and de la Torre 2000).

1. Emotional and symbolic values as an aspect of the role of earth and water in the life of the fellah;
2. Heritage values as a vernacular heritage and an aspect of traditional lifestyle in the villages of the Nile Valley;
3. Functional value as it is most suitable for rural lifestyle and everyday needs;
4. Economic value as it represents a very high value for money, when compared with other architectural materials and techniques;
5. Economic value through the potential of rural tourism, which has not yet been explored by the tourism industry in Egypt;
6. Socioeconomic value as a labor-intensive activity that offers job opportunities in construction, maintenance, repair, and conservation;
7. Sociocultural value as it guarantees the conservation of relevant traditional crafts and skills;
8. Environmental value because of its high environmental performance and because of its environmentally friendly consequences;



FIGURE 5 The demolition of the old Gournna traditional mud houses in 2006. Photo: Sameh Zaki

9. Aesthetic value that contributes to the integrity of the cultural landscape of the Nile Valley;
10. Identity value as an essential component of the identity of place in the Egyptian rural countryside;
11. Continuity value as a continuation of the ancient Egyptian cultural heritage; and
12. Cultural value as the Nile Valley is a cultural route of high significance for all humanity. This is an “across borders” value that should include other Nile Valley countries.

Whose Awareness?

Identifying stakeholders is not a problem. Initiating a dialogue among stakeholders of different status, backgrounds, and interests is the real challenge, let alone getting each stakeholder to appreciate, recognize, and respect others' views and priorities. An awareness program should be based on a significance statement that is elaborated and accepted, to the extent possible, by all stakeholders.

Talking about community participation and involving all stakeholders seems quite logical and possible. However, in the real world of the Egyptian village and after millennia of serfdom and colonization it is not an easy matter to get the fellahin to sit with local governmental officials as equals in a stakeholders' meeting, let alone to influence each other's opinions.

It is also quite a challenge to get an economist or a planner on the national level to incorporate cultural, heritage, emotional, and continuity values in development schemes. On the one hand, an architect who designs a prototype for a

village community center without leaving his office in Cairo cannot understand that his designs are likely to be inappropriate. On the other hand, a heritage specialist will hardly accept incorporating the functional and economic needs of the local community into his conservation schemes.

A culture of democracy, negotiation, interdisciplinary cooperation, and local community participation must be embedded in an awareness-raising program. Identifying stakeholders will only be meaningful and useful if channels for dialogue and mechanisms for cooperation among different stakeholders are established.

What Is the Message?

The value of earthen architecture for living and working is only possible to sustain as part of a bigger picture. An awareness-raising program should be based on a significance statement that is comprehensive and acceptable to all stakeholders. A message should be tailored for each group of stakeholders that share interests and value systems. The message should use a language that is understood and that is based on values that are accepted by its target audience.

A fellah needs to be convinced that function, services, and living standards in a mud house are no less than in reinforced concrete block. A local village doctor needs to be convinced that a health clinic built with earth can be as hygienic and functional as one built with modern materials. And a planner needs to be convinced that it is possible to sustain a healthy economy without the trade and employment of modern building materials and that earthen architecture is a good answer to development needs in the Nile Valley.

There are also the questions of village-city relations and apparently conflicting activities such as conservation versus development, living and working requirements versus cultural activities, and planning and decision making on the national level versus local participation and community empowerment.

Provisional Objectives

An awareness-raising program should aim to achieve the following provisional objectives:

1. The conduct and publication of research on the identity of place for the Nile Valley and its historical, geographic, sociological, and cultural dimensions;
2. The documentation, study, and analysis of earthen architecture in the Nile Valley, old and new; vernacular and architect designed; formal and informal;
3. The establishment of a platform that brings together the different disciplines relevant to all aspects of living and working in earthen architecture;
4. The establishment of pilot projects where all stakeholders actively participate in the formulation of strategies and decision making regarding rural earthen architecture;
5. The establishment of a media platform/network for the dissemination of the values of earthen architecture for living and working;
6. The production and dissemination of educational packages on earthen architecture in the Nile Valley directed to children and youth.

Conclusion

Raising awareness of earthen architecture for living and working is essential for the safeguarding of the vernacular heritage and the preservation of the identity of the Nile Valley. It is also essential for appropriate and sustainable improvements in the living conditions of the Egyptian fellah. Fragmented efforts will not improve awareness. There is a need for a long-term comprehensive program that addresses all relevant issues and involves all stakeholders.

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Evaluation of the Conservation and Monitoring and Maintenance Programs for Polychrome Earthen Bas-Reliefs of the Royal Palaces of Abomey, Republic of Benin

Francesca Piqué, Leslie Rainer, and Léonard Ahonon

Abstract: *In collaboration with the Ministry of Culture and Communication of the Republic of Benin in West Africa, the Getty Conservation Institute carried out the Abomey Project for the conservation of polychrome earthen bas-reliefs. The project was completed in 1997 and included training, documentation, conservation, exhibition, and a long-term monitoring and maintenance program for fifty bas-reliefs from the Palace of King Glélé. This paper describes the results of the 2006 evaluation of the bas-relief conservation project, which was part of the World Heritage Centre's review of conservation activities at the Royal Palaces of Abomey.*

Résumé : *En collaboration avec le Ministère de la Culture et de la Communication de la République du Bénin en Afrique de l'Ouest, l'Institut Getty de Conservation a mené le « Projet Abomey » pour la conservation de bas-reliefs polychromes en terre. Le projet a pris fin en 1997 et comportait la formation, la documentation, la conservation, l'exposition et l'élaboration d'un programme de suivi et d'entretien à long terme pour les 50 bas-reliefs du Palais du roi Glélé. Cette communication décrit les résultats de l'évaluation du projet de conservation des bas-reliefs effectuée en 2006, dans le cadre de la mission de suivi entreprise par le Centre du patrimoine mondial des activités de conservation des Palais royaux d'Abomey.*

The Abomey Project, undertaken from 1994 to 1997 as a collaboration between the Ministry of Culture and Communication of the Republic of Benin in West Africa and the Getty Conservation Institute (GCI), conserved fifty polychrome earthen bas-reliefs from the Palace (Ajalala) of King Glélé (Piqué and Rainer 1999a, 1999b) (fig. 1).¹ These bas-reliefs were detached from the walls of the Ajalala of King Glélé in 1988



FIGURE 1 Ajalala of King Glélé before the original building was razed and reconstructed. The bas-reliefs on its facade tell the rich history of the Fon people of the Dahomey Kingdom through representations of mythical and symbolic animals, weaponry, and battle scenes. Photo: Eva or Herbert V. Meyerowitz. Courtesy of the Museum of African Art, Smithsonian Institution, Eva Meyerowitz Collection, Eliot Elisofon Photographic Archives, 1937

when the building was razed and reconstructed. Of the fifty-six bas-reliefs originally on the facade, fifty were found in various states of disrepair and six had been lost (fig. 2).

The polychrome earthen bas-reliefs, believed to date from the late nineteenth century, are among the last remaining original historic bas-reliefs at the Royal Palaces of Abomey,² a World Heritage Site and listed as a World Heritage Site in Peril until 1997.³ They represent an important record of the history of the Fon people, who, prior to French colonization, had



FIGURE 2 From 1988 to 1993, prior to the start of the Abomey Project, the bas-reliefs detached from the Ajalala of King Glélé were stored in different parts of the museum and were in various states of disrepair. Photo: Leslie Rainer. © J. Paul Getty Trust, 1993

no written language and who recorded their history through visual images and oral tradition. Preservation of these bas-reliefs is significant, not only in the context of the museum collection, but also as an archive of Fon history (Piqué and Rainer 1999a; Waterlot 1926).

Initially the principal cause of damage to the largest bas-reliefs was their aggressive detachment from the facade of the Ajalala of Glélé in 1988. At that time the panels were manually cut out of the walls and encased in heavy cement and earthen frames to stabilize them. The reinforced panels weighed 300 kilograms on average. The detachment process not only caused significant structural damage but also contextually and physically transformed the panels, from integral architectural elements of the palace facade into isolated museum objects. Subsequent transport of the heavy detached bas-reliefs between storage areas aggravated their fragile condition (fig. 3).

In addition to transport-related damage, previously applied portland cement repairs weakened the original earthen materials and accelerated deterioration of the bas-reliefs. Wall bases and lower-register bas-reliefs eroded from rain back-splash were patched with portland cement, which introduced additional soluble salts into the decorative surfaces. Together, the physical incompatibility of the earth and the cement combined with accelerated disintegration of the earth from soluble



(a)



(b)

FIGURE 3 Example of a bas-relief, before (a) and after (b) treatment. The broken base of the frame is an indication that the principal cause of damage was the transport of these heavy objects following their detachment. Photo: Susan Middleton. © J. Paul Getty Trust, 1995 (a) / 1997 (b)

salt phase cycling left the bas-reliefs in poor condition. Insects and animals caused additional deterioration.

The conservation treatments developed to stabilize the detached bas-reliefs were based on the principle of minimal intervention and compatibility of the treatment materials with the original earth. Forty-eight bas-reliefs were stabilized, and two were left untreated as didactic examples of the condition of the bas-reliefs prior to conservation. Components of the project included the study, documentation, conservation, and exhibition of the bas-reliefs, as well as training of Beninois professionals in all aspects of the project. Training was essential to ensure sustainable preservation of the bas-reliefs. Documentation in written, graphic, and photographic form was also an important component of the project and continues



FIGURE 4 At the end of the Abomey Project, twenty-one bas-reliefs were selected for display in the museum. The permanent exhibit focuses on the history, conservation, and significance of the bas-reliefs of the Royal Palaces of Abomey. Photo: Susan Middleton. © J. Paul Getty Trust, 1997

to be essential for long-term monitoring and maintenance of the bas-reliefs, as illustrated later in this paper (Piqué and Rainer 1998, 1999b).

At the end of the project twenty-one bas-reliefs were selected for exhibit as part of the museum collection (fig. 4). They were installed in one of the museum buildings designated specifically for this purpose. The remaining twenty-nine bas-reliefs were placed in storage (fig. 5).

Maintenance Program

It is widely acknowledged that for conservation efforts to be successful and sustainable, regular monitoring and maintenance must follow treatment. A post-treatment maintenance program is accepted in theory as an essential component of current conservation methodology and practice;⁴ however, maintenance can often be technically challenging, time-consuming, and unrewarding, hence not always strictly followed.

Maintenance—also called programmed conservation—involves the ongoing care of heritage following stabilization and conservation treatment. In practical terms this includes regular inspections (monitoring) followed by operations aimed at maintaining stability and preventing (or slowing) deteriora-

tion. To be sustainable, these procedures must be simple but effective, and trained and committed personnel must be able to implement them over time.

As part of the Abomey Project, the conservation team developed long-term monitoring and maintenance protocols for the bas-reliefs to be carried out regularly by trained staff of the Historical Museum of Abomey (MHA) (fig. 6). The inspection forms were simple and consisted of checkboxes with additional space for notes and included a field indicating “actions to be taken.” These monitoring inspections were to be followed by maintenance activities involving surface cleaning, as well as repair and stabilization of damage incurred in the interim. The suggested frequency of inspections was twice a year in conjunction with the rainy seasons, when most damage was likely to occur.

Both project partners agreed that monitoring and maintenance were essential for long-term preservation of the bas-reliefs and that it was the responsibility of the Department of Cultural Patrimony of Benin (DPC) to carry it out. At the end of the project, monitoring forms were left for the regular



FIGURE 5 Most bas-reliefs in long-term storage were placed upright in rows. Individual wooden base supports, constructed locally, were fabricated to provide stability for each panel. The supports rest on metal sheeting placed over the bare floor to prevent animal and insect attack from the ground (e.g., termites). The bas-reliefs were then covered with cloth and plastic to reduce dust accumulation. Photo: Leslie Rainer. © J. Paul Getty Trust, 2006



FIGURE 6 The Beninois team members and three of the Abomey Museum staff were trained to carry out regular inspections between campaigns during the project. These inspections included not only the bas-reliefs but also the storage buildings to ensure that there was no damage due to water infiltration, animal attack, or other causes. Photo: Valerie Dorge. © J. Paul Getty Trust, 1996

periodic examination of the bas-reliefs and of the buildings containing the bas-reliefs on exhibit and in storage.

Evaluation Ten Years after Completion

Evaluation of the conservation and post-treatment maintenance of the polychrome earthen bas-reliefs at the Historical Museum and Royal Palaces of Abomey presented here is based on a site visit made by the authors in February 2006, nearly ten

years after the completion of the Abomey Project. This assessment was part of a larger evaluation of conservation activities at the Site of the Royal Palaces of Abomey organized by the World Heritage Centre and led by Lazare Eloundou Assomo.⁵

Evaluation Sources and Methods

Various sources of background material were used for the evaluation, including information from project reports, files and archives at the GCI, references furnished by CRATERRE-ENSAG, and the Documentation Center at the Royal Palaces of Abomey. Written, graphic, and photographic records from the project proved especially useful for the evaluation. The site visit to the Royal Palaces of Abomey provided the opportunity to obtain firsthand information on the condition of the bas-reliefs, the conservation facilities set up and used during the project, and related conservation activities carried out after the project. Following the project these buildings were meant to be used for further conservation activities at the site and to house bas-reliefs. The site visit also provided an excellent opportunity to interview the trainees about their experiences since completion of the work.

Conservation Treatment

During the evaluation visit, the bas-reliefs and buildings were inspected using the monitoring protocols and pro formas developed for the project. The first objective of monitoring was to detect changes that may have occurred to the bas-reliefs. To do this, it was essential to have the after-treatment photographs of each bas-relief and to examine each bas-relief closely with good illumination. This was not always possible, especially for the bas-reliefs that were tightly packed into one storage space. The lack of access and light made inspection difficult and is a hindrance when carrying out maintenance operations such as cleaning and stabilization.

In cases where changes in the condition of the bas-reliefs were observed, it was important to identify the causes so as to prevent the problem from recurring. In most cases changes consisted of significant dust accumulation, along with the presence of spider webs and animal droppings. Occasionally, new losses were observed in the paint layer and/or in the added support of the bas-reliefs both in storage and on exhibit. The assessment information was compiled in a written table illustrated by digital images of each bas-relief recording the condition at the time of evaluation.

If a change was observed we used the original before- and after-treatment graphic and photographic documentation to determine whether or not the new loss was associated with

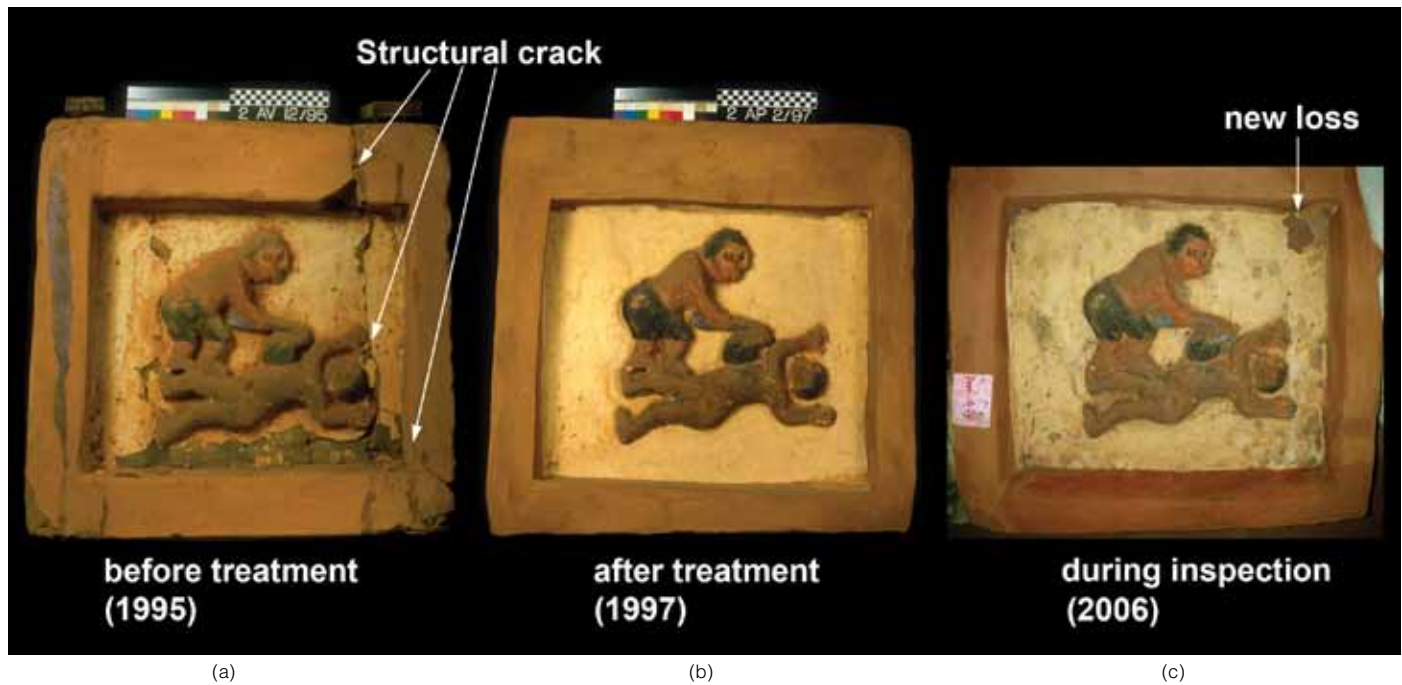


FIGURE 7 The changes observed included not only dust and dirt deposition but also loss of a portion of the background. This new loss runs along an existing structural crack that was filled and reintegrated in 1997. This bas-relief is large and heavy and is one that had been moved to a different storage location after completion of the project. It is likely that transport caused stress along the structural crack, which caused a portion of the painted background to delaminate. Photos: Susan Middleton (a, b) and Francesca Piqué (c). © J. Paul Getty Trust, 1995 (a) / 1997 (b) / 2006 (c)

a previous treatment. In most cases the new damage was not related to the previous treatment. A significant finding was that the two bas-reliefs left untreated had several new losses due to their unstable condition. Ten years later it was clear that these bas-reliefs have continued to deteriorate. Stabilization is needed to prevent further damage.

Assessment of the buildings showed some structural problems that could lead to deterioration, in particular, from infiltration of water, which would affect both the buildings and the bas-reliefs housed in them.

Almost ten years after completion of the project, damage to the bas-reliefs, which appears to be associated with their transport to other storage areas and with external, environmental factors such as humidity and animal activity, likely could have been prevented with regular monitoring and maintenance. The main points regarding the observed new deterioration are summarized below.

- Most of the structural damage associated with the cement-based added support, such as cracks and losses in the frames, is due to impact during trans-

port. After the project's completion in 1997 the museum exhibit and the storage room were not completed and the bas-reliefs were again transported after the end of the project.

- The two untreated bas-reliefs have continued to deteriorate, and there are additional loose fragments. It is advisable to stabilize these for their long-term preservation.
- Most of the bas-reliefs are stored vertically, as was recommended; however, there are three lying horizontally that have more problems associated with dust accumulation and animal activity. Bas-relief no. 2 in the storage area shows new losses in the paint layer that should be reattached to avoid further damage (fig. 7).

Monitoring and Maintenance

Inspection forms were developed for long-term monitoring and maintenance. These inspections were to be carried out biannually, followed by maintenance that included surface cleaning and repair of any damage incurred in the interim.

Unfortunately, soon after the project ended, use of these forms was discontinued because the former curator in charge of the MHA buildings thought them too repetitive, and the same conditions were found over and over. Thereafter, informal and undocumented inspections were carried out once a month but only on the bas-reliefs on exhibit. Maintenance included dusting and removal of debris, but no follow-up stabilization was carried out. The bas-reliefs in storage were not regularly inspected.

It is important to analyze this situation. Possibly the importance of monitoring and maintenance was underestimated and no personnel were available to accomplish it. Our inspection carried out ten years after completion of the project indicated that the few new losses identified could have been prevented or minimized by maintenance.

Training

During the project three conservation technicians were trained, and they participated in all aspects of the work. They acquired the skills necessary to transport and treat polychrome earthen bas-reliefs and became proficient in documentation and maintenance procedures. Since the project ended, however, they have moved on to other positions in the DPC, and only one trained conservation technician has remained at the site at any given time. Though it is encouraging that the individual trainees have been promoted, it has disrupted the continuity of knowledge gained from the project and any follow-through after its completion. The use of trained personnel is crucial for preserving the bas-reliefs over time and for ensuring that regular monitoring and maintenance are performed. Unfortunately, there is now a dearth of trained personnel to conserve these bas-reliefs, both from the Ajalala of King Glélé and from other buildings in the region.

During the project, the three technicians trained other museum personnel to carry out basic maintenance of the bas-reliefs on exhibit and in storage. This training was beneficial for the museum staff in building their competencies, although many of those who were trained have since retired and have not been replaced. In this sense the training effort was not sustainable in the long run. Training of the next generation of museum and DPC staff should have continued after the project.

Training in maintenance procedures was not very effective insofar as could be evaluated during this site visit. Minimal sweeping and dusting had been done in the exhibit gallery, and little attention had been paid to the bas-reliefs in storage. Since only one of the conservation technicians trained throughout



FIGURE 8 Following the Abomey Project, the bas-reliefs from the Ajalala of King Behanzin were conserved by the former site conservator, one of the conservation technicians trained on the Abomey Project, with assistance from local youth. The conservation of these bas-reliefs followed the approach used for the conservation of those from the Ajalala of King Glélé. Photo: Leslie Rainer. © J. Paul Getty Trust, 2006

the project has remained at the site and the second-stage trainees all left the MHA after the project was completed, there was very little continuity in the maintenance portion of the project. Due to the insufficient number of trained personnel on-site, the lack of regular, documented monitoring and maintenance has led to otherwise avoidable deterioration of the bas-reliefs and the buildings where they are stored.

Since 1997 some of the museum staff trained during the project have conserved other bas-reliefs on the site of the Royal Palaces of Abomey, from the Ajalala of King Béhanzin. This work was carefully executed following the conservation methodology developed during the Abomey Project. However, a monitoring and maintenance program is also necessary for this building and its bas-reliefs (fig. 8).

Conclusion

The February 2006 evaluation showed that the bas-reliefs from the Ajalala of King Glélé were in good condition overall, indicating that they are stable and that the conservation treatments carried out were successful. To conduct this evalu-

ation it was essential to have the conservation project records, in particular, the photographs of the bas-reliefs before and after treatment, as well as the written documentation. The project documentation allowed us to determine if the damage observed was new or related to past treatments. It is essential to carry out monitoring and maintenance with easy access to and proper illumination of the bas-reliefs.

Less satisfactory was the evaluation of the monitoring and maintenance program, which had been discontinued shortly after the end of the project. The minor damage and deterioration observed could have been prevented if regular monitoring followed by conservation maintenance had been performed.

The future looks promising. Since completion of the project a preliminary management plan has been drafted for the site. Conservation of bas-reliefs on other palace buildings is included in that plan.⁶ It will be necessary for the MHA staff to conduct regular monitoring and maintenance followed by conservation and/or stabilization treatment as necessary for the bas-reliefs from the Ajalala of King Glélé, and to ensure the preservation of the ensemble of bas-reliefs at the Royal Palaces of Abomey by dedicating human and material resources to conservation efforts at the site.

It was clear in this evaluation that training of the next generation of museum and DPC staff is crucial to the long-term preservation of the bas-reliefs, and even more so as the conservation technicians trained during the Abomey Project near retirement. Keeping in mind that these bas-reliefs have been kept inside, this experience gives a glimpse at the vital role monitoring and maintenance play in preventing or reducing deterioration. When dealing with this issue at the scale of the site and its complex earthen buildings, combined with exposure to the environment, then monitoring and maintenance is paramount.

Notes

- 1 For additional information on the project, see www.getty.edu/conservation/field_projects/abomey and F. Piqué and L. Rainer, *History Told on Walls*.
- 2 For information on the Royal Palaces and the Historical Museum of Abomey, see www.epa-prema.net/abomeyGB/history/htm.
- 3 The Royal Palaces of Abomey were removed from the List of World Heritage Sites in Danger in July 2007.
- 4 Recent conferences and research programs on the topic of monitoring and maintenance include MOMOREX (completed in 2005), which focused on acquiring useful diagnostic technologies for the identification and specification of the significant criteria for monitoring of the state of conservation of exterior painted facades; Monitoraggio e Conservazione programmata (Workshop on Monitoring and Maintenance), Turin, Italy, November 25, 2005; Managing Material Change Symposium, London, December 10–11, 2007; Monitoring of Monumental Surfaces (see www.surfacemonitor.eu/), Florence, Italy, October 27–29, 2008.
- 5 The mission is documented in the report “Mission de suivi de la décision 28 COM 15 A 14 du Comité du Patrimoine Mondial (28ième session), 11–18 février 2006.”
- 6 Plan de conservation du site des palais royaux d’Abomey, République du Bénin, UNESCO, septembre 1998.

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Conservation et pratiques traditionnelles de conservation au *na-yiri* de Kokologho

Bakonirina Rakotomamonjy et Barthélemy Kaboré

Résumé : Situé à 45 km de Ouagadougou, Burkina Faso, le *na-yiri* de Kokologho est la résidence officielle et privée du *naaba* de Kokologho. L'histoire toute particulière de ce bien a fait qu'aujourd'hui il reste encore en très bon état, alors que selon la coutume, il aurait dû être abandonné comme les centaines de *na-yiri* érigés depuis le XV^e siècle en pays moaga. Le projet de conservation et de mise en valeur du *na-yiri* de Kokologho et de ses pratiques traditionnelles, mis en œuvre dans le cadre du programme Africa 2009, a permis de développer une méthodologie et des approches sensibles aux spécificités d'un site vivant du patrimoine africain.

Abstract: Located 45 kilometers from Ouagadougou, Burkina Faso, the *na-yiri* of Kokologho is the official and private residence of the *naaba* of Kokologho. The particular history of this property explains why it is still in very good condition today, whereas in keeping with custom it should have been abandoned, as were the hundreds of *na-yiri* built since the fifteenth century in the Moaga country. The conservation project for the *na-yiri* of Kokologho and its traditional practices implemented within the framework of the Africa 2009 program has enabled the development of a methodology and of approaches that are sensitive to the specificities of a living African heritage site.

En pays moaga, tout *naaba* (chef traditionnel), se doit, à son intronisation, de construire son *na-yiri* (concession du *naaba*). En édifiant sa demeure, le *naaba* démontre non seulement son pouvoir de mobilisation des communautés impliquées dans sa construction, mais aussi bâtit les lieux clés associés aux multiples rites et coutumes qui lui permettront d'accomplir sa lourde tâche de chef traditionnel.

Situé à 45 km de Ouagadougou, le *na-yiri* de Kokologho est la résidence officielle et privée du *naaba* de Kokologho.

C'est de ce lieu qu'il joue un rôle de conseiller et de médiateur pour les 8 villages sous sa responsabilité. Depuis le XV^e siècle, des centaines de *na-yiri* ont été érigés. Mais la tradition voulant qu'ils soient abandonnés au décès du *naaba* régnant, ces patrimoines bâtis étaient voués à disparaître, avec tout ce qu'ils portaient d'histoire et de vécu. L'histoire toute particulière du *na-yiri* de Kokologho a fait qu'aujourd'hui il reste encore en très bon état, alors que selon la coutume, il aurait dû être abandonné.

Dans le cadre du programme Africa 2009 pour la conservation et la gestion du patrimoine culturel en Afrique sub-saharienne, la Direction du patrimoine culturel du Burkina Faso en collaboration avec le programme Africa 2009, a eu à travailler sur « la conservation et la mise en valeur du *na-yiri* de Kokologho et de ses pratiques traditionnelles de conservation ». En travaillant sur ce patrimoine vivant et ses pratiques traditionnelles, on aborde un système de variables dynamiques, que sont les valeurs, les usages et les pratiques. Ce système, sous influence des parties prenantes, a un fonctionnement propre qui participe de la valeur du patrimoine. Notre intervention va modifier le fonctionnement de ce système et ceci va nous amener à nous poser de nombreuses questions sur l'impact de nos actions.

Nous nous sommes posés, en particulier les deux questions suivantes :

- Si les pratiques traditionnelles doivent évoluer pour accompagner l'évolution d'un bien, faut-il les conserver et comment ?
- Comme le patrimoine évolue, comment les projets de conservation pourraient-ils aussi prendre en compte cette évolution lente, pour accompagner les parties

prenantes dans leur choix d’user ou non d’un bien ; de le conserver ou non et de lui donner ou non de la valeur ?

Intervenir sur le *na-yiri* de Kokologho, nous a appris combien il est important de comprendre le système sur lequel on intervient et de lui laisser le temps de s’approprier du projet.

Cet article porte sur :

1. Le *na-yiri* de Kokologho, patrimoine vivant évolutif ;
2. Les questions de conservation qu’il pose ;
3. Les réponses proposées ;
4. Conclusion : les points à retenir en termes d’approche et de méthodologie.

Le *na-yiri* de Kokologho, patrimoine vivant évolutif

• *Témoignage d’un métissage culturel*

Le *na-yiri* est constitué d’une part d’un bâtiment central avec cours et dépendances, le tout entouré d’un haut mur de clôture à merlons, et d’autre part, d’un ensemble de petites cases et courettes appelé cour coutumière (fig. 1). Construit en 1942, le *na-yiri* témoigne des métissages et évolutions des mœurs et coutumes engendrés par les échanges culturels liés à la période coloniale. Ainsi, malgré le plan typiquement colonial du bâtiment central (fig. 2), le *na-yiri* se conforme dans son organisation aux règles cosmogoniques *moaga* et contient les divers symboles et espaces utiles aux multiples rites et coutumes qui s’y déroulent.

C’est dans le *zaon kassinga* (la cour d’entrée officielle), que le *naaba* accueille et conseille ses sujets ; sous l’*apatam* (case semi-ouverte) que le mariage coutumier est béni par le *naaba*, et dans la cour coutumière que sont les lieux clés liées aux pratiques traditionnelles (fig. 3).

• *Des pratiques traditionnelles en évolution*

○ L’abandon des *na-yiri*

Contrairement aux coutumes, avant sa mort, le *naaba* Boulga, le constructeur du *na-yiri* de Kokologho, a souhaité que son *na-yiri* ne soit pas



FIGURE 1 Le *na-yiri*, entre tradition et modernité : les toitures des cases coutumières et le bâtiment soudano-sahélien.
Photo : T. Joffroy. © CRAterre-ENSAG

laissé en ruine. De ce fait, le *na-yiri* est aujourd’hui l’un des rares de toute la région du Boulkiemde à être en si bon état de conservation.

○ Pratiques traditionnelles de conservation

Ce *na-yiri* est l’un des seuls encore entièrement construit en terre crue et en paille (fig. 4). Conformément à la tradition et malgré la pression du modernisme et les difficultés socio-économiques, le *na-yiri* de Kokologho bénéficie encore aujourd’hui de pratiques traditionnelles de conservation.

Il s’agit entre autres :

- Des préparatifs du ran-gnoug (fête du mil rouge) pendant lesquels l’enduit des cases, la devanture et les toitures en terre sont refaites (fig. 5) ;
- Le soukpilli qui, traduit du moore, veut dire réfection des toitures en chaume des cases des coutumes. Il s’agit d’un travail collectif, réunissant l’ensemble de la population rattachée au *naaba*, soit 8 villages (fig. 6).

○ Premières conclusions

Au *na-yiri* de Kokologho, les traditions ont été tantôt respectées, tantôt modifiées, et parfois abandonnées. Mais c’est grâce à ces premières exceptions à la tradition, que soixante ans après sa construction, le *na-yiri* a pu, malgré tout, conserver sa forme d’origine, son authenticité de fonction et d’usage et reste un site vivant (fig. 7).



FIGURE 2 Le plan du *na-yiri* de Kokologho. B. Rakotomamonjy et A. Misse. © CRAterre-ENSAG



FIGURE 3 Le *naaba* de Kokologho en audience sous l'apatam. © CRAterre-ENSAG. B. Rakotomamonjy

• **Un patrimoine familial, communautaire et national**

Le *na-yiri* de Kokologho est un patrimoine familial, communautaire et national. Si le *na-yiri* est aussi bien entretenu aujourd'hui, c'est bien sûr, parce que le *naaba* Boulga a su unir la famille autour de ce bien, mais aussi grâce au soutien constant des communautés et leurs pratiques traditionnelles de conservation. Enfin, du fait de son bon état de conservation, il est inscrit depuis 2002 à l'inventaire national, et connu des visiteurs nationaux et internationaux.

De ce fait, toute décision prise sur ce patrimoine, concerne le *naaba*, sa famille, sa cour, sa communauté et l'ensemble des burkinabé.

Mais, toutes ces parties prenantes n'ont pas la même part de décision. En, effet nous ne pouvions



FIGURE 4 Les matériaux utilisés. © CRAterre-ENSAG.
B. Rakotomamonjy



FIGURE 6 Le *soukpilli*, entretien traditionnel des toitures de la cour coutumière. © Direction générale du Patrimoine culturel du Burkina Faso. B. Kaboré



FIGURE 5 L'entretien des murs avant la fête du *Ran Gnouga*.
© Direction générale du Patrimoine culturel du Burkina Faso.
B. Kaboré



FIGURE 7 La fête du *Ran Gnouga*, occasion de réunir la communauté au *na-yiri*. © CRAterre-ENSAG. B. Rakotomamonjy

pas sous-estimer l'importance qu'a ce bien pour la population de Kokologho et pour les membres de la cour des *naaba* de Kokologho, qui depuis 1942 veillent sur ce patrimoine.

Ainsi, durant toute la mise en œuvre du projet, le *naaba* n'a cessé de nous répéter que ce patrimoine était celui de la population de Kokologho, et que pour préserver les pratiques traditionnelles et sociales qui doivent s'y dérouler, il pourrait s'installer dans sa seconde résidence en béton, et ainsi changer l'authenticité d'usage de l'actuel *na-yiri*.

Le *na-yiri* de Kokologho est un patrimoine vivant, qui évolue dans sa patrimonialité, et ceci en fonction de la valeur qu'un ou plusieurs individus lui assignent et des usages et pratiques qui s'y déroulent.

A Kokologho, la « non-pratique » d'une tradition, en l'occurrence celle de l'abandon des *na-yiri*, a conféré à ce dernier une valeur toute particulière et a permis à d'autres pratiques – telles que les pratiques de conservation traditionnelles, de se poursuivre avec vigueur.

Questions de conservation du bien

Les différentes exceptions à la tradition mise en place par le *naaba* Boulga ont eu des influences sur le bien et sa conservation jusqu'à nos jours, comme le montre notre analyse diagnostique détaillée.

- **La toiture : Quand les pratiques traditionnelles ne correspondent plus à l'usage du bien**

Les travaux de rénovation de la toiture (rajout de couche de terre) ne devaient traditionnellement se poursuivre si longtemps. En prolongeant la vie de ce bâtiment et en poursuivant ces pratiques telles qu'auparavant, le *naaba* risquait de mettre en péril le bâtiment. En effet, les couches de terre après plus d'une cinquantaine d'année de pratiques traditionnelles, ont fini par constituer une couche de près de 80 cm d'épaisseur pesant lourdement sur les poutres de bois ; des fissures sont alors apparues.

Pour remédier à ces fissures, le premier réflexe a été de recourir à un enduit de béton, qui n'a fait qu'aggraver la situation, en empêchant cette importante couche de terre de respirer et d'évacuer sur



FIGURE 8 Les femmes chargées de l'entretien des sols en terre battue. © CRAterre-ENSAG. T. Joffroy

l'ensemble de sa surface l'eau qu'elle absorbait en quelques points précis.

Face à ce problème, comment fallait-il réagir ? Fallait-il poursuivre ces pratiques traditionnelles au détriment de la stabilité structurelle du bien ? Ou bien, fallait-il y mettre fin au risque de perdre avec elles le sens social qu'elles incarnaient (fig. 8) ?

- **Les cases coutumières : Quand les pratiques traditionnelles ne correspondent plus à l'usage du bien**

Au cœur de la tradition, les cases coutumières sont sacrées. Toutefois, leur conservation est difficile car seules les anciennes femmes du *naaba* sont habilitées à y coordonner les travaux de réfection des enduits, et elles seules peuvent y résider. Ou, les *naaba* de Kokologho depuis un peu moins d'un demi-siècle sont monogames et, de ce fait, les anciennes femmes de *naaba* sont de moins en moins nombreuses.

Se pose alors pour le *naaba* et sa cour, la question de la conservation de la cour coutumière et de son usage. Comment conserver, et pour qui ?

Bien que le *na-yiri* soit un patrimoine privé, c'est aussi un bien communautaire dont la gestion et la conservation sont régies par des règlements dictés par un conseil de sages qui accompagne et guide le *naaba*. Avant-gardiste, le *naaba* a évoqué auprès de

ses conseillers la possibilité de réaménager ces cases en chambres d'hôtes, de les faire visiter, ou d'autres solutions. Pour l'instant, cela semble impossible aux sages.

Face à ce problème de conservation de la composante la plus sacrée du *na-yiri*, comment projeter nos actions de conservation ? Faudrait-il proposer un enduit stabilisé plus durable ? Dans quelle mesure ces actions vont-elles interférer avec les responsabilités des personnes traditionnellement en charge ?

- **Quand les pratiques traditionnelles sont essentielles dans la préservation de la cohésion sociale, mais ne sont plus socio-économiquement viables**

Les pratiques traditionnelles de conservation du *na-yiri* donnent lieu à des festivités qui renforcent la cohésion sociale, mais l'évolution sociale et le contexte économique actuel en rendent la poursuite difficile ; les matériaux se raréfiant et devenant de plus en plus coûteux et la main-d'œuvre de plus en plus précieuse et difficile à mobiliser autour de travaux manuels pénibles tels que le puisage de l'eau à plusieurs kilomètres du site.

Face à cette carence de matériaux ne faudrait-il pas remplacer les matériaux nécessitant un entretien important par des matériaux dits plus durables ?

Confronté à ces questions de conservation et en attendant d'autres opportunités que le projet pourrait éventuellement offrir, le *naaba* a opté pour différentes solutions visant à préserver certains aspects immatériels liés au site.

Pour le bâtiment colonial, il a opté pour un renforcement des enduits avec un enduit stabilisé au bitume, effectué par une entreprise de la région, à renouveler tous les cinq ans. Parallèlement, les pratiques traditionnelles annuelles ont été maintenues pour de petites réparations, l'objectif étant de perpétuer la rencontre, l'échange et la participation de la population.

Quant à la manifestation du *soukpilli*, la pratique a été maintenue sans changements.

- **Premières conclusions**

Pour assurer la conservation du *na-yiri* et de ses pratiques traditionnelles, il était essentiel de comprendre :

- que les pratiques évoluent ;
- que la documentation permettrait de garder une mémoire de ces pratiques traditionnelles à un temps donné ;
- qu'il était important d'effectuer un suivi de ces pratiques pour étudier leur impact sur le bien ;
- que la conservation des pratiques traditionnelles doit correspondre aux usages du bien, et que leur maintien à tout prix peut parfois être inutile ;
- que toute réponse doit préserver les aspects intangibles du site et le maintien de la cohésion sociale autour du bien.

Les réponses proposées

Ayant appréhendé ce contexte dynamique, il fallait résoudre les questions d'ordre technique et financier auxquelles doit répondre le *naaba* pour conserver le *na-yiri*.

- **Approche et méthode**

Les projets de conservation sont souvent ponctuels par rapport à la durée de vie d'un bien. Ils se confrontent ou s'ordonnent dans un système complexe de variables qui constituent l'environnement du bien (sages, valeurs, pratiques et acteurs concernés).

Dans le cadre de la « conservation et la mise en valeur du *na-yiri* de Kokologho et de ces pratiques traditionnelles de conservation », et considérant le caractère vivant et dynamique du bien, nous avons choisi de mettre en place un projet de conservation qui accompagne l'évolution du patrimoine. Ce projet vise à outiller et renforcer les acteurs concernés, et à leur proposer des possibilités de développement à saisir s'ils les estiment conformes à leurs besoins.

La méthode choisie pour intervenir au *na-yiri* a été de mettre l'accent sur la concertation, seul moyen de comprendre et d'accompagner l'évolution du bien.

- **Activités mises en œuvre**

Face à ce patrimoine vivant en constante évolution, les activités choisies visaient essentiellement à faciliter le fonctionnement du *na-yiri*, dans le respect d'une tradition également évolutive.

De ce fait les activités mises en œuvre ont consisté à :

- documenter le bien et les pratiques traditionnelles qui s'y déroulent ;
- effectuer un suivi rétrospectif, afin de comprendre comment ces pratiques ont pu influencer sur le bien ;
- mettre en œuvre des travaux structurels d'urgence sur la toiture, car ces interventions allaient au-delà des prérogatives des pratiques de conservation traditionnelles et dépassaient les moyens techniques et financiers du *naaba*. Ainsi, le projet a permis de diagnostiquer les problèmes, réparer les bâtiments, et sensibiliser la population à de nouvelles techniques d'entretien de ceux-ci ;
- répondre aux besoins financiers en rédigeant une brochure promotionnelle et en ouvrant une partie du site au public, et ceci dans le respect de son usage traditionnel ;
- répondre aux besoins techniques en testant des enduits stabilisés avec la population chargée de l'entretien ;
- faciliter les travaux de conservation traditionnelle en installant un puits (pour disposer d'eau pour les travaux et pour les populations environnantes), ainsi que des panneaux solaires permettant de poursuivre les festivités traditionnelles toute la nuit, en éclairant la résidence du *naaba*, ainsi que l'espace et la communauté aux abords du site.

Conclusion : Les points à retenir en termes d'approche et de méthodologie

- Travailler sur un tel site est un questionnement permanent, qui remet en question les *a priori* de tout conservateur, et qui permet de rester à l'écoute des premiers bénéficiaires concernés.
- La documentation des pratiques traditionnelles effectuée sans suivi tend à figer ces pratiques, alors qu'il est primordial d'en comprendre l'évolution.
- Il est essentiel de prendre le temps d'expliquer en concertation l'impact d'un choix de projet sur les aspects tangibles et intangibles du bien.
- Il faudrait savoir harmoniser le calendrier du technicien avec le calendrier traditionnel qui exige de longues phases de concertation et de réflexion. Dans ce cas particulier, il faut rappeler que le chef ne prend jamais ses décisions seul, mais avec l'appui de ses conseillers et de sa population. Cette concertation peut prendre un mois ou parfois plus, voire un temps indéfini, selon la complexité du projet.
- Enfin, face à un chef traditionnel, il convient d'être assez diplomate pour engager des concertations avec une personne qui n'a pas l'habitude qu'on remette son jugement en question.

La planification de la conservation du patrimoine bâti en terre : Le cas des mosquées en terre de Côte d'Ivoire

Koffi Tizie Bi

Résumé : *La Côte d'Ivoire abrite de nombreuses mosquées en terre datant du XV^e siècle. Le matériau utilisé, leur âge et leur signification culturelle font d'elles des monuments importants. Leur état actuel reste toutefois alarmant du fait du relatif désintérêt des populations, du mauvais entretien et des dégradations dues à des interventions inappropriées.*

Ces mosquées centenaires risquent de disparaître. De la centaine de ces monuments qui existaient dans les années 20, il ne reste qu'une vingtaine. Un plan de gestion et de conservation pour ces mosquées a été établi. Il faudra parvenir à un consensus sur le travail de conservation de ce qui reste de ces monuments.

Abstract: *Ivory Coast has many earthen mosques dating to the fifteenth century. They are important monuments because of their age, their cultural significance, and the fact that they are made of earth. Yet their condition is alarming due to the neglect of the population, poor maintenance, and degradation as a result of inappropriate interventions. There is a risk that these several-hundred-year-old mosques may be lost. Of the hundred mosques that existed in 1920, only twenty or so remain. A management and conservation plan for the mosques has been drawn up. A consensus should be reached on the work to conserve what remains of these monuments.*

Les mosquées anciennes en terre ont été introduites en Côte d'Ivoire par les populations mandingues à partir du XV^e siècle, grâce à l'action de l'empereur Kankan Moussa qui a favorisé le développement de cette architecture en Afrique de l'Ouest. La fonction sociale, la période d'implantation et le matériau de construction donnent à ces mosquées une

dimension patrimoniale qui intéresse particulièrement les professionnels du patrimoine et les communautés locales.

La situation de ces mosquées reste toutefois très alarmante. Un relatif désintérêt s'installe : elles sont de moins en moins utilisées car la communauté préfère désormais les mosquées de type moderne. Ces mosquées centenaires, lieu d'enseignement et de transmission du savoir depuis des décennies, risquent de disparaître. Elles se dégradent car elles ne sont pas entretenues comme il convient. De la centaine de mosquées anciennes qui subsistaient dans les années vingt, il ne reste qu'une vingtaine, d'où la proposition d'un plan de sauvegarde de ces constructions en terre.

Après avoir décrit les mosquées en terre de Côte d'Ivoire, l'exposé portera sur leurs caractéristiques et leur signification culturelle, les méthodes de conservation traditionnelle, et finalement des propositions de plan de conservation de ces œuvres ancestrales.

Situation des mosquées anciennes de Côte d'Ivoire

Les mosquées en terre de Côte d'Ivoire sont situées dans la partie septentrionale du pays, comme le montre la carte ci-après (fig. 1).

Description des mosquées en terre

Les mosquées en terre sont généralement de style soudanais qui se caractérise par un toit plat ou toit terrasse auquel on accède par au moins un ou deux escaliers. Elles présentent une diversité de formes. Toutefois, elles comportent



FIGURE 1 Carte des mosquées anciennes de Côte d'Ivoire.
Ministère de la Culture et de la Francophonie, Direction du
Patrimoine culturel, République de Côte d'Ivoire

une constante qui permet d'établir un schéma commun. Généralement construits sur un plan rectangulaire, ces édifices religieux ont une structure compacte avec des pilastres et des tours pyramidales. Les mosquées soudanaises sont principalement composées d'une salle de prière au centre, à laquelle est adjoint le mihrab situé dans la tour du minaret. Les mosquées anciennes furent édifiées manuellement sans utilisation des matériaux et matériels (équerre, truelle, fil à plomb) modernes de construction.

Le matériau de construction des mosquées est essentiellement la terre. Cette terre à base d'argile est imbibée d'eau. On y ajoute des fibres, de la paille et différents produits naturels – comme le beurre de karité – pour en augmenter la plasticité, l'imperméabilité et l'adhérence. On mélange le tout pour obtenir une pâte appelée *banco*. La construction des murs avec ce matériau obéit à trois techniques principa-

les : le pisé, l'adobe et la bauge. Le mur est enduit de la même pâte, qui sert également de jointolement. Outre les murs, la toiture (toit-terrasse) est également à base de terre. Le toit lui-même est entouré de garde-corps munis de gargouilles en terre cuite. La construction est constituée en grande majorité du matériau terre. Toutefois, le bois est aussi utilisé en proportion limitée, afin de soutenir les parties de l'édifice les plus contraintes aux efforts de traction. Des pièces de bois sont fichées sur toute la surface des murs. Certaines renforcent l'édifice en terre, tandis que d'autres servent à faciliter l'accès aux différentes parties de l'édifice lors de son entretien, tout en présentant un bel effet décoratif.

Fonctions, signification culturelle et authenticité des mosquées en terre

Les fonctions des mosquées

Les mosquées en terre de la Côte d'Ivoire, de style sahélo soudanais, ont d'abord une valeur historique car elles ont été introduites en Côte d'Ivoire aux environs du XV^e siècle et furent le lieu de prière de certaines personnalités historiques comme le grand guerrier Samory Touré. Ensuite, elles prennent une valeur religieuse en tant que lieu de culte des fidèles musulmans. Ces mosquées constituent une véritable institution de régulation sociale. Elles servent de lieu d'annonces publiques et de règlement des problèmes d'intérêt communautaire. Les mariages et les baptêmes y sont célébrés. Leur entretien donne lieu à un évènement, ce qui renforce les liens de fraternité entre les membres de la communauté locale.

La signification culturelle des mosquées

Les mosquées anciennes, du fait de leur implantation uniquement au nord de la Côte d'Ivoire, témoignent de la pénétration de l'islam par cette zone. Construire ces mosquées sans angles droits et les voir résister au vent est la preuve qu'il a été fait appel à de véritables connaissances et savoir-faire techniques, notamment en matière d'orientation. Bien qu'importé, le mode de construction des mosquées anciennes est le plus souvent inspiré de la culture constructive des localités d'implantation. Ceci explique leur appropriation et leur adaptation à un climat plus humide, par comparaison avec les mosquées soudanaises du delta du Niger, milieu plus sec. Une corporation de bâtisseurs de mosquées en terre a vu le jour. Leur technique et leur force mystique les rendent incontournables. La plupart des musulmans sont convaincus que les vœux exprimés dans ces mosquées anciennes sont souvent exaucés.

L'authenticité des mosquées

Les mosquées en terre de Côte d'Ivoire conservent généralement leur authenticité de fonction et d'usage. Toutes, même celles qui sont à l'abandon, ont gardé leur structure d'ensemble et sont considérées comme des lieux de culte et de socialisation. Elles sont comparables à celles de Djenné, Sankoré et Gao (Mali). Toutefois, les édifices religieux en terre de Côte d'Ivoire, à la fois inspirés de l'architecture locale et adaptés au climat pluvieux ont un caractère unique.

La conservation traditionnelle des mosquées en terre de Côte d'Ivoire

Toute œuvre humaine a une durée de vie limitée dans le temps, à l'image de l'homme lui-même. Si l'être humain suit des traitements pour prolonger son espérance de vie, il en va de même pour sa création architecturale. Avant d'aborder la méthode de conservation traditionnelle appliquée aux mosquées en terre, ayons d'abord une idée sur leur statut. Ce sont des biens communautaires ou des constructions familiales. Ainsi, par exemple, les mosquées de Tiéningboué et Nambira appartiennent à la communauté villageoise. Celles de Tingréla et M'bengué sont l'œuvre respective de la famille Cissé et de la famille Konaté. Quoi qu'il en soit, les travaux d'entretien suivent la même démarche, étant donné que traditionnellement, ce qui appartient à un individu se partage avec plusieurs personnes. Un dicton ivoirien ne dit-il pas que l'éléphant tué par un individu se partage avec tout le monde !

Les travaux d'entretien sont effectués chaque année avant la saison pluviale, de manière préventive ou après celle-ci, en vue de réparer les dommages causés par les pluies. Le moment venu, l'imam de la mosquée lance un appel aux fidèles le jour de la forte audience. Dès lors, chaque fidèle, considérant le travail sur les mosquées comme une quasi-obligation religieuse et sociale, apporte sa contribution en nature (matériaux) ou en espèces. Dès que tous les matériaux sont réunis, y compris le banco qu'on fait macérer pendant plusieurs jours avant l'emploi, l'annonce du jour des travaux se fait un vendredi par le même iman. On passe alors à l'exécution le dimanche qui suit, dans une ambiance chaleureuse, avec la participation des hommes, des femmes et des enfants sous la conduite des maîtres maçons et le regard vigilant des personnes âgées. Se retrouver, communier, tisser des liens de fraternité, se réjouir et apprendre en travaillant, voilà quelques uns des avantages qu'apporte l'entretien des mosquées à toute une communauté. Cet entretien augmente l'espérance de vie de ces mosquées et constitue la véritable efficacité de

la conservation traditionnelle, qui demande à être perpétuée d'autant plus que nous avons le devoir de transmettre cette architecture de terre aux générations futures en veillant à ne pas en altérer la forme ni la substance.

Malheureusement, actuellement, les travaux d'entretien sont menacés. Ils ne se déroulent plus automatiquement tous les ans. Même s'ils le sont, les résultats ne sont pas toujours satisfaisants en raison d'interventions empiriques. Toutes sortes de matériaux inadaptés et inattendus comme le goudron, le papier d'aluminium, le ciment et autres les dénaturent fortement. La communauté musulmane préfère maintenant les mosquées de type moderne construites à proximité des mosquées anciennes. Celles-ci sont plus fréquentées ou deviennent même le lieu exclusif de culte au détriment des anciens édifices. Toutefois, il ne faudrait pas penser que la communauté détentrice veut se détourner définitivement de ses sites religieux séculaires. Ces mosquées en terre demeurent la création de ses ancêtres. L'ambivalence dans le comportement des populations concernées s'explique également par le fait que la dimension immatérielle de ces lieux de culte l'emporte sur la présence physique des bâtiments, c'est-à-dire que, même dans un état de conservation précaire, un bien ayant une forte portée sacrée ou culturelle, présente un degré d'authenticité aux yeux de la communauté détentrice. Aussi, en ruine ou en bon état, il reste vivant dans les esprits. Il convient donc de prendre des mesures de conservation actuelles en conformité avec les méthodes anciennes, afin de préserver non seulement un patrimoine national mais surtout à répondre aux besoins de la communauté locale qui s'efforce de sauver son patrimoine avec des moyens limités.

Le plan de sauvegarde des mosquées en terre de Côte d'Ivoire

La conservation repose sur la gestion participative, suite d'actions cycliques qu'il s'agit d'abord de classer par priorité en fonction de l'urgence de la tâche à mener et de la disponibilité des moyens. Notons que la première des priorités est la formation d'une équipe de travail.

Le comité de gestion

Le comité de gestion des mosquées anciennes de Côte d'Ivoire n'existe pas encore. Les parties prenantes seront identifiées, encouragées, soutenues et informées sur les valeurs des mosquées en terre par une action de sensibilisation et des réunions et séances de travail. Il sera créé à cet effet une antenne spéciale *in situ* avec les objectifs suivants :

- faire comprendre les points forts, les problèmes, les menaces, les chances qu'offrent ces sites ;
- énoncer une vision partagée de ces mosquées centenaires, pour en planifier le développement.

La documentation

Son rôle est double. Elle révèle les secrets d'un site culturel, ainsi que les facteurs de dégradation et leur degré de nuisance. En tout état de cause, la documentation est une activité très importante en matière de conservation. Sans elle, les sites sont menacés d'oubli. Tout cela exige un immense travail. Cependant, aucune base de données n'existe au Ministère de la Culture et de la Francophonie. Les photographies, films, croquis, dessins, rapports techniques, résultats d'enquêtes, articles de presse, plaquettes, mémoires et autres documents sur les mosquées en terre sont éparpillés en divers endroits. Pour y remédier, il faudrait créer un Centre de documentation digne de ce nom et réserver un rayon spécial aux mosquées anciennes de Côte d'Ivoire. Il importe aussi de poursuivre la documentation car cette activité n'est jamais définitive.

La conservation préventive

Sans véritablement mettre en cause le mode de conservation traditionnelle, il est cependant, aujourd'hui plus que nécessaire de privilégier la conservation préventive pour ces mosquées. Du fait de sa régularité, elle présente l'avantage de faire engager peu de moyens et de minimiser le coût des travaux. On peut ainsi la résumer :

- textes réglementaires de protection ;
- inspections régulières ;
- travaux de conservation préventive (désherbage, drainage, réparations provisoires ou définitives, clôtures et autres).

La plantation d'arbres

L'essence qui entre dans la construction des mosquées est très résistante et transcende le temps. En prévision des futurs besoins, un programme de plantation de ces espèces doit être lancé dans les localités d'implantation des mosquées en terre à l'instar de la décision prise par le comité de gestion du Tombeau des Askia à Gao au Mali.

La réutilisation des mosquées en terre

Une des conditions de la sauvegarde du patrimoine, notamment, des mosquées du Nord de la Côte d'Ivoire est de les adapter aux exigences de la vie de la communauté. Ces mosquées ne répondant plus totalement aux besoins de la population du fait de leur exigüité, il convient de leur trouver une nouvelle affectation tout en créant des activités économiques. On peut ainsi en faire des centres de vente et de lecture des ouvrages islamiques.

Conclusion

La conservation des mosquées anciennes passe aussi bien par le maintien des mécanismes traditionnels de gestion que par les nouvelles méthodes développées par les conservateurs. Cependant, trois principes fondamentaux sont à retenir. Ils consistent d'abord à privilégier les intérêts communs des parties prenantes, ensuite à créer un consensus autour de ces biens et enfin à travailler ensemble pour sauvegarder ce qui reste de cette architecture de terre au moins centenaire. En tout état de cause, l'accent doit être mis sur la gestion participative.

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PART THREE

**Local Knowledge Systems
and Intangible Aspects of
Earthen Architecture**

**Les savoirs locaux et les
aspects immatériels de
l'architecture de terre**

Mitigating Threats to Local Knowledge Embedded in Earthen Architecture: The Case of Preserving African Architectural Semiotics

Allan Kenneth Birabi and Barnabas Nawangwe

Abstract: *Earthen architecture remains the most common housing mode among Africa's habitations, containing powerful semiotics expressing vibrant local knowledge systems. Local earthen architecture is the encyclopedic deposit of these priceless knowledge systems that have supported the dying oral traditions inherited by successive generations. Qualitatively, this paper illuminates knowledge systems embedded in earthen architecture with selected examples of renowned cultural landscapes in the context of African architectural semiotics and advocates for their preservation and continuity.*

Résumé : *L'architecture de terre demeure le mode d'habitat le plus répandu en Afrique et comporte une grande puissance sémiotique et des systèmes vibrants et exubérants de connaissances locales. L'architecture de terre locale est le témoignage encyclopédique de ces précieux systèmes de savoirs ayant soutenu les traditions orales en disparition par lesquelles elles ont été transmises de génération en génération. Cette communication cherche à mettre la lumière sur les systèmes de savoirs que referme l'architecture de terre à l'aide d'exemples choisis de paysages culturels connus dans le contexte de la sémiotique architecturale africaine et plaide en faveur de leur préservation et leur pérennité.*

For centuries earthen architecture has remained the most common mode of housing among Africa's urban and rural populations. Consequently, vibrant indigenous knowledge systems and other varied heritage values have become part of the living traditions of Africa's human habitations. The local earthen architecture is the encyclopedic deposit of these priceless knowledge systems, supporting the dying oral traditions

through which they were inherited by successive generations. Alongside this, petroglyphs, rock art, textiles, ceremonial objects, tattoos, masks, legends, fables, metaphors, and proverbs provide artisanal, symbolic, mythologic, magical, metaphoric, proverbial, and poetic representations of these knowledge systems (Hamel 2004). As such, they also communicate ideas about the cosmos, society, religious beliefs, wisdom, and politics. However, it is in African earthen architecture that these knowledge bases have best been preserved and celebrated in tangible fusion with the continent's civilizations. These knowledge bases are best categorized as African architectural semiotics, a humanistic embodiment of planning, designing, and creating architecture that radiates messages.

Architectural semiotics is an artistic and imaginative language authoritative in the psychologies of perception and architectural creation, poetry and music, content and meaning. It also denotes an organic social science articulating the fields of linguistics and arts, psychology, information theory, visual communication, rhetoric, and symbolism of form and "visual poetry." This art occupies little space in the proliferating earthen architecture of today, and yet the continent's surviving historic architectural landscapes exhibit civilizations that were sophisticated in architectural semiotics.

These semiotic representations prevail as decorative embellishments of people's homes, spaces in which they live, work, play, and worship, and as powerful venues for communication. Indeed, these semiotics help transform and fuse space with the sense of place. Semiotics intimately enriches spaces and connects them to the human body; to notions of gender and identity; to religious beliefs and practices; to expressions of power and resistance and social, political, and cultural identity; and to aesthetic concepts and the living arts.

Today, however, the production, sustenance, and appreciation of African architectural semiotics have declined. This is in part because the conservation of earthen architecture has been sluggish, which has catalyzed the varied threats against attendant architectural semiotics. Subsequently, the role played by architectural semiotics and attendant knowledge bases in the conception of reality among African communities has also diminished, which requires urgent reversal, as we argue in this paper. First, however, an appraisal of surviving examples of this heritage is informative regarding the character, technical, and aesthetic wealth of African architectural semiotics.

The Nature of Architectural Semiotics Latent in African Earthen Architecture

In their rich varieties of time and place African architectural semiotics have operated as a means of imprinting a sign system stemming from the shared interpretations of the society within which they have been produced. Ordinary people, gifted craftsmen, and professional and self-taught native architects are party to the organic evolution of imprinting attendant meaning (Bauer and Preucel 2000).

African architectural semiotics may have been influenced by cicatrization and painting of designs on the human body with the juices of plants and chalk, or ocher, which was fashionable among various African communities for enhancement of especially feminine bodily beauty. Some tribal groups did simple rows of parallel scars or tattoos, and others produced highly elaborate and beautiful abstract patterns (Trowell 1960). Both abstract designs and stylized forms were cut on various parts of the body. This aesthetic legacy finds parallel application to their earthen habitations. This influence propagated a refined decoration heritage on built heritage ensembles, which dot renowned African cultural landscapes (Moustafa 1988). Superb examples of attendant architectural semiotics can be found on walls, windows, gates, and the layout of compounds.

These semiotics still prevail in some landscapes of former imperial Africa, which developed along the great Sahel (Corridor), an ancient trade route between East and West Africa. The semiotics are well developed, for instance, among the fortified houses of the Gurunsi (Kassena) tribe in the Tiebélé region bordering Burkina Faso and Ghana (fig. 1). Among the Gurunsi, it is the women who create the beautiful fresco semiotics that decorate the walls of their mud huts, whose functional lines inspired the renowned Swiss architect Corbusier. Similar accomplishments by women are also found



FIGURE 1 Richly frescoed walls of Gurunsi earthen architecture.
Photo: Sébastien Moriset, CRATerre-ENSAG

in the ancient desert town of Walata, among Mauritania's oldest cities. The city center of Walata, which formed part of the ancient empire of Ghana, was inscribed on UNESCO's World Heritage List in 1996. The local adobe architecture is exceptional, and the semiotic mural decoration is reminiscent of the local traditions that make Walata city stand out.

However, a more elaborate semiotic symbolism and decoration rooted in the earthen architectural legacy is echoed in Akan architecture, in Ghana (fig. 2). In addition to its elaborateness in terms of function and building technology, Akan architecture is a reflection of native architectural forms and design principles and an embodiment of the spirit of independence of these Ghanaian people. In this regard the Akan use architectural semiotics and symbolism to portray their beliefs about, relation to, and attitudes toward God and his creation. These symbols are used as bas-reliefs or plinths, banisters, and walls in their architecture.



FIGURE 2 An example of an Akan domestic dwelling enhanced with high-relief sculptural semiotics. Photo: Bakorina Rakotomamonjy, CRATerre-ENSAG

A case comparable to Akan semiotics is that of ancient Egypt, which drew from both the animal and plant kingdoms to give life to its architectural legacy. Though stonework was dominant, some earthen structures still survive. The lion, the cow, the ram, the falcon, the snake, and the crocodile and flora such as lotus buds were important symbols in the ancient architectural semiotics of Egypt. A large number of Egyptian architectural semiotics were also connected to the human body. Multiple combinations of these botanical, zoological, and humanistic representations are evident in some of the large-scale temples built of sun-dried mud bricks.

Another cradle of semiotics is Upper Nubia in Sudan, stretching between the Nile's Second Cataract close to the Egyptian border and the river's extraordinary S-curve some 350 kilometers to the south. In the former Nubia Kingdom, the people have maintained their linguistic and architectural identity (Werner 2006).

A typical Nubian house is richly decorated on both the exterior and the interior. The doors are flamboyantly garlanded with vibrant colors, adobe brick filigree, and figurative and geometric semiotics in mud and/or white lime-plaster relief. The walls are decorated with motifs depicting objects such as ceramic plates, automobile headlights, mirrors, cow horns, and dried crocodiles. Most of the Nubian architectural semiotics are attributed to Ahmad Batoul, a twentieth-century builder-artist whose iconography has transformed traditional semiotic artistry (Werner 2006). While the full range of these semiotic expressions has diminished in recent

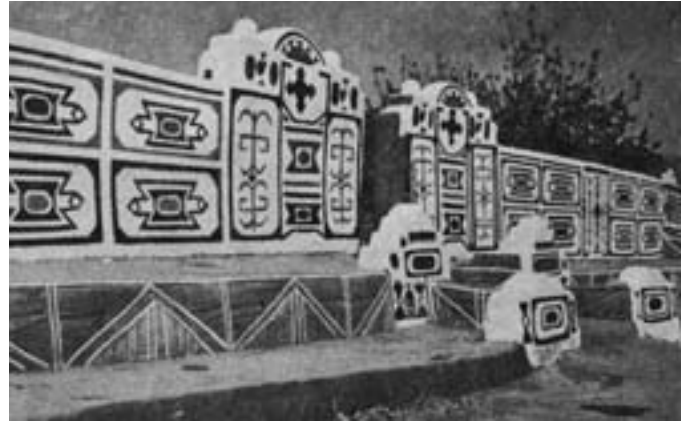


FIGURE 3 Spectacular patterned geometric semiotics adorning the wall enclosure of a Ndebele homestead. Photo: J. L. Moss

years, the impulse to draw attention to one's home, and to its doorway as a symbol of the family, remains strong.

Though not part of imperial Africa, South Africa's Ndebele tribeswomen have become world renowned for the vivid designs originally produced for the walls of their homesteads (fig. 3). Passed down from generation to generation, the patterns often feature brilliant colors and strong geometric expressions, and most of them are also combined with native Ndebele beadwork. Using brushes made of bundled twigs and feathers, the women choose bright pigments, which they combine with traditional cow dung, pigments, clays, and contemporary acrylics. The designs are broadly abstract and represent the tastes and talents of their creators.

This cultural legacy of African architectural semiotics remains vibrant in Nigeria as well. A number of Nigerian tribes combine religious and cultural expression in relief wall panels, motif production, ornamentation, decoration, pattern work, and monumentalism.

This conference pays homage to the great earthen architecture of Mali, our host nation. However, it does no harm to mention the magnificence and grand nature of this architecture exemplified by the Great Mosque in Djenné, one of the largest mud-brick buildings in the world and a World Heritage Site since 1998 (fig. 4). Whereas the walls of the Great Mosque are without elaborate symbols or motifs, its organic form is punctuated with wooden toron spikes used for scaffolding during the yearly process of resurfacing. Yet a plain semiotic language of unique local mosque architecture can be attributed to these toron spikes.



FIGURE 4 The Great Mosque of Djenné. Photo: Arlen Heginbotham

It is evident that African architectural semiotics are well informed by the African genius for artistic, decorative, proverbial, poetic, metaphoric, sentimental, and philosophical communication. They are attempts at continuity of this endowment to match contemporary tastes. Brilliant exterior wall painting combines the intricacies of individual artistic expression with traditional architectural forms. Influences have spread to modern building materials, styles, and techniques.

Threats to Indigenous Knowledge Systems in Earthen Architecture

Despite the impressive array of architectural semiotic heritage, African earthen architecture-driven semiotics are no longer as potent as they once were. This rich heritage has fallen prey to various degrees of obsolescence associated with globalization, eroded artisanal craft skills, changes in cultural tastes and preferences, and so on. These varied dimensions of obsolescence are unsympathetic to encyclopedic cropping of attendant knowledge systems by earthen architecture. Earthen architecture can be compared to some given knowledge bearer. In many indigenous African communities, when a knowledge bearer dies, his knowledge dies with him. Similarly, earthen

architecture is dying with the indigenous knowledge systems it bears.

Indeed, much of this African architectural semiotic language is fading because it appears worthless to new generations. Earthen architecture, the very canvas for these semiotics, is considered primitive, backward, or old-fashioned. Among the contemporary black African elite class, it is ridiculed further as archaic, dirty, inferior, or degrading to live in. The trickle-down effect on peasants is more than can be imagined: diminished pride and heightened social prejudice against this material heritage. It is often wrongly undervalued in view of the cosmetic Eurocentric architectural legacies.

Furthermore, architectural education in most African schools of architecture is an unimaginative imitation of European models. Without demeaning in any way the valuable inspiration received from these models, African design skills, philosophies, ethics, and aesthetics are not adequately integrated into the curricula. In addition, most African governments have had little or no interest in the promulgation of earthen architecture projects. Yet in past traditional societies this material heritage proved effective in sustaining societies and the status quo. Regrettably, lost knowledge leads to intergenerational discontinuities and development failures

that are quite vivid today in Africa. Such a trend represents community loss. The conservation of earthen architecture would not only preserve a page of African history and cultural tradition but also make possible the contemporary use of a heritage treasure trove.

Not Too Late

We do not intend to suggest that African earthen architecture and its legacy of embedded knowledge systems are completely doomed. An effort could be made to rejuvenate some of this knowledge where artisanal, technical, sociocultural, ethnographic, and political continuities are desirable. There is a need for identifying, taking stock of, recording, describing, testing, analyzing, validating, codifying, protecting, and exploiting this ancient knowledge to the fullest extent possible. This is a task that can be embraced by a collaborative effort among social scientists, artists/artisans, museologists, conservators, and architecture academics and their schools of architecture. Therefore, by means of practical projects, African architectural knowledge gurus need to work toward incorporating knowledge of African architectural semiotics and decorative building crafts into the African architectural education enterprise.

In addition, cultural departments of governments and all other stakeholders can endeavor to set up museums and galleries that propagate earthen architecture and related semiotics. Although money for such projects is scarce, it is a worthy cause to extend the call to charitable organizations to support this undertaking.

Finally, there is a need to eliminate the prejudice against these knowledge systems and reinvigorate interest among the African people about them. Africa should not regard its building crafts and related knowledge systems as omnipotent, but it should reduce its reliance on Western architectural design values, aesthetics, idioms, and philosophies that may be irrelevant or redundant in African contexts. Concomitantly, African architectural design values should be promoted.

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Earthen Architecture in Indian Tribes

Om Prakash Joshi

Abstract: India has 461 tribes, and most of the tribal communities construct their houses themselves. The main materials used for house construction are earth, bamboo splits, dung, and straw or husk. Planning of the house is done with the help of senior leaders. Women do most of the preparatory labor, such as preparing walls of bamboo splits and mixing the materials for mud, and men do the technical work of house building. This paper presents three examples of building with earth by different tribes in India.

Résumé : Il existe 461 tribus en Inde et la plupart des communautés tribales construisent elles-mêmes leurs maisons. Les principaux matériaux de construction utilisés sont la terre, le bambou, le fumier, et la paille ou les écorces. Le plan de la maison est dessiné avec l'aide des anciens. Les femmes participent à la construction et préparent l'ossature en bambou et la boue en mélangeant de la terre, du fumier, des écorces ou de la paille et de l'eau. Ce sont les femmes qui effectuent la plupart des travaux de préparation, tandis que les hommes font le travail technique de construction. Cette communication présente trois exemples de construction en terre par différentes tribus indiennes.

Primitive architecture has not generated much interest among anthropologists and architects around the world. This may be because its form is usually very simple and unadorned and because this work is inaccessible; for example, it can seldom be viewed in museums, as is possible with other art forms. To some extent the explanation also lies in the lack of concern with folk architecture among the former colonial powers. The concept of architecture in art-historical thinking remains lim-

ited in general to stone, brick, timber, and large wooden buildings and thus to more durable materials.

In India nearly 20 to 30 million families live in earthen houses. Simple huts and houses constructed with earth or mud demonstrate the concept of architecture that each culture has used at one time or another and without which all later development remains unintelligible. In India there are 461 tribes and 172 subtribes, living on meager means. They live in all twenty-five states and Union territories of the country. According to a 2001 census, the total tribal population of India is 84,326,240, of the total population of 1,028,610,328. Some tribes are very small and primitive, for example, the Andmanese (42 persons), Jarwas (31), Chaimal (18), Onges (97), Arandan (236), and Kochuvelan (53). A total of 64 tribes have been recorded that have a population of less than 500.

Tribal people are not only peasants and laborers but also craftsmen and artisans. Carving (58 tribes), wall painting (56 tribes), and drawing (39 tribes) have emerged as major art forms in recent years. Of crafts, basketry involves the largest number of tribes (279), followed by weaving (215), cloth (57) and leather (1) embroidery, and pottery (36). Dancing and music are part of tribal cultural life. Among the tribal communities institutions of social control have remained relatively intact. Tribes follow Hinduism (378), Christianity (149), Islam (19), Buddhism (44), and tribal religion (292). Most subscribe to more than one religion.

Among Indian tribes earthen houses are popular. As tribal communities still live in forests and hilly areas, their habitats or villages are very small (fig. 1). Six to ten families live in a habitat. Family members construct their hut on a hill-ock in order to keep watch over their farm on the slopes.



FIGURE 1 Part of the village.

Houses on Hillocks

On marrying, a young man establishes his own home and makes plans to build a house. The method of house construction used by the primitive Kotwalia tribe is common to nearly three hundred tribes. The main livelihood of Kotwalias is earned by making bamboo baskets. Their houses are also constructed of bamboo.

They design their houses with the help of a senior leader or tribal technician. First they prepare the foundations, which are commonly made of mud. An 18-inch-deep and 9-inch-wide foundation and 20-inch base wall are necessary to carry the load of the house. Above, the base walls, floors, beams, and roof are prepared.

As Kotwalias make their walls with bamboo splits, very large, deep foundations are not needed. Trenches 18 inches deep and about 6 to 9 inches wide are filled with mud and pieces of stone. Then a wooden pillar is erected at each of the four corners. The bamboo split walls are only 5 to 6 inches thick, and two wooden pillars are erected on both sides to support the roof beam. In the center a *khambha* (pillar) is also erected, higher than the other pillars. The floor of the house is two feet higher than the ground to prevent the infiltration of rainwater. Every Kotwalia house has a *chabutara* (platform) outside for sitting and working.

Kotwalia people know which type of soil (clay) is good for house building. Below two or three strata of soil an ideal combination of the mud paste for building can be found. The color of the soil indicates whether the mud is good or bad.

Deep yellow, orange, and red, ranging to deep rich browns, indicate iron content and almost certainly good building mud.

Men dig the clay or useful soil, and women transport the soil on their heads to a location near the house. Men and women prepare the mud by mixing in the stabilizers. Straw pieces are mixed with the clay as the straw bits minimize cracking. People in different areas use *bhusa* (chaff) and various fibers to strengthen the mud. Cow dung often contains fibrous material and traditionally is used in all sorts of mud work. Cow urine is also used as the urea acts as a binder, or a sort of glue. Sometimes sugar and molasses are also used as stabilizers. The most common and effective stabilizer is the soil itself. After collecting the soil and stabilizers, women mix and mash the paste with their feet. The men apply the paste on the bamboo-split walls, while the women mix the material and bring it in iron vessels.

Generally a house is divided into three parts separated by granaries (*kothis*). These granaries are made of earthen material, are generally 4 to 5 feet high, and divide the house into bedroom, drawing room, and kitchen. A family keeps food grain in these granaries, as well as clothing and precious items such as money and jewelry. The house has two gates, one in the front and one in the back.

Outside the house an *otla*, or platform, is built (fig. 2). Here the family works and receives guests. Children also play and study on the *otla*. Children learn to process bamboo and prepare baskets and other items by observing their parents at work. In addition, important kitchen equipment—grinding stone, pestle, tongs—is stored on the *otla*. Water is kept in earthen pots in summer and in steel pots in winter. After every rainy season the house is fully maintained and repaired. The woman of the house plasters (*lipna*) the floor every month (fig. 3).



FIGURE 2 Women decorating a floor.



FIGURE 3 Woman plastering a floor.

The roof is slanted to prevent rain from entering the house. To cover the roof, bamboo is arranged in such a way that a gap of 2 to 3 inches may remain. The roof is covered with palm leaves and on them *naliyas* (half pipe, 18 inches long), or Mangalore tiles are arranged in such a way that rainwater does not stay on the roof. Water is the constant enemy of a mud wall, so it must be protected against rain and dampness with extended roofs (fig. 4).

The platform at the back of the house is used for bathing. Women who are menstruating use this platform for bathing. Generally these houses do not have latrines; people use the nearby forest for this purpose.



FIGURE 4 Front of an earthen house.

Solid-Wall Houses

Houses constructed with solid earthen walls are the trend among the Bhil and Mina tribes. The Bhil are the second largest tribe in India. They live in rural areas of Rajasthan, Madhya Pradesh, Gujarat, and Maharashtra states. For the walls and floor of their houses mud is used (sometimes stones). Doors are of wood, and roofs are made of bamboo and backed *naliyas*.

The technician of the tribe, known as *suthar* or *karigar* among the Bhil, plans the house mentally and then puts the house design on the ground. He puts four wooden nails in the earth where the four corners of the house will be located. He ties string (*dori*) around the wooden nails to make a rectangular shape. On the auspicious day and time determined by the senior member of the *fala* (part of the village having eight to ten families) construction work begins.

The technician and the senior persons advise the house owner at which place the *Muhurat* is to be done. Two coconuts (*shrifal*) and local sugar (*jaggery*) are used for worshipping the earth and the gods. Small pieces of coconut, jaggery, and coriander seeds are distributed among those present.

Most Bhil houses face to the east. After the *Ghar Chokana* (mapping the house) ritual is done, the close relatives of the house owner help dig the foundation trenches, which are 2 to 3 three feet deep and 2 feet wide. The foundations are filled with mud and small pieces of stones of varying size. Foundations are made of soil that sticks when wet combined with silt and pieces of stone. When the foundation reaches two feet higher than the ground, the *Darvaja Baithanam* ritual, or fixing the main doors, is done under the supervision of the technician. A copper coin, a cowrie (small shell), and *akha* (rice) in red cloth are attached to the upper part of the frame to protect the house.

Tribal and rural peoples throughout the world have been building earthen houses for thousand of years. Our forefathers, by trial and error, found various types of stabilizers, and the better ones have continued to be used.

Preparing Mud by Mashing

For constructing the walls, mud with cow dung, cow urine, and small pieces of straw as stabilizer with clay plus sand is prepared. Women mash (*ghundana*, "to knead") the material with their feet for two to three days. The main objective is to make the wall strong at the height of a man, and, having reached that height, it must be capable not only of remaining upright but also of carrying the weight of the roof.

FIGURE 5 A decorated house.



The first, simplest, and almost certainly oldest system is called “cob.” A large lump of very stiff mud, made with only a little water—as much as one can hold between two hands—is roughly molded into the shape of an elongated egg. The Karigar usually makes cobs that are 30 to 40 centimeters long and about 15 centimeters in diameter.

For building the wall, a row of the cobs are laid neatly side by side, preferably somewhat pressed together. Then another row of cobs is laid on top, with the cobs lying in the depressions between the cobs in the lower row. When three or four courses have been laid, one above the other, the sides are smoothed over so that the holes and cracks disappear. The Karigar sometimes uses only his hands and sometimes a *karni* (trowel) to achieve a very smooth, flat surface.

In practice the experienced wall builder literally throws the cobs with accuracy and force. However, wall building is better if done slowly. After two or three layers of cobs are placed all around the house, it is best to wait until they have hardened and set before continuing with the next two or three rows. At some places stones are also put into the cobs in order to protect the wall from thieves.

Arranging Cobs and Building a Wall

For keeping the wall straight and vertical the Karigar stands astride it while he works. Soon after the wall is completed, only

the hands are used for smoothing it. The main advantage of cob is that it can be employed by anyone, without requiring special tools or molds or other types of equipment.

To make the walls, wooden pillars (*thambalas*) are erected at the corner to serve as roof supports. On these pillars *kumi* (wooden brackets) are placed on which the *pat* (beam) is to be fixed. In a house one main beam is implanted and two supporting beams are also set in place so these can bear the weight of the roof.

For making the roof, bamboo is arranged in a slanting fashion. The walls on both sides make standing triangles, so it is easy to make the roof by putting the main beam on top of the triangles. The house is divided into *galas* (rooms) by erecting walls.

In the Kutch area small earthen houses are constructed in a round shape. To build curved or circular walls, cob is the ideal system. These circular huts depict a simple culture. Sticks and leaves are used, as these can be formed into curves. The huts are light and not very durable, measuring from 3 to 5 meters. The huts serve only nuclear families. The roof is conical and made with grass and bendable material. Because of the climate, none of these structures survives longer than three to five years. However, they seem to be able to withstand earthquakes. In a recent earthquake it was cement structures that were heavily damaged, resulting in a substantial number of deaths.

The last example is the earthen houses of the Meena tribe of Rajasthan. These houses have solid earthen walls enclosing a bedroom, a kitchen, and a verandah. Women maintain and plaster not only the floor but also the inner and outer walls. They make very fine, white drawings on the red ocher walls of their houses. The area is close to a tiger sanctuary, which perhaps inspires their drawings of tigers, peacocks, birds, and other wildlife (fig. 5).

I would like to conclude with a poem by Amit Sharma.

Mud is another name of Earth,
 It never gets tired, giving birth,
 To dwellings in Bamako or in Perth.
 It is one of the few sources,
 Which does not require artificial forces,
 And easy to use, if used in courses.
 Buildings that use mud,
 Have a lot of strength,
 Depending on requirements can have any width or length,
 Or height, which may reach floor, eighth, ninth or tenth.
 For thousands of years it had been used in a simple way,
 But now they have started experimenting and play,

With different percentages of sand, silt, aggregate and clay.
 You can learn how to use it, without going to school,
 It follows certain principles, and one simple rule,
 That while building with mud, you have to keep your cool.

Acknowledgments

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A Semantic Web Portal for Supporting Knowledge Contribution, Sharing, and Management in the Earthen Architectural Heritage Domain

Saverio Mecca, Chiara Cirinnà, and Marco Masera

Abstract: *The conservation of earthen architectural heritage (EAH) is a challenging domain of competence resulting from the intersection of scientific, empirical, and practical knowledge, either tacit or implicit. In this paper we illustrate the development of a cooperative Web portal enabling semantic access, querying, and supporting distributed contributions. The relevance of the development of ontologies allowing a basic support for a heterogeneous community of practice is evaluated: the use of ontologies and modeling technologies indicates the development of a new paradigm that could contribute to the arrangement of Semantic Web architectures with high potentiality such as interoperability, cooperation, adaptation, and ability to evolve over time.*

Résumé : *La conservation du patrimoine bâti en terre est un domaine de compétence qui pose de multiples problèmes car il se trouve à la croisée de connaissances scientifiques, empiriques et pratiques, qu'elles soient tacites ou implicites. Cette communication explique la mise en place d'un portail Web coopératif permettant l'accès sémantique, la recherche et la consultation de contributions dispersées. La pertinence d'une mise au point d'ontologies capables d'assurer un soutien de base à une communauté hétérogène de praticiens est évaluée : le recours à des ontologies et technologies de modélisation préfigure le développement d'un nouveau modèle qui pourrait contribuer à l'aménagement d'architectures Internet sémantiques à fort potentiel – notamment d'interopérabilité, de coopération, d'adaptation et de capacité à évoluer au fil du temps.*

The diffusion of information and the decentralization of knowledge are turning out to be among the most innovative

and effective domains that guarantee the success and appropriate use of a building technique. Migration from the inner Sahara and Europe has led to the gradual concentration of communities with specific cultures, habits, and traditions in the Mediterranean, making it a region where all the knowledge of earthen material and building techniques converges. This situation provides the motivation to invest in the continuous development of and research on earthen materials to improve their potentialities and value, not only concerning their physical aspects but also in order to implement policies for sustainable development, at present scarcely understood and applied.

The strategic value associated with the capitalization and management of knowledge is crucial for sustaining effective development plans and for fighting global poverty.¹ Local know-how includes the huge and complex body of knowledge, experiences, and skills that have been maintained and handed down from generation to generation. The restoration and the protection of local knowledge are considered key elements in efforts to sustain the conservation of cultural diversity and to guarantee an active role of communities in the management of their resources.

Ontologies: Definitions

In recent years the development of ontology has been playing a key role in knowledge management. The term *ontology* has its origins in metaphysics and philosophy. In computer science there are at least a dozen definitions of *ontology* in the literature (Uschold and Gruninger 1996). One of the most recent definitions states that an ontology provides the skeletal knowledge and an infrastructure for integrating knowledge

bases at the knowledge level, independent of particular implementations (Fensel 2000). In summary, ontologies add meaning to information in order to provide clear value, delivering the right information to the right person at the right time and in the right way.

Ontology is the name given to a structure of knowledge, used as a means of knowledge sharing within a community. An ontology is a “data skeleton” that can be developed for a variety of data-based and knowledge-based systems. It consists of a collection of concepts (or classes) and relationships between them. The ontology might include principal synonyms (abbreviations, common misspellings) for each term. It could contain only a single type of relationship between terms, for example, a “kind-of” relationship, such as “pisé and adobes are kinds of earthen building techniques.” However, ontologies can represent other relationships (e.g., part-of, precedes-in-process, reports-to). An ontology includes basic knowledge relationships that a variety of types of knowledge applications might use. For humans, ontologies enable better access to information and promote shared understanding. For computers, ontologies facilitate comprehension of information and more extensive processing.

The use of ontologies and modeling technologies indicates the development of a new paradigm that could contribute to the arrangement of Semantic Web (SW) architectures with high potentiality, such as interoperability, cooperation, adaptation, and ability to evolve over time.

In this perspective the ontological approach makes it possible to reach several goals; the most relevant are the following:

- For their intrinsic vocation, ontologies allow the explicit representation of semantic models that combine the nonambiguity necessary to the technical specifications with the capability for IT experts and stakeholders to understand each other.
- Ontologies enable the application of reasoning technologies aimed at information search, knowledge aggregation, and inference, generating new knowledge.
- Ontological models are well suited for distributed contexts, allowing the development of models for reuse, aggregation, and adaptation of ontology fragments that have been developed in a concurrent and distributed way.
- Ontologies make it possible to model evolving domains over time, overcoming several complexities

resulting from the use of traditional domain modeling schemes.

In this paper we illustrate the development of a cooperative Web portal, called Muddy, that enables semantic access, querying, and supporting distributed contribution.

The Application Domain

Within the wide area of local and traditional building techniques, the proposal will work specifically on earthen architectural heritage (EAH) building techniques, a widespread form of building, from complex monumental urban structures to simple construction, but everywhere a heritage in danger. In the EAH domain there are some elements that hinder the diffusion of this building technique:

- Lack of specific information: a great deal of information exists in gray literature that is not readily accessible or reported on.
- Absence of cross-disciplinary desk assessment and synthesis: identified missing pieces will have to be adopted/adapted from other disciplines or generated as a result of a specific research effort.
- Difficulty of access to existing data: access is severely limited due to the lack of centralized databases, online catalogs meeting international library standards, and the like.
- Results of the research not being broadly accessible: solutions should be improved, especially through the development of appropriate diagnostic methods and analytical tools.
- The research that has developed a Web portal enabling semantic access, querying, and contribution of new knowledge aims at developing an ontological perspective to give a knowledge base to a heterogeneous and geographically dispersed community of practice and experimenting with a cooperative system to support the processes that entail the management of both explicit and tacit know-how and skills.

The final results are expected to provide an operational tool, accessible on the Web, that will be flexible to different building cultures and adaptable to diverse circumstances, for creating, storing, and managing valuable knowledge, and make it usable by the actors involved in earthen building processes.

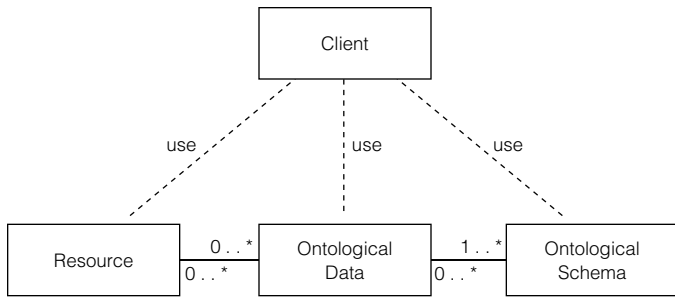


FIGURE 1 Relation between traditional resources and semantic annotation.

The System Architecture

The first step in weaving the Semantic Web into the structure of the existing Web is the creation of ontologies to structure knowledge domains: the traditional resources are completed with a *semantic description*. The semantic information is organized through ontological models, which are technologies used for knowledge representation.

The model in figure 1 describes the relation between traditional resources and semantic annotation that characterizes the Semantic Web, in which information has to be semantically defined so as to enable automated processing. As illustrated in figure 1, the “Client” is a Semantic Web reader (a human or an application); he is considered the generic contributor/user of resources. “Resources” identifies any information object on the Web: a text file, an HTML page, an image, a movie, and so on. Each Resource is related to its Ontological Data, that is, the semantic information of a resource that can be assimilated to the records of the database constituted by the ontology. The Ontological Schema is the underlying ontology model, a conceptualization shared among users that is composed of concepts and relations among them, described through OWL formalism, according to the W3C standards (W3C 2004).

Overview of the Web Portal Muddy

The key performance expected from the Web portal Muddy is the identification of a new way to represent and manage the existent fragmented body of knowledge (fig. 2). The research has started from the definition of the overall objectives, namely:

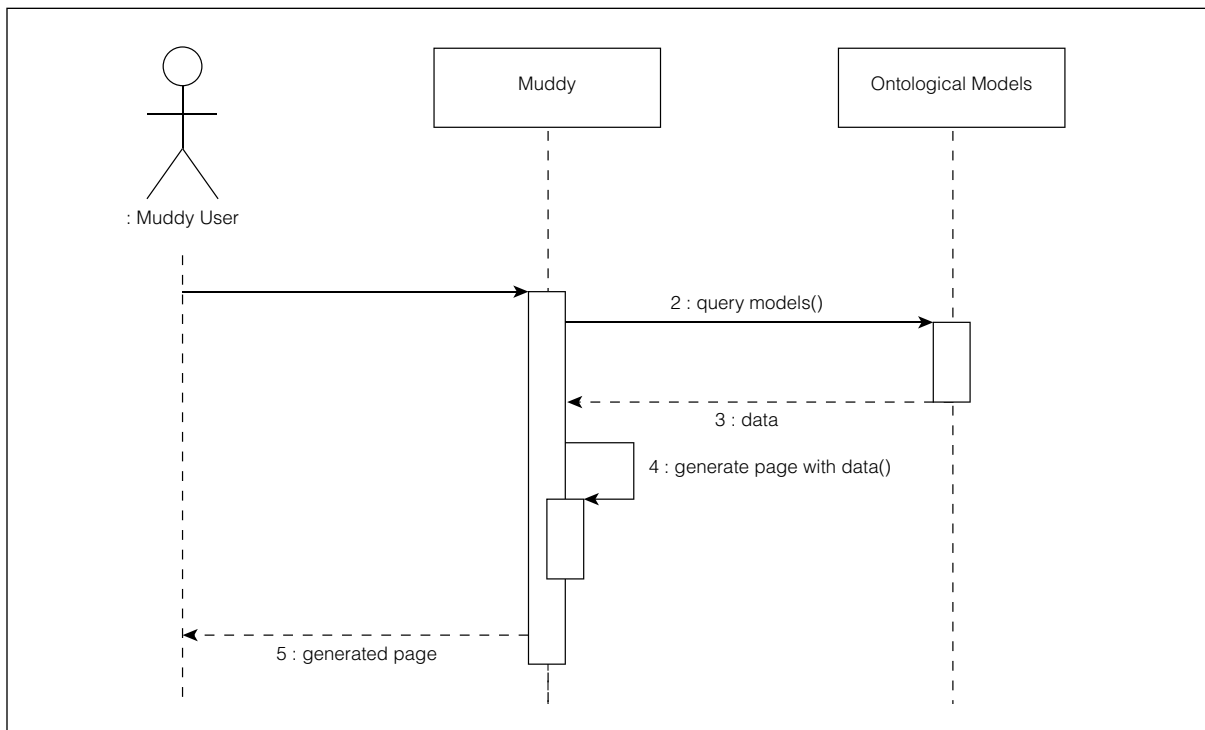


FIGURE 2 Muddy at work.

- the organization of large amounts of information;
- the possibility of making explicit the tacit knowledge;
- the possibility of sharing structured knowledge; and
- the opportunity to access the knowledge base using semantic queries.

In order to achieve these first objectives, the research has evaluated the possibility of using ontologies in association with Web technologies. One of the main obstacles associated with the use of ontology technologies concerns the difficulty of creating a shared, implementable, and maintainable model.

Analyzing the state of the art in the EAH domain and the environment of the research makes it possible to infer the following:

- No relevant existing models are available.
- The number of experts able to build the model is limited.
- The contribution of experts takes place in different locations.
- Experts should be able to improve and enlarge the model over time.

After having defined these more specific objectives, the research has analyzed the software requirements that could help satisfy them. First the application domain was analyzed. In collaborative environments such as the Muddy portal, several actors with different and complementary skills are involved in building the same ontology (Tempich et al. 2005):

- The Domain Expert, who is the content creator and has in-depth knowledge of the domain to be modeled, with his own terminology, which is usually difficult to understand for users from a different domain. He does not necessarily know much about ontologies.
- The Ontology Expert, who can interpret the knowledge provided by the Domain Expert by producing the corresponding ontology model; moreover, he knows how to create, modify, and update the model, following the indications of the Domain Expert.
- The Stakeholder, who is the generic user interested in the application domain but does not necessarily contribute new knowledge.
- The IT Expert, who has to develop the software, according to the requirements expressed by all the other actors.

The research has therefore identified two main system requirements: the abstract roles and the use cases, which reflect the users' needs, so as to provide and manage the possibility of having different operating roles corresponding to different types of users. In this sense, *abstract roles* refers to the distinction between two generic users, the Reader and the Writer.

Use cases refers to the operations that the Reader and the Writer are allowed to perform. The first one is interested mainly in understanding the organization of concepts (the traditional resources in the conventional Web) rather than their creation. He is interested in actions like browsing pages, navigating links through the semantic relations, and querying the knowledge base. The Writer, besides having access to information, can contribute new knowledge by inserting, updating, and deleting resources or modifying the model (the Ontological Schema) by fixing errors or changing or extending the model. Writers can also send or receive feedback and comments about the ontological model.

Abstract roles and use cases have been made operational through the definition of the following profiles, necessary for the implementation of the cooperative portal:

- Administrator: a peculiar type of user who is allowed to execute every kind of available operation. His specific task is to assign certain privileges to a user.
- User: represents the generic user who is allowed to consult the information available on the Web site but is not allowed to perform any kind of feedback.
- Special user: allowed to read and modify the information on the Web site in the provided way.
- Expert user: a Special user who is allowed to express a vote about the different resources available on the Web site; these votes make it possible to determine the official ranking of a document.

Functionality of the Web Portal Muddy

To access the portal, users have to go to the index page, with login and registration. Users can be Reader, Writer, or Administrator. Only the Administrator can assign them a more precise role, providing them with different functions or giving them other privileges.

Once the user has accessed the main page, he or she can start navigating the knowledge base by means of different search criteria. The first one is the Directory page (fig. 3): at first glance, the portal has a weblike organization, where pages are organized in a taxonomic tree structure and the list



FIGURE 3 Directory page.



FIGURE 4 Resource page.

of categories corresponds to the root concepts of the ontological model. By selecting a category, the user goes to a page that contains the list of instances of that category and the list of direct subclasses.

The second one is represented by the Search page. By specifying one or more words, the user can find one or more resources that contain that word. Besides this keyword search,

the system implements a more powerful search method: the user can indicate the kind of relations existing between the desired resource and the specified words. For instance, the expression “causes Pathology = humidity” helps the user to find all the resources (e.g., the causal factors) that have “humidity” as a resulting pathology.

The third way to navigate the portal and find appropriate results is constituted by navigation via the Resource page. This page contains all the information about a resource (fig. 4). The user can navigate through semantic links that are on the right side of the page: these links lead the user to other resources, identified by semantic relations (properties), so as to allow a more focused search for the most relevant resources.

On the left side of the page, the hierarchical taxonomy helps the user to understand which section of the ontology model he is navigating.

The header of each page allows the user to explore the other functions of the portal. The Upload and Download pages allow the user to contribute with new content or to download the ontology model; the User Data page lets the user modify his personal data.

Moreover, the portal gives the user the opportunity to give feedback on each resource by expressing a vote: each vote consists of a numerical score. The average score permits the user to give a qualitative opinion on the resources and their content.

Conclusion

The Muddy project has evaluated the potentiality of ontologies as operational tools for creating, storing, and managing valuable knowledge and how to make them usable by the actors involved in earthen building processes. Ontological technologies become an important enabling technology for semantic discovery, cooperative contribution, and integration of heterogeneous sources.

- At this advanced stage of the project, it is possible to outline the results achieved so far.
- In light of the expressed potentialities, ontology models allow one to effectively represent and organize dispersed and abundant knowledge domains such as the EAH, providing them with a clear, sharable structure of relevant concepts, by disambiguating the inherent semantics, harmonizing the terminology among the community of users, and facilitating discussions.
- By making use of a site structure and a page layout typical of a portal with weblike organization, the

Muddy portal allows navigation driven by the inherent semantics of content rather than a hierarchical upfront classification.

- The kind of searches implemented allow the user to choose among customized navigation paths, from a traditional ordered way to a definitely improved search by querying the system or following the proposed underlying semantics.
- The portal supports distributed contribution, enabling the user to directly provide the model with ontology fragments, domain individuals, or concepts, accumulating shared knowledge and making tacit or embedded knowledge become explicit and consistent.
- Ontological models are well suited for distributed contexts, involving different stakeholders who have different purposes and needs and who usually are not at the same location, stimulating the process of consensus building between the involved participants.

Note

- ¹ UNESCO, General Conference, Paris, October 3–21, 2005.

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Earth Building Culture in Daura, Nigeria: From Mythological Origin to Reality

Ishanlosen Odiaua

Abstract: *In Hausa mythology Daura is the birthplace of the Hausa states. This paper outlines the similarities between the architecture of Daura and the generic nature of Hausa architecture as it is known and serves as preliminary documentation of dying earth construction practices in Daura. It focuses on the specific nature of Daura architecture and highlights those aspects that are unique and original to it. Documentary sources were drawn from a literature review, oral resources, and observations from fieldwork in Daura.*

Résumé : *Dans la mythologie haoussa, Daura est le berceau des états haoussa. Cette communication souligne les similitudes entre l'architecture de Daura et l'architecture générique haoussa telle qu'on la connaît ; elle constituera une documentation préliminaire sur des pratiques de constructions en terre en voie de disparition à Daura. Elle traite de la spécificité de l'architecture de Daura et en souligne, le cas échéant, les aspects originaux et uniques. Les ressources documentaires proviennent d'une revue de ce qui a été publié, de sources orales et d'observations rassemblées lors de travaux sur le terrain à Daura.*

Daura, in northern Nigeria, is named after the ninth, and last, queen of Daura (Daurama), who moved her capital from Tsohon Birni to present-day Daura, and is widely accepted, in Hausa mythology, as the origin of the political and administrative structure of the Hausa states. It is believed that this structure came about with the marriage of the mythical Baghdad prince Bayajida (Abu Yazid), who saved the town from a tyrant snake and was recompensed with marriage to the queen, Daurama.¹ Their descendants eventually founded the Hausa states, Hausa Bakwai: Daura, Katsina, Kano, Gobir,

Rano, Biram, and Zaria. These core states are spread over northern Nigeria, and the wide spread of the Hausas across the subregion is a result of movements occasioned by trade and migration. The Bayajida legend is widely accepted among the Hausas. However, because of the legend's complexity historians have found it difficult to establish a chronology of the events it describes (Mahamane 1999).

The town of Daura remains significant in Hausa history, and there is a regular convergence there of the rulers of all the Hausa states. These meetings usually serve as a point of exchange on all that concerns governance in their individual domains. To date, Daura is reputed to be the only Hausa state to maintain a pure Hausa (Habe) royal lineage, the other Hausa states having become Hausa-Fulani as a result of the inclusion of the Fulani in the political administration of Hausa land following the jihad of Usman dan Fodio in the eighteenth century (Ahmadu and Mamman, pers. com.). The jihad led to the displacement of the dynasty from its capital in Daura to Zinder (in present-day Niger), and it was restored by the British in 1906 (Smith 1978). Today Daura covers ten districts in Katsina state in northwestern Nigeria. In this paper "Daura" refers to the town by that name, where the headquarters of the Emirate Council is situated (fig. 1).

Background of the Earthen Building Culture in Daura

Over time, the rapid expansion of the Hausa states led to the development of various centers within Hausa land. In terms of architecture, Zaria and Kano eventually gained prominence, and the architectural feats of the master builders of Kano and Zaria are well documented. In the case of Kano, it



FIGURE 1 Approach to the palace complex, seat of the Emirate Council, Daura, January 2008. Photo: Ishanlosen Odiua



FIGURE 2 Street scene in Daura, January 2008. All the buildings on this street are of earth, plastered over with cement mortar. Photo: Ishanlosen Odiua

could be inferred that the development and expansion that came as a result of the trans-Saharan trade and associated cultural exchanges led to the sophistication for which its architecture is known. Daura is aptly described by Mahamane (1999) as “le parent pauvre de l’administration moderne des anciens Hausa Bakwai” (the poor parent of modern administration in the original Hausa Bakwai).

According to the Galadiman Daura, a noble of the Emirate Council, the architecture of Daura is typically that of the Hausas. However, he identified a few distinctions that could be said to be peculiar to Daura. In Daura, for example, streets are much wider than in the other large Hausa towns (fig. 2). The exception to this is within the *dole* quarters, where the streets are uncharacteristically narrow. Therefore, for the most part, Daura did not face the challenges experienced by other cities with the introduction of the automobile and the attendant need to widen the streets. These wide streets also served as fire breaks and reduced the risks of disease spreading in the town (Ahmadu, pers. com.).

Building construction could be carried out on a communal basis (*gayya*) for the highly placed in society. It often involved the provision of labor in exchange for a good lunch and entertainment by the “employer.” The entertainment often took the form of music and songs in praise of the builders present (Ahmadu, pers. com.). It was often a joyful and intensive activity and helped to maintain a sense of community.

The roofs of buildings in Daura are flat and made of mud, whereas those of Zaria are domed. This is because the

rainfall in Daura is not as heavy as it is in Zaria, which is located in the wetter guinea savannah. Dmochowski (1990) describes the roof construction method of Daura and remarks that the construction of the flat roof involved the use of a central support that was never used in either Kano or Katsina. Foundations were usually made of earth or, when available, stone. The walls were usually made of *tubali* (pear-shaped mud bricks) laid in mud mortar. The most innovative earth buildings in Daura are within the palace complex, which is described in Dmochowski’s (1990) introductory text on traditional Nigerian architecture.

The construction of the entire building was usually done by men. The decorative work on the walls was also done by men. Floor finishes were the exclusive preserve of women; this is true of the rest of Hausa land. However, the women of Daura also participated in the finishing of the flat roofs. This usually involved treatment of the roof structure in a way similar to that used for the floor structure. After the structural construction had been done by the men, the women would climb up on the roof to do the final finishing and waterproofing. A surface of earth would first be laid on the finished earth structure, then watered and beaten with a *madabi* (a wooden ramming tool). This layer was further hardened by pouring *makuba*—a liquid obtained from locust bean pods, *Parkia filicoida*—over it, and the layer was then beaten into place. This work was carried out with a lot of taunting, lewd songs sung by the women and directed at the men, who supplied the women with building earth for their work (Ahmadu, pers. com.).



FIGURE 3 Courtyard within the Daura palace complex, January 2008. The paints applied on the wall are of industrial origin. Photo: Ishanlosen Odiaua

Other associated cultural practices in Daura include tending graves. Soon after burial of the dead the grave is guarded to protect it from wild animals or dogs, which are known to dig into graves. Later, the grave of a loved one is marked with stones, often raised as a memorial to the departed.

The State of Earthen Architecture in Daura Today

Daura prides itself on being the first of the Hausa states to develop professional groups or guilds of tradesmen (Isaka, pers. com.). One of these guilds is that of the traditional builders, which is headed by the chief builder, or *Sarkin gini*, who is usually the person in charge of the construction and maintenance of palace buildings. This group deals with the organization of building activities in the town and sees to the welfare of the members of the association. This culture is still very much alive in Daura.

The architecture of Daura has changed slightly over the past fifty years, especially with regard to materials. This change can be attributed to the effects of colonization and external influences. Cement and other industrial materials have been introduced for the construction of buildings. However, there are certain practices remaining today that help to ensure the preservation of earth building culture in the emirate. The *tubali* bricks, which were usually small in size and labor inten-

sive, have been completely replaced by rectangular adobe blocks that are usually molded in the riverbeds during the dry season.

The practice of *gayya* has practically died out with the introduction of a cash economy and the changing needs of those who offer their services. However, there remains a semblance of this practice, although at the community level, and there is no cash exchange for the service offered. While *gayya* used to involve the construction of personal residences, it has evolved to cover activities such as clearing drains that affect the entire community rather than individuals (Ahmadu, pers. com.).

There is a conscious effort by the palace authorities to preserve the beauty and originality of palace buildings so as to preserve the rich building tradition of the emirate (Ahmadu, pers. com.). Even at the palace the massive earth walls are covered by cement plaster as an innovation to avoid the routine replastering necessary for earth plaster. Industrial paints have also been introduced into wall finishes (fig. 3), replacing paints derived from natural mineral or organic materials (colored earth, bones, vegetable pigments, etc.). On a practical level, industrial paints are better suited than organic-based paints for application to cement walls. In addition, industrial paints are easier to apply and less labor intensive: organic paints are often prepared by hand. As in every human society, trends are often set by the ruling classes and the wealthy, and Daura is no exception. The other building owners in the town have also followed suit. However, in spite of all the changes that have been occasioned by new materials, earth architecture remains vibrant, and a large number of buildings in the town are constructed of earth and covered over with cement render. The use of adobe blocks is on the increase, and the countryside is dotted with quarry pits where the blocks are fabricated. This writer observed that there is a seeming lack of discrimination in the location of these pits, and they pose potential erosion problems.

One of the reasons for the vibrant earth building culture in Daura is also the enduring institution of the *magina*, or traditional builder. It is interesting to note that with the increasing use of cement blocks and the abandonment of the *tubali*, most bricklayers in Daura are judged by their ability to lay mud blocks rather than cement blocks (Isaka, pers. com.), and any builder worth his salt must be proficient in the laying of mud walls before he can be considered a good mason. It is not unusual to see buildings in which there is a mixture of earth and concrete elements, and new buildings often rise out of the ruins of the old (fig. 4).



FIGURE 4 New and old buildings in Daura. Note the use of cellular concrete bricks for aeration purposes to the top left of the building under construction. Photo: Ishanlosen Odiava

The flat mud roofs that prevailed both in large towns and in rural villages are gradually disappearing, replaced with galvanized iron roofs (fig. 5). This is due to two major factors: the difficulty of getting laborers to build the roofs in the old ways and the scarcity (and increasing cost) of the palm wood used as reinforcement for the beams of the flat roof. The disappearance of this type of roof construction also means that the cultural activity linked to its construction (women carrying out the roof finish) is also gradually disappearing.

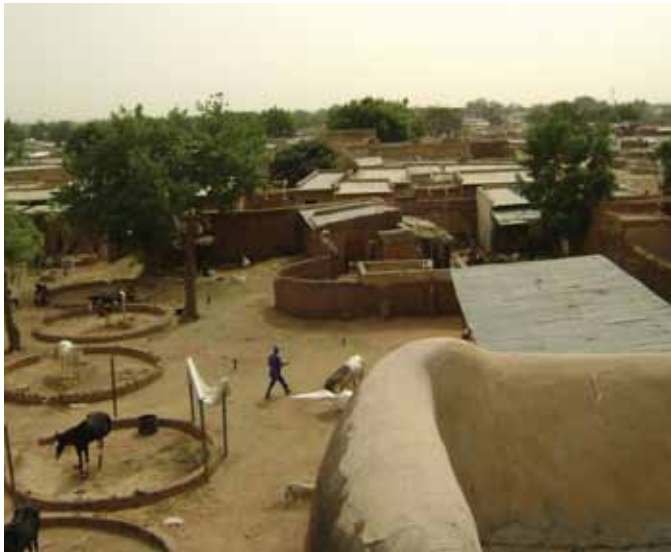


FIGURE 5 View of the palace complex from the top of a palace building. All earth roofs have been replaced with corrugated iron roofing sheets, surrounded on three sides by parapet walls (detail in foreground). Photo: Ishanlosen Odiava

Conclusion

Daura has undergone various changes in its history, yet maintains pride of place in the history of Hausa land. There is a conscious effort to maintain the earth buildings in the area, and this effort starts from the highest level, at the palace and traditional administrative quarters. The enduring consideration given to the mastery of earth construction in the training of bricklayers in the area also helps to maintain this vibrant culture. However, the introduction of new materials has also brought about change, especially as related to certain cultural practices associated with buildings, such as the participation of women in roof construction. It must be acknowledged that in the face of changing lifestyles and economic practices, Daura has adapted to the challenges and is experiencing an interesting evolution of its building tradition.

Note

- 1 Oral interviews were conducted with the following individuals at the Daura Emirate Council: Galadiman Daura, Alhaji Ahmadu Ahmed, January 2, 2008; Mallam Mamman, palace historian, January 3, 2008; *Sarkin magina* (chief builder) Daura, Mallam Adamu Isaka, January 2, 2008.

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Oral Traditions in the Conservation of Earthen Architecture

Julias Juma Ogega

Abstract: *From time immemorial, communities throughout the world have told stories. In the oral tradition storytelling has always involved both the teller and the audience. The storyteller creates the experience, and the audience perceives the message and creates personal mental images from the words heard and the gestures seen. This paper presents the opportunities offered by oral performances to create mental repositories of intangible heritage about the built environment, especially earthen architecture. The participants are not always passive but may become co-creators of the messages passed along in both social and individual memory—messages that are very important in the conservation of earthen architecture.*

Résumé : *Depuis les temps immémoriaux, les communautés d'Afrique et d'ailleurs racontent des histoires. Dans la tradition orale, le récit implique un conteur et un public. Tandis que le conteur crée l'expérience, le public perçoit le message et se crée ses images mentales personnelles à partir des mots qu'il entend et des gestes qu'il voit. Cet exposé évoque les possibilités offertes par la narration pour créer des répertoires mentaux permanents du patrimoine immatériel sur l'environnement bâti, et notamment sur l'architecture en terre. Au cours de la narration, les participants ne sont pas toujours passifs mais deviennent les co-créateurs des messages à faire passer dans la mémoire sociale et individuelle, et qui sont très importants pour la conservation de l'architecture de terre.*

Defining Oral Performances

Storytelling is one of the oldest methods of communicating ideas and images, and it is the oldest profession in human society (Mello 2001; Woolf 1998). Simply put, performances of oral

tradition are the communication of beliefs, norms, and practices. Performances in traditional cultural contexts are part of a creative art form that has entertained and informed across centuries and cultures (Aiex 1988). The technical structuring of oral performances is “informed by a chain of causes and effects, both subtle and explicit, the ultimate outcome of which is a specified moment of resolution” (Wells 1998: 68), and it can range from a straightforward linear pattern to a nonlinear order of events (Wells 1998; Kerlow 2000). Oral performances are used in conserving earthen architecture, especially when the performance takes place within the built environment.

In oral performance a story is told in a number of different ways, encompassing nonverbal and visual communication. Throughout history, stories have incorporated the arts, in pictures, paintings, ceremony, theater, reenactment, dance, and puppetry (*Storytelling and the Arts* 2002).

Methodology of Performance of Oral Traditions in the Conservation of Earthen Architecture

Conservation narrative is communicated through many forms and mediums, including animation. A performance in earthen architectural places characterizes and defines the identity of individuals and groups (Mello 2001). It is unarguable that “stories are the most common and most powerful vehicle we use to talk about life” (Kerlow 2000: 279). Oral traditions communicate facts and provide answers to questions. They “provoke actions, positive actions that shape the reality of heritage conservation” (Kerlow 2000: 279). Simply, the main function of oral performance is “to explore human emotions, values, and beliefs” (Rubie 1996: 11). These values and beliefs are the basic tenets of the conservation of traditional earthen architecture.

Traditional performances for the conservation of heritage places were passed from person to person (Wolf and Levy 2002; Criss 1997; Furniss 1998) and “generally were simple and direct but structured to hold interest” (Furniss 1998: 116). They were intended for and popular with all audiences, regardless of age, gender, and class. They involve the audience and the performer: the performer creates the experience, and the audience perceives the traditional conservation messages and creates personal mental images and conservation scenarios best for the site from the words heard and the gestures seen. The audience thus becomes co-creator of the conservation messages to be passed on. Performers engage with their audience, adjusting their words to respond to listeners and to the moment, thus creating and re-creating age-old conservation traditions, scenes, and moments.

In African societies, performance of tradition is interwoven with sociopolitical structures and systems such as kinship, lineage, priesthood, kingship, and chieftainship. These define structures and strata of traditions and knowledge and how these are passed on by individuals. The interweaving of performance with the social fabric of the society ensures checks and balances on the authenticity, validity, and reliability of the performances.

As Saxby explains, “The ancient tales demonstrate the universality and ongoing nature of the human condition” (1996: 169). Human interest in the universal gives a possible explanation for why the same heritage conservation themes, messages, motifs, and character archetypes “turn up over and over again, in tales from many different cultures” (Wolf 1998). The examples presented below show how the conservation of immovable cultural property has, through traditional methods, been recognized throughout Africa. It is for these reasons that performances of oral traditions remain illustrative of collective experiences. Storytelling and its many related mediums are as popular today as they were in the past, because the archetypes in traditional stories remain applicable to us today (Livo and Rietz 1988).

Recognition of Conservation through Traditional Methods

Recently in Africa the conservation of immovable cultural property, including earthen architecture, through traditional methods has been acknowledged, and international heritage institutions have recognized the important role of traditional owners and local communities (Africa 2009 2004; ICOM 1992, 2003, 2004, 2005; UNESCO 2003). Many sites are con-

served through traditional knowledge that includes spiritual values and technical practices (Joffroy 2005). The spiritual values embody beliefs and norms that are used to protect sites. Technical practices depend on the cultural values inherent in particular sites. Often, specific traditional conservation practices are concerned with special events that reinforce the social cohesion of a community.

Traditionally, Africans have revered talented performers of oral tradition, as have most past and present peoples around the world who are rooted in oral cultures and traditions. Though ancient writing traditions exist on the African continent, most Africans today, as in the past, are primarily oral peoples. Their art forms are oral rather than literal. In contrast to written “literature,” African “orature” is orally composed and transmitted and often created and re-created to be verbally and communally performed as an integral part of dance and music in heritage places. The oral arts of Africa are rich and varied, developing with the beginnings of African cultures, and they remain living traditions that continue to evolve and flourish.

The Case of the Naaba in Burkina Faso

Among the rich earthen architectural heritage sites of Burkina Faso, the Na-yiri of Kokologho is one of the most outstanding. It is a living heritage, where the Naaba, chief of eight villages, lives. The community and the Naaba continue to practice traditional conservation, so that this site has kept its cultural and architectural significance. The Naaba, however, foresaw that there would be difficulty keeping this traditional conservation practice alive. They wanted to explore a way to reinforce this practice with funds made available through the Africa 2009 project (Africa 2009 2004), whose objectives were to restore the Na-yiri and reinforce the traditional conservation practice, put in place a site tour and its presentation, ensure its promotion, and inscribe the project in a sustainable development policy for the benefit of the whole community.

This project was a very interesting case study of how a management mechanism can be established to allow traditional conservation methods to continue while accepting visitors and in turn generate revenue from visitors to help traditions survive. Another very interesting aspect of this project is that it has been an opportunity to actually address development issues, with the construction of a borehole or well useful not only for conservation purposes but also for the community.

The project benefited from the fact that annual maintenance work at the earthen palace of Naaba at Na-Yiri of

Kokologho is linked to the festival of Na-Basga. Preparation for the festival involves meticulous planning and inspection of the palace to determine its conservation status. The traditional opinion of the guardian is meant to incorporate indigenous conservation knowledge. Time-tested indigenous conservation knowledge systems are infused in the spoken word, dances, and gestures performed at the festival.

Lamu Old Town, Kenya: Conservation of Traditional Swahili Earthen Architecture

Lamu Old Town is a unique and rare historical living heritage site built of coral and earth that has had more than seven hundred years of continuous settlement (fig. 1). In 2001 it was declared a World Heritage Site by UNESCO. Since then the Lamu Cultural Promotion Centre and the National Museums of Kenya have organized an annual cultural festival to promote and preserve the unique Swahili architectural cultural heritage of the Lamu Archipelago (fig. 2). Preceding the festival there is meticulous preparation that involves various stakeholders and interest groups, including the Ministry of State for National Heritage, the National Museums of Kenya, the Department of Culture, and the local community.

Before the festival local community experts repair traditional Swahili architecture at Lamu Fort, which was built in 1821 by the sultan of Oman soon after Lamu's victory over Pate and Mombasa in the battle of Shela. Other sites that are repaired using traditional knowledge are Takwa National Monument on Manda Island (a settlement dating to 1500, with ruins of a great mosque and a pillar tomb); the Ruins of Shanga, an eighth-century Swahili settlement, on Pate Island, containing remains of the coral walls of 160 houses, two palaces, three mosques, and hundreds of tombs; the early Swahili settlement of Pate, once a power in the region; and numerous



FIGURE 1 Aerial photograph of Lamu. Photo: Julius Juma Ogega



(a)



(b)

FIGURE 2 Performances during the Lamu World Heritage Site Festival. Photos: Julius Juma Ogega

sites and monuments that are representative of Swahili civilization at its height in the fifteenth century.

The three-day festival showcases traditional music and dances, displays of handicrafts, competitions on water and land (Swahili poetry contests, donkey races, dhow races), and music and theater performances from local and visiting artists who share a common heritage. Through the performances traditional conservation methods are reinforced.

Discussion

Critics of the performance of oral tradition as a source of conservation of shared heritage have pointed to the fallibility of human memory and questioned its reliability and validity for this purpose (Finnegan 1996; Hoffman 1996; Tonkin 1992). Most conventions concerned with the conservation of earthen

architecture mention oral performances as a way to ensure that these masterpieces are preserved, safeguarded, and promoted for posterity, though questions arise, for example, can earthen architecture be conserved through performance and not by universally accepted coded conventions, and how can one deal with issues of authenticity and the fallibility of memory?

Others have pointed out that oral tradition is uniform, undifferentiated, unitary, or self-evident, making it difficult to analyze and assess. Still another point of view is expressed by Finnegan:

Just saying that something is oral sometimes seems to release scholars from the need to go on to investigate—as if once the term is used we can just focus on the minor details for we already know the broad characteristics of, for example, the processes of composition, social function, transmission from the past, outlook of poet and audience. (1996: 143)

While there is no disputing the fallibility of human memory, especially in personal testimony, it should be understood that individuals are social beings, molded in ever-changing interactions, reproducing and altering their societies. Thus memory depends on the interest one has in a shared past and how one perceives that past. This varies depending on circumstances. For instance, among the Bambara of Mali when a poet added something new to the traditional account, he had to warn his audience by stating, “This is what I am adding. If I am wrong, do not forget that, like you, I live on a handful of millet, a mouthful of water, and fresh air” (Ba 1990: 64).

Humans as social beings choose what to remember. However, in orate societies the word is considered the sacred agent of occult forces; it is venerated and handled with caution, and there is special virtue in the spoken word (Hofmeyr 1995). Similarly, authenticity of memory in orate societies refers only to reliability and validity, where reliability means the consistency of the story of the same events told the same way on a number of occasions and validity means degree of conformity with recorded hard evidence. However, validity in memory cannot be tested unless it can be measured against a body of hard evidence; when the evidence is lacking, it becomes an isolated description of an event (Hoffman 1996).

Conclusion

Festivals performed in earthen architectural places embody holistic processes of their conservation. Everyone participates

formally and informally through interactive oral performance. Such participation is an essential part of traditional African communal life. Basic training in a particular culture’s oral arts and skills is an essential part of children’s traditional indigenous education on their way to initiation into adulthood.

Early modern historians, antiquarians, and heritage managers, whether in Africa or the West, have relied to a greater extent not only on manuscript or archaeological evidence or materials for the conservation of heritage but also on a variety of oral sources ranging from popular traditions to the personal recollections of the aged. In the African context, the importance of performance of oral tradition in conservation of earthen architectural heritage is undisputed (Vansina 1985).

Performance of oral tradition is the only path that can lead us into the history and spirit of earthen architectural heritage conservation by African peoples. Further, performance of oral traditions is a time-tested and verified historical methodology of heritage conservation. Similarly, it is well known by oral historians that the use of oral sources in earthen heritage conservation can be valid to the extent that they are reliable, meaning that when oral sources are consistent, conformity is important only to the extent that it confirms the reliability of the source (Vansina 1996).

Theater has been part of heritage site interpretation plans both for education and enjoyment and for safeguarding age-old conservation traditions (Bridal 2004). Since the 1990s there have been paradigm shifts in the management of heritage sites from collections with “Do Not Touch” labels to public spaces where communities can meet and engage in dialogue (Abungu 2001; Konare 1992; Rassool et al. 2001; Msemwa 1996).

Due to this paradigm shift, performances have been used to interpret heritage spaces, earthen architecture, and objects. They bring new audiences and help to create a museum for the people and by the people (Abungu 2001; Aghan 2006). In addition, performances offer important support for their conservation.

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Les savoirs locaux et les aspects immatériels de l'architecture de terre dans le nord-ouest argentin : Le tourisme et la sauvegarde du patrimoine culturel

Mirta Eufemia Sosa

Résumé : *L'identité des peuples dans la région du nord-ouest argentin, étroitement liée à l'environnement naturel, est définie par leurs modes de vie, leurs coutumes et leurs rites ; par leur musique, leur cuisine et leur artisanat ; et par leur connaissance de la construction en terre, dont témoigne la qualité de l'architecture populaire. Depuis quelques années, le développement touristique – et le déploiement des infrastructures qui en résulte – ont sensiblement transformé le paysage architectonique vernaculaire qui tend à se dégrader. Cette situation regrettable nous rappelle que l'activité touristique doit répondre aux directives d'une planification du développement régional qui intègre la conservation et la mise en valeur du patrimoine historique et culturel.*

Abstract: *The identity of peoples in the northwestern region of Argentina, which is connected to the natural environment, is defined by their way of life, customs, and rites, by their music, cuisine, and crafts, and by their skill in building with earth, as expressed in the quality of their architecture. In the past few years one of the consequences of intensified tourism and the infrastructure development that has ensued has led to a significant transformation of the vernacular architectonic landscape, which is becoming degraded. This regrettable situation is a reminder of how important it is that tourism obey the guidelines for planned regional development that take into account conservation of historical and cultural heritage.*

Les symboles et les valeurs significatives d'une communauté s'expriment à travers des aspects tangibles et intangibles de son patrimoine culturel. Cette approche se vérifie particulièrement pour la région du nord-ouest argentin, connue pour l'empreinte culturelle héritée de l'occupation de populations

agro-céramistes pendant plus de 1 700 ans, jusqu'à l'arrivée des Incas en 1484, et des Espagnols en 1536. Cette région, aujourd'hui frontalière avec le Chili et la Bolivie, est, depuis plus de cinq siècles, le lieu de passages, d'échanges économiques et d'influences des hautes cultures andines du Nord de la Bolivie et du Pérou.

La géographie de la région et ses ressources naturelles, mais aussi son histoire particulière, ont modelé et configuré les expressions de la vie de ses habitants. Son identité est intimement liée aux ressources que la Terre-mère – *Pachamama* – lui offre. Dans sa cosmovision du monde, la terre atteint différentes dimensions et significations.

Les plus anciennes architectures de terre qui subsistent sont des églises datant de la période hispanique, c'est-à-dire entre le XVII^e et le XVIII^e siècle. Mais l'architecture populaire est tout aussi remarquable et les réponses constructives et formelles sont aussi bien adaptées que pour l'architecture religieuse, et parfaitement inscrites dans le respect de l'identité architecturale de la région.

Contexte géographique

La République d'Argentine est le pays le plus méridional de l'Amérique du Sud (21° 47' 3" de latitude sud) et le huitième en taille, avec une surface de 2 791 880 km² répartie sur une bande longitudinale nord-sud qui lui confère une grande variété de paysages naturels.

Les facteurs naturels (climat, végétation, flore et faune), économiques et politiques ont une grande influence dans la répartition de la population. Les régions les plus peuplées actuellement se trouvent en plaine. La région dont traite cette étude comprend les provinces de Jujuy, Salta et Catamarca.

Elle est peu peuplée par rapport au reste du pays, avec presque 3 700 000 habitants répartis sur une surface de 335 000 km². C'est la surface de l'Italie qui compte 58 000 000 d'habitants, huit fois celle de la Hollande et presque dix-sept fois celle d'Israël.

La région du NOA (nord-ouest argentin), du point de vue géographique, est un lieu de transition entre les hautes plaines boliviennes et chiliennes et la région de plaines et forêts humides et tièdes de l'Argentine. La morphologie du sol monte du sud-est au nord-ouest de 200 m à 4 000 m, avec une haute plaine appelée *puna* qui se caractérise par des chaînes de montagne de presque 6 000 m avec des volcans, des lacs et des étendues couvertes de sel appelées *salares*, entre lesquels s'étendent de grandes vallées qui descendent vers l'est et le sud, liées par des passages étroits entre deux montagnes appelées *quebradas*.

Le climat (température et humidité) est directement en rapport avec l'altitude et les caractéristiques du relief, avec comme particularité une grande ampleur thermique entre le jour et la nuit presque toute l'année.

Contexte historique

La délimitation de la région nord-ouest est due à une division morphologique du territoire argentin. Cependant, on ne peut pas considérer isolément toutes les populations qui l'ont habitée sans les considérer comme intégrées au passé culturel commun à tous les peuples de l'Amérique du Sud.

Le NOA argentin a été parcouru il y a plus de 10 000 ans par des groupes de chasseurs et cueilleurs nomades. Lorsqu'ils sont devenus sédentaires, ils se sont installés dans les vallées de *quebradas* et de *puna*, en deux périodes : la période formative (600 av. J.-C. à 950 ap. J.-C.) et la période du développement régional (950 à 1480 ap. J.-C.). Vers le milieu du XVI^e siècle, les Incas sont arrivés sur le territoire et ont transmis leur influence dans la région comme le prouvent les vestiges archéologiques trouvés dans la vallée de *puna*, les vallées *calchaquies* et les *quebradas* : des sanctuaires (*tampus*), des auberges, des centres administratifs, des entrepôts (*collicas*), des mines, des enclos, ainsi qu'un réseau de routes construites stratégiquement, qui liaient les centres administratifs avec Cuzco et le Chili. Des années plus tard, en 1536, ces mêmes routes furent utilisées par les Espagnols pour conquérir le territoire.

Les dernières populations autochtones, les *Diaguitas* et les *Calchaquies*, ayant occupé les vallées de Salta, Tucumán et Catamarca, ont constitué une unité sociopolitique forte.

Avec les peuples de la *quebrada* à Jujuy, il constituaient la population la plus évoluée d'Argentine, non seulement en termes de densité mais aussi de culture.

Avec la conquête et la colonisation espagnole à partir du XVII^e siècle, les populations se sont établies sur des lieux stratégiques du territoire, soit sur de nouveaux emplacements, soit entre les noyaux indigènes préexistants. Dans un premier temps, les circulations se faisaient principalement par les « chemins de l'Inca », raison pour laquelle les édifices les plus anciens se situent dans la *puna* et dans les vallées *calchaquies*. Lorsque la présence espagnole s'est renforcée, la *quebrada* d'Humahuaca est devenue une importante voie de communication et d'échange commercial entre le Pérou et Río de la Plata (Buenos Aires), permettant la croissance et le développement des populations placées sur cette route.

À partir de la fin du XIX^e siècle, avec les changements qui se sont produits dans l'économie du pays, les secteurs ruraux de la région sont devenus des marchés périphériques pour l'industrie nationale. En revanche, les villages les plus isolés et éloignés ont connu peu de changements de leurs caractères originaux (paysage naturel et modes de vie des habitants), ce qui a favorisé la conservation des styles architectoniques et des techniques constructives traditionnelles (fig. 1).

Les peuples et l'architecture de terre

Dans un étonnant paysage de formes, de couleurs et de textures, ce paysage naturel et l'architecture font partie du patrimoine culturel de la région.



FIGURE 1 Rue du village d'Iruya, Puna.

Le patrimoine culturel tangible et intangible reflète les valeurs appropriées et partagées par la communauté. Ces valeurs se traduisent dans les modes d'occupation et d'exploitation du territoire, dans les architectures monumentales ou domestiques, les manières et les modes de vie, les diverses formes d'expressions artistiques et les savoir-faire constructifs, basés sur la connaissance d'une technologie ancestrale : la construction en terre.

L'expression architecturale de la période coloniale résulte d'un processus de synthèse fondé sur trois facteurs fondamentaux : l'habitant natif avec son savoir faire culturel et technologique, l'Espagnol avec son savoir architectonique, et le milieu naturel. La confrontation des modèles architectoniques et des savoir-faire européens avec la culture constructive locale a abouti à une volumétrie pure et des formes simples caractérisées par des murs épais et bas, et des toitures plates légèrement pentus pour s'adapter à la pluviométrie de la région. La connaissance de la technologie constructive adaptée au milieu naturel (géographie et climat), a déterminé la conception architecturale de cette époque. Jusqu'à la moitié du XX^e siècle et dans quelques régions encore, la terre comme principal matériau de construction définit le caractère et l'expression des constructions (fig. 2).

Les constructions caractéristiques sont les églises qui datent des premières fondations espagnoles entre les XVII^e et XVIII^e siècles, les demeures des fermes et l'habitat rural. Des villages entiers sont construits en terre, en parfaite symbiose avec l'environnement, sur lequel se détache le profil des églises plus hautes et peintes en blanc (fig. 3).



FIGURE 2 Façade d'une demeure traditionnelle du village de Tilcara, Quebrada.



FIGURE 3 Église d'un village de la puna.

L'église et la chapelle, anciens symboles de l'action évangélisatrice espagnole, sont aujourd'hui les principaux lieux de rencontre du peuple, à l'occasion des activités religieuses et sociales qui s'y déroulent. Le bâtiment est constitué de volumes de différentes tailles et proportions, le principal étant celui de la nef, à laquelle s'adossent une ou deux tours clochers et, occasionnellement selon l'envergure du bâtiment, d'autres volumes plus petits qui correspondent à la sacristie, aux chapelles latérales et au baptistère. La chapelle, en général, ne comprend ni chapelles latérales ni sacristie.

Par leur mode de vie, les peuples autochtones accordent une grande importance aux espaces extérieurs. L'église est ouverte sur la grande place par un espace religieux de transition, l'*atrium*, où la population peut se réunir. On note une typologie particulière dans certains villages de la vallée de *puna* qui présentent une place publique totalement intégrée à la vie de l'église avec des chapelles (*posas*)¹ dans chaque angle et la chapelle *Miserere*² au centre. L'un d'eux, le village de Casabindo, est très connu pour la fête religieuse de la Vierge et le culte de la célébration de la *Pachamama* qui s'y déroulent sur la place le 15 août, en même temps que la fête populaire du taureau de la *vincha*³ (fig. 4).

Une autre typologie constructive concerne les demeures des propriétaires de fermes et les maisons rurales parsemées dans la campagne ou regroupées en villages. La cour centrale et la galerie qui l'entoure sont les éléments caractéristiques de cette architecture. C'est le lieu du travail quotidien et des réunions familiales. C'est là aussi qu'on enterrait les morts à l'époque préhispanique.



FIGURE 4 Fête populaire du « Ruban du taureau » sur la place de Casabindo.

La maison isolée, avec son caractère résidentiel et son autonomie productive, se maintient dans le monde rural (fig. 5). Cette typologie, à son tour, a été transférée par ceux qui ont émigré dans les villages, et ont adapté sa configuration à la trame du centre habité.

Le peuple et la terre

L'identité culturelle du NOA, avec son paysage de *puna*, de *quebrada* et de vallées, de maisons et d'églises de terre en harmonie avec l'environnement, son économie agricole et pastorale typique, ses propres expressions artistiques – musique de *sikus*⁴, *cajas*⁵, *erquencho*⁶ et des artisanats imprégnés des couleurs de la terre – résulte de la symbiose entre les cultures agro-céramistes autochtones et espagnoles (fig. 6).

Les différentes expressions artistiques, coutumes et rites, transmis oralement de génération en génération, coexistent avec les fêtes religieuses. La manifestation du sentiment de l'homme rural et son lien à la terre est exprimée dans le culte le plus populaire des cultes indigènes : le tribut à la Mère Terre ou la Nature, la *Pachamama* (*pacha* : univers, monde et *mama* : mère). Dans la cosmovision de l'homme rural andin, la terre n'appartient pas à l'homme mais l'homme appartient à la terre. La *Pachamama* est présente dans les différentes étapes de la vie de l'homme et c'est elle qui fournit les aliments, les animaux et la laine pour les tissus, les minéraux, le matériel pour la poterie, pour les demeures ; c'est l'inspiration de sa production artistique. La tradition constructive dit que l'on



FIGURE 5 Habitat rural de la quebrada.

ne peut pas utiliser la terre pour faire de l'adobe à n'importe quelle époque de l'année, mais seulement au moment des récoltes, quand elle donne des fruits, quand la terre est vivante. De toute façon, actuellement, un adobe ne se « coupe » presque pas à la saison des pluies ou quand il fait très froid.

La vie austère et silencieuse de la population change lorsque l'on rend hommage au mois d'août à la *Pachamama*, en donnant « à manger et à boire » à la terre avec des offrandes de nourriture, de boisson et de feuilles de coca ; ou quand on fait la fête le jour du saint patron du village ; ou encore, lors



FIGURE 6 Fête en l'honneur de la Vierge.



FIGURE 7 Fête des « copleras » dans le village de Pumamarca, Quebrada.

du carnaval qui mêle le religieux et le païen. Les maisons, les rues, l'église, la place, s'habillent de couleurs avec la procession des *misachicos*⁷, la musique des *sikus*, des danses, des chants, et des *bagualas*⁸ (fig. 7).

Des festivals folkloriques, avec des chansons, des danses et des repas typiques sont organisés depuis une dizaine d'années. On fête ainsi la fécondité de la *Pachamama* et chaque communauté célèbre les fêtes de la noix, du maïs, du tabac, des légumes et autres.

L'architecture et le tourisme

Depuis le siècle dernier, l'activité productive, minière et agricole s'est renforcée, les routes d'accès se sont développées, tout comme l'activité touristique. Le développement des infrastructures entraîne la démolition d'édifices anciens, le morcellement des terrains dans les zones agricoles, la vente de propriétés appartenant aux communautés autochtones et l'apparition d'une architecture (de vacances, d'hôtellerie, de restaurants et de locaux commerciaux) qui transforme le paysage de l'architecture vernaculaire.

Cela se produit dans toute la région, mais plus encore dans les vallées *calchaquies* et dans la Quebrada de Humahuaca (site inscrit au patrimoine mondial en 2003). Certains bâtiments nouveaux interprètent et incorporent des éléments typologiques de l'architecture coloniale en fonction des besoins et des demandes du tourisme. D'autres ne sont que de médiocres imitations qui n'ont rien à voir avec les sites



FIGURE 8 Les nouvelles façades ne respectent pas la tradition locale.

où ils sont bâtis. D'autres enfin sont construits sans maîtrise des technologies de la terre comme matériau de construction, et sans en considérer les qualités ni les limites. Ces nouvelles constructions ne s'intègrent pas bien à l'architecture locale car elles ne font pas le lien avec le patrimoine existant et ne tiennent pas compte de la valeur culturelle des sites lors du choix des emplacements (fig. 8).

De fait, on ne peut arrêter le processus de développement d'une communauté, toutefois la nouvelle architecture et les interventions sur des édifices existants doivent respecter les valeurs culturelles de l'endroit, qui sont justement les moteurs de l'activité touristique. Dans ce contexte, il est nécessaire et juste que la nouvelle architecture constitue une alternative valable pour le développement local, la conservation et la mise en valeur du patrimoine historique et culturel, et notamment de l'architecture de terre, monumentale ou domestique.

La connaissance transmise de génération en génération, qui a permis le maintien des constructions en terre en milieu rural, s'est malheureusement affaiblie dernièrement. On assiste en effet à une perte progressive de connaissances des nouveaux constructeurs concernant les techniques constructives autochtones. Il semble donc essentiel de maintenir et de préserver les savoirs traditionnels en faisant appel aux communautés. Il faut aussi renforcer les connaissances et les compétences des professionnels et techniciens qui doivent intervenir dans cette région pour des constructions neuves ou pour la conservation de bâtiments existants.

La sauvegarde du patrimoine culturel, en revalorisant l'identité des peuples, constitue un des principes de base du développement local, qui devrait répondre à une planification du développement régional. De même, l'intervention dans le paysage construit, s'agissant de restauration et de conservation du patrimoine en terre, implique la reconnaissance de principes théoriques de conservation du patrimoine et d'identité culturelle des peuples, mais aussi de revalorisation des pratiques et des connaissances techniques locales.

Notes

- 1 Petites chapelles où l'on met des images pieuses pendant les fêtes religieuses.
- 2 Endroit comportant une croix marquant le lieu où sont enterrés les morts.
- 3 Cette fête consiste à décorer les cornes d'un taureau avec un ruban (*vincha*) décoré de pièces de monnaies que l'on offre à la Vierge. *Vincha* est un mot quechua.
- 4 Instrument de musique à vent composé d'une double rangée de roseaux de longueur décroissante.
- 5 Petits tambours.
- 6 Instrument de musique à vent composé d'une grande clarinette réalisée avec une corne de vache et une embouchure de roseau.
- 7 Urnes vitrées ornées de fleurs multicolores en papier, où l'on place l'image de la Vierge ou d'un saint.
- 8 Chansons populaires en vers octosyllabiques, que l'on accompagne à la caisse (petit tambour).

Traditional Experiences in Mud-Brick Conservation and Its Optimization

Mohammad Hassan Talebian and Afshin Ebrahimi

Abstract: *Many historic earthen buildings are lost or damaged because older structures require serious maintenance, which often does not occur. At the same time, we lose invaluable experience and knowledge of workmanship that come from building with traditional materials and methods. Clearly in such conditions, one must attempt, at the very least, to document this heritage. Preliminary documentation has been carried out by conducting interviews with workmen in different parts of Iran. As a first step, our inquiries, which included thirty questions, were given to workmen. The result after two years was 391 interviews from thirty provinces. This research has produced considerable data on current conditions and experiences.*

Résumé : *De nombreuses constructions en terre disparaissent ou sont endommagées car les anciennes structures exigent un sérieux entretien, souvent négligé. Nous perdons là une expérience et un savoir-faire précieux associés aux méthodes et aux matériaux anciens. Dans ces conditions, il faut au moins tenter de documenter ce patrimoine. Une documentation préliminaire a été effectuée à partir d'entretiens avec des ouvriers dans différentes régions d'Iran. Dans un premier temps, notre enquête portant sur 30 questions a été effectuée auprès des ouvriers. Deux ans plus tard, 391 entretiens avaient été réalisés dans 30 provinces. Cette recherche a permis de collecter des données capitales sur les conditions et expériences actuelles.*

The research plan presented here was developed by the Mud Brick Studies Bureau under the auspices of the International Project of Choghazanbil and the Parsa-Pasargadae (Persepolis) Research Foundation. Since 1998 the Mud Brick Studies Bureau has based its research plans on the identification and

preservation of Iranian earthen heritage, which includes the following steps:

- Compiling and analyzing local experiments regarding the conservation and optimization of mud brick in Iran;
- Recording conservation experiences to salvage Iranian earthen heritage;
- Developing a typology of mud-brick and earthen architecture in the context of Iran;
- Providing a distribution atlas of Iranian earthen heritage; and
- Conducting studies of Iranian earthen heritage.

The research plan is aimed at the introduction and documentation of invaluable technical experiences regarding the earthen architecture of Iran, which have come to us from previous generations (figs. 1–3).

In order to develop a national research plan for the conservation and optimization of mud brick in Iran, our research team prepared a questionnaire to determine the needs of those working in the field. A comprehensive approach was needed because of the inconsistent nature of the available data, the need to readily access information, the broad geographic expanse of the country and variety of climatic zones, the technical challenges, and the exceptional restrictions placed on projects, especially with respect to field operations. The questionnaire was administered in various parts of the country using an interview format. Experienced head artisans of earthen structures were targeted for their knowledge and expertise.



FIGURE 1 Acropolis—Susa, 2007.



FIGURE 2 Ghale Pachenar—Semnan, 2006.



FIGURE 3 Kushk-e Jajerm—Khorasan, 2007.

The questionnaire consists of thirty technical questions posed in simple words that focus on mud-brick and earthen architecture. The format was designed so that respondents could express their views and experiences in a relaxed manner. Specific topics included soil selection, soil preparation and optimization, mud-brick processing, consolidation of materials using additives, proper usage of materials in construction, traditional knowledge, and revitalization of earthen architectural heritage.

In addition to developing a questionnaire that was sensitive to the respondents, another important point was to test our research methodology to see where and how it should be

conducted and with whom. Special attention was paid to relevant locations and persons, and priority was given to gathering information in those regions where workers had the capacity and capability to answer the questions with judgments based on substantial background and experience in all areas related to mud-brick architecture. Due to the broad scope of this plan, 108 locations were selected in twenty-eight provinces of Iran. A total of 391 interviews were conducted over two years (fig. 4). The following section includes a completed questionnaire from Kermanshah province (Mahidasht township), one of the 391 interviews conducted.



FIGURE 4 Interviews were conducted with experienced head artisans in 108 locations in Iran's provinces, 2006.

Questionnaire and Interview Forms

A-Interviewee

Name: Noorullah Abbasi

Age: 52

Place of Occupation: Kermanshah province (Mahidasht)

Record of Service: 40 years

Notes: This person has been active in mud-brick construction and maintenance since childhood and is one of the most experienced users of *kahgel* (mud plaster).

B-Interviewer

Mahdi Nasiri

C-Date of interview

18th Aban 1383 A.H.

D-Questionnaire

1. *What soil is suitable to produce high-quality mud brick and kahgel (composed of straw and mud), and where do you obtain it?*

Dead soil, which is a kind of reused soil, is better for mud brick making and *kahgel* producing. To every five to six carts of this soil, a cart of plowed desert soil is added, which makes it very strong, just like mud and gypsum mortar.

2. *What are the physical characteristics of a soil appropriate for mud brick and kahgel production?*
Soil belonging to ancient hills, which are actually rubble or dead soil, is suitable for mud brick making because the mud brick produced will have no defects for five years even when exposed to rain.
3. *Which soils are better for producing mud brick and kahgel: riverside or plain soils?*
Riverside soils lose their adhesiveness because they are getting wet constantly, so they are not proper for making mud brick and *kahgel*.
4. *How do you prepare the soil used for mud brick and kahgel production?*
First, clumps of soil. Clods must be crushed using the back of a spade and the hard ones discarded. I have

plastered one of the rooms of my own house with this mud. It became so smooth that no gypsum was needed, and I painted it directly.

5. *In your opinion, what proportion of clay and sand is suitable for making mud brick and kahgel?*
Usually we do not use sand.
6. *How much straw do you think is suitable to add to soil in order to make mud brick and kahgel?*
During mud brick making, two sacks of straw are used for every ten carts of soil. Using *kolash* is preferable because it is longer than straw and lasts longer.
7. *Do you use large or small soft straw for making mud brick and kahgel? Why?*
We use *kolash* in order to make mud brick, but for *kahgel* wheat straw is used. If straw fibers are too long, we cut them with the edge of a spade.
8. *Without the addition straw, if the mud brick does not crack, do you still recommend adding it?*
Usually straw must be used, but not using a large amount of it is preferable. I cure the straw for two or three days by spreading it on the ground until it is soaked. Then I knead it so the mud brick does not crack. After mud brick making some water and straw are rubbed on it to prevent cracking.
9. *Have you ever thought of using another material instead of straw?*
Nothing else can be used. An alternative method is to cure the mud for one week, not adding any water to it; try to avoid kneading it with the feet but separate it using a pick, and then add a little water.
10. *How do you prepare mud in order to make mud brick and kahgel? (How do you perform the processing?)*
Mud must be cured for one week, then dehydrated completely. Thereafter no more water is added to it, and it is not kneaded; instead it is broken by a pick and put into the mold. For every thousand molds of mud brick, about 30 kilograms of straw is used. For *kahgel*, every ten sacks of soil need approximately 120 kilograms of straw. It is better if there is an equal amount of soil and straw. If the straw contains wheat and barley grains, it must be abandoned for a few days until they decay.
11. *During mud brick molding, what do you do to speed up the operation and increase the quality?*

This mostly depends on the person's physical strength. For example, I am fifty years old and cannot press mud in molds as my son does. Many people add clods and stone pieces to the mud inside the mold in order to produce more mud bricks, which makes them break during their transfer. Usually for easy removal of mud bricks from molds, straw is sifted to produce soft straw, then poured inside the mold. In addition, molds are not made very thick so that mud can be easily pressed in.

12. *During mud brick drying, what do you do to prevent cracking and deformation?*
Mostly it depends on the way mud is produced. If it contains any gravel, bones, or refuse, it will fracture during drying, but adding some straw to the mud brick reduces its cracking.
13. *Is there a certain method of arranging mud bricks in order to dry them better?*
Usually the ground surface is covered with straw so that the mud bricks do not touch the ground. After one day, the mud bricks must be transferred gently and arranged in a chainlike fashion in order to dry on both sides. Then they must be numbered, for example, one mold is put aside for every one hundred mud bricks, so that eventually their number is calculated.
14. *Do you prefer the properties of a wetted mud brick or a dry mud brick?*
It depends on the relevant use as well as individual taste.
15. *What do you do for better adhesion of kahgel plaster on mud-brick walls?*
Plowed and strawless soil is cured for one day after dehydration, then mud is applied on the mud-brick wall, which then cracks. Afterward a layer of *kahgel* is rubbed on the fractured layer to fill up the cracks. Otherwise, the *kahgel* layer bulges and collapses during winter. But if the above-mentioned method is used, the *kahgel* layer lasts for more than ten years. Also, it is better to press *kahgel* into the joint between the mud bricks, if possible, with the end of a trowel.
16. *Does the type of kahgel change depending on where it is used in a building? How?*
For inner walls, no large straw should be used because it is usually overlaid with gypsum or painted. Of course, it is better to apply gypsum and soil before the gypsum layer.

17. *What are the differences between underlay and overlay (finishing) kahgel regarding their production and usage?*
First the wall must be scraped and then watered. Kahgel must be cured for one week by being spread on the ground and kneaded more when applied until fermented. Also, the straw should be fresh.
18. *If polishing the surface of kahgel is necessary, how do you do it, and with what tools?*
At present a trowel is used, but this requires some skill. *Pialeh* (a piece of glazed ceramic) has also been used. Kiln makers used to rub a piece of glazed ceramic on the kiln surface in order to make it smooth and polished.
19. *What sort of mortar do you suggest for mud bricks?*
Mud mortar applied between mud bricks is the best.
20. *What are your experiences and knowledge about increasing the quality of mud brick and kahgel using additives?*
Using residual straw (that remaining on the floor of the barn) improves the quality of mud brick and kahgel. Also, if sheep dung ashes are used in the soil, resistance of mud brick and kahgel plaster increases significantly.
21. *What method do you suggest to fight against termites?*
There are not many termites here.
22. *What method do you suggest to deter the growth of plant roots in mud brick and kahgel?*
After adding water to the soil, we wait for one week until plant seeds grow; some do not grow and decay.
23. *What do you do in order to improve the resistance of mud brick and kahgel plaster against rain or moisture?*
After filling up the foundation of the building, stones are laid one course above the ground and then mud bricks are placed on them.
24. *What do you do to improve the strength of mud brick against pressure and abrasion?*
Depends on mud processing, which if done accurately makes mud brick and kahgel stronger. For example, if in kahgel production clean straw is used and there are no pebbles in the soil, it lasts for many years.
25. *What is the difference between ordinary mud bricks and those used in brick burning?*
The soil does not differ. In mud bricks to be fired, some straw is used too, but it must contain no pebbles. Sheep dung is also delivered to Hamedan and Kangavar to be mixed with soil, which is eventually used in mud brick and brick making.
26. *How do you produce and use chineh (cob)?*
First, the earth is plowed, then water is poured in order to get sour ("processed"). Then it is stirred with the feet. Afterward, it is made into a mound and cut in pieces to be handed to the master to build chineh.
27. *What are the advantages of mud-brick buildings compared with other ones (brick, stone, wood)?*
Mud-brick homes are cooler than brick or cement ones in summer and warmer in winter. Stone, brick, or cement homes get warm with difficulty, which is not true of mud houses because in these homes, even during wintertime, the doors can be left open. In summer there is no need for a cooler or fan. It seems as if we are in a tent in the middle of a forest.
28. *What do you think is the most important characteristic of mud-brick architecture in this region?*
We only put sticks on straw piles in order to protect them, and then a layer of kahgel is applied.
29. *What is your most important recommendation for restoring a historic mud-brick building?*
Depends on the financial situation. If brick is available we use it; otherwise we apply mud.
30. *What do you suggest for increasing the usage and popularity of mud-brick architecture?*
As long as brick and cement are available, mud-brick structures will not become popular. I recommend constructing at least the non-load-bearing walls with mud brick so that heat and cold cannot penetrate.

Statistical Study

As previously noted, in addition to documentation, analysis of the raw data collected from scientific and statistical aspects is an important aspect of the current research plan. As there is no opportunity in this brief paper for discussion of all the research achievements, only a portion of the statistical investigations conducted in Kermanshah province are discussed. Among the thirty questions posed in the questionnaire, question numbers 2, 3, 9, 12, 19, 20, 21, 22, 23, and 24 have a more functional nature. A preliminary statistical examination of these ten questions shows the following:

Question 2: About 50 percent of the interviewees mentioned the redness of soil; about 25 percent, the age of soil (meaning historical hills); about 10 percent, its purity (lacking any rubble or rubbish). The remainder gave no definite answer.

Question 3: 100 percent of the interviewees believe that plain soils function better due to their cohesion.

Question 9: 100 percent of the interviewees believe that straw is the best option, but in mud brick making, it must be used as little as possible; 25 percent also had experience using ash.

Question 12: About 25 percent of the interviewees mentioned proper layout during mud brick drying; about 25 percent, appropriate mud processing; about 15 percent, level ground surface; about 10 percent, wind and the climatic condition as an effective factor. The remainder had no definite answer.

Question 19: 100 percent of the interviewees believe that mud mortar (preferably without straw) is the best option.

Question 20: About 75 percent of the interviewees cited spilling salt on roof kahgel and its subsequent rolling; around 15 percent, using sheep dung ash, about 10 percent, applying animal hair.

Question 21: About 50 percent of the interviewees said smearing wood sticks with burnt oil or gas oil; around 25 percent, using poisons; about 10 percent, applying lime. The remainder had no definite opinion.

Question 22: About 35 percent of the interviewees recommended removing green grass and rolling the roof again; about 15 percent, pouring salt on the roof; about 15 percent, cleaning the straw and removing seeds before usage; about 15 percent, abandoning grass (due to its lack of roots); about 10 percent, leaving the seeds to rot during mud processing. The remainder had no definite opinion.

Question 23: About 85 percent of the interviewees recommended constant inspections, blocking moisture penetration

routes, utilizing materials such as stone and lime in foundations, and strengthening *abccheks* (a traditional method of architecture diverting the course of rainwater in order to protect walls); about 15 percent cited appropriate mud processing before production and use of the material.

Question 24: About 75 percent of the interviewees recommended appropriate mud processing and compressing materials (pressing the mud inside mud-brick molds and rolling kahgel after slight drying); around 15 percent cited precise pointing with mud mortar. The remainder gave no clear answer.

Conclusion

The data collected, though not sufficient to answer all the questions concerning mud-brick and earthen architecture, established a reliable basis for research and can guide researchers and those interested in these matters toward a clear way for their studies. This plan, while introducing practical guidelines of conservation, also contains theoretical issues that can be used by the public and conservation specialists alike. Only when mud-brick monuments are no longer regarded as excessively complex can we express our satisfaction with the research results.

Seemingly, earthen structures will be accepted by the public only if the buildings both satisfy daily needs of life and are presented in a modern form. Unfortunately, it seems that the prevalent perception in our society is that the conservation of earthen architectural heritage is a hindrance to development. Lack of knowledge about conservation issues, as well as occasional mismanagement by relevant authorities, plays a significant role in these negative perceptions. Undoubtedly, introducing the cultural and physical values of these architectural products to the public and focusing on research plans will greatly improve the present situation.

Features in the Intangible Domain of Ndebele Earthen Architecture

Chris J. van Vuuren

Abstract: *The documentation of the intangible cultural heritage in Ndebele earthen architecture requires research techniques that are embedded in oral inventories such as age class dating and studies of early settlement sites. Other manifestations of intangible heritage emerge from an understanding of the spatial and cosmological order in the homestead and the mediation of space between the sexes. Ritual becomes a tool of empowerment for women to relieve tensions as well as reverse the male-dominated order. A comprehension of Ndebele mural art is captured in the intangible and protected knowledge base of women in a male-dominated society.*

Résumé : *La documentation du patrimoine culturel immatériel dans l'architecture de terre ndébélé requiert des techniques de recherche sous-jacentes dans les inventaires oraux comme la datation des classes d'âge et les études des premiers sites de peuplement. D'autres manifestations du patrimoine immatériel se fondent sur une compréhension de l'ordre spatial et cosmologique du foyer et la médiation de l'espace entre les femmes et les hommes. Le rituel devient un instrument d'autonomie pour les femmes, qui leur permet de soulager les tensions et de renverser l'ordre dominé par les hommes. La connaissance de l'art pariétal ndébélé fait partie de la base des savoirs intangibles et protégés des femmes dans une société dominée par les hommes.*

International (UNESCO 2003: 2–3) and South African (National Heritage Resources Act 1991: xxi) frameworks emphasize the issue of intangible heritage. The domains of intangible cultural heritage include “traditional craftsmanship” and “oral traditions and expressions.” The heritage of indigenous manifestations of the built environment is, therefore, also guided by the above

stipulations. In the South African act, the reference “living heritage” includes “skills and techniques,” as well as “Indigenous Knowledge Systems” (IKS).

This paper is an attempt to address the research process whereby these intangible inventories can be uncovered. A number of manifestations of the intangible niche in Ndebele architecture are also discussed.

Ndebele House Types

Ndebele settlement architecture evolved through three major typological stages: a precolonial grass (beehive) dome, a cone-on-cylinder (rondavel) type, and the current square and rectangular shapes. These developments should be seen not in terms of precise datable stages but rather as succeeding stages that often overlapped as earlier types were gradually phased out (Van Vuuren 1993: 51). The settlement layout of the Ndebele homestead also changed considerably over time. The precolonial model was similar to other Nguni (Zulu, Xhosa, and Swazi) patterns in what archaeologists term the “central cattle pattern” (CCP) (Huffman 2007: 25). This pattern consisted of a cattle byre in the middle surrounded by homes (for wives and children) and storage huts and similar facilities. The houses of the wives of the polygamous male head were usually positioned in order of rank and seniority (Van Vuuren 1983: 49–51).

The layout patterns changed considerably after 1883 (the Mapoch War), especially because of the introduction of large courtyard walls (*iirhodlo*) and square and rectangular house forms (called *iirhaesi*, derived from “house”) (Van Vuuren 1983: 44–45). The cattle byre (*isibaya*), now four-cornered in shape, still occupied a central position, but the general layout

resembled an elongated *n* or linear shape (see fig. 1). This pattern, although still in existence in some rural areas, has largely disappeared.

Memory and the Ndebele Cone-on-Cylinder House

By 1978 the use of this type of house, a thatched conical roof on a double earthen wall, had lapsed, as had the knowledge base of its construction. The written record (Meiring 1955) also presented serious limitations, such as data on house form variation and the listing of building materials. At this time the author located almost thirty sites in the Middelburg district, Mpumalanga, that had archaeological remains of early cone-on-cylinder houses. A decision was made to access the oral records to the extent possible. A major challenge, however, was locating and interviewing those Ndebele men and women who possessed the necessary oral knowledge. The author took note of the existence of a unique local dating system that is ingrained in the Ndebele initiation age class system.

In brief, the system operates as follows. The Ndzundza-Ndebele allocate fifteen regimental names (*iindanga*) in a fixed cycle to males, who are initiated every four years. The cycle repeats itself after approximately sixty years. It is possible to backdate each regimental date of installation to at least the nineteenth century. Men remember their own *indanga* names, as well as those of all the members in their male lineage. Ndebele women also associate themselves with the regimental names of their husbands for comparative purposes.

If a man named Peter Sibiya, for example, was initiated in the Dzibha regiment in 1939, it would be possible to calculate his approximate date of birth to 1919 (1939 minus between 18 and 20 years). This would place him in an age-time category during which he would have gained some knowledge of the cone-on-cylinder houses from at least the 1930s onward (see also Van Vuuren 1993: 52–54). The author decided to identify a number of these “dated” elders and accompany them to these unidentified settlement sites.

The men who were initiated in regiments in the period 1907–23 were remarkably helpful. The author obtained important design information, such as the approximate diameter, the spatial arrangement of structures in the homestead complex (*umuzi*), and indigenous terms for various construction components and processes. These men were also able to supply data on building materials—some of which had strong regional variables. In most cases the author was able to establish the ownership of early homesteads and trace many

descendants using the genealogical method. Subchronologies for this type of house were also established. The approximate settlement histories were established for about 90 percent of the case sites.

Spatial Orientation in Ndebele Architecture

The human body often serves as a source of inspiration. This notion is not uncommon in Africa, as Tilley (1999: 45) reminds us: “Human metaphors in architecture are grounded in the use of the body as a model for comparable structural, decorative and symbolic forms.” In the same vein, spatial orientation and direction stemming from the bodily metaphor are reflected in architecture and settlement. Directions are presented and represented in dichotomies that are gender-specific. Other orientations are reflections of rank, status, and seniority within the homestead and Ndebele society.

The Ndebele homestead (*umuzi*) used to be occupied by a male and his wives. Homestead remains dating to between the 1930s and 1950s, however, reflect layout patterns that were typical of the three generational polygamous types, such as a man with four wives and his descendants.

The early Ndebele homestead was divided into two halves along the 12:00–6:00 axis if one compares it with a watch. These halves are invisible and consist of a right-hand side (*ububene*) and a left-hand side (*ikhohlo*) (fig. 1). The Ndebele determine right and left by turning the back on the 12:00 position of the homestead, thus facing the main entrance. The house (*indlunkulu*) of the principal wife is placed at the 11:00 position and that of the second (*ikhohlo*) wife at the 1:00 position. Third, fourth, and lower-ranked wives are placed on either side of the abstract line, thus third and fifth wives right (10:00 and 09:00 positions) and the fourth and sixth wives on the left-hand side (2:00 and 3:00 positions) (Van Vuuren 1983: 43). This orientation dualism is not uncommon in the South African homestead, especially among Nguni-speaking communities such as the Zulu, Swazi, and Xhosa (Kuper 1980).

The left/right dichotomy is still, to a certain extent, maintained within the Ndebele house. The house (*indlu*) is divided into right and left sectors. The right-hand sector is known as the *incamadoda*, literally, “of men”; the left-hand sector is known as *incabafazi*, literally, “of women” (Van Vuuren 1983: 200–201). This gendered dichotomy depicts binary oppositions between the daily worlds of the male and female. The dividing line is abstract or intangible, running from front (door entrance, called *umnyango*) to back (the *umsamo*, which is an elevated earth-built bench). The abstract line functions as



FIGURE 1 Linear-shaped Ndebele homestead near Stoffberg, Mpumalanga. Typical left/right dichotomy indicated. Photo: C. J. van Vuuren

an indicator of perceived male and female space even within the modern square and rectangular house. Only in this case the back is not turned toward the 12:00 position of the house.

Kuper's (1980: 15) suggestion of a dichotomous orientation, that is, a diametric (left/right) and concentric (inner/peripheral) orientation, is convincing. Symbolically, the left/right dichotomy often accounts for the categories of left (evil/female) and right (good/male) (Tilley 1999: 39) and front (the living world) and rear (the ancestral world) (Kuper 1980: 14).

Gendered Space

The patriarchal order in the Ndebele homestead is also embodied in the design of thoroughfares and corridors in the homestead. Houses in the Ndebele homestead are interlinked by an impressive courtyard wall system. Each house is surrounded by a courtyard (*isirhodlo*), which accentuates privacy and ownership and provides protection against nature (fig. 2). Tilley (2006: 24) argues that the house serves as the domestic, creative center and personal "other" of the public domain. Before the 1950s these courtyard walls were built to a height of up to 180 centimeters, but this practice has largely fallen away since the 1980s (Van Vuuren 1983: 261). A courtyard wall, constructed along the 09:00–15:00 axis of the house, divides the front and rear sections. The rear section is known as *isibuya* and the frontal section as *isirhodlo*. *Isibuya*, as space, equals female territory, that is, space to rear children, pre-



FIGURE 2 Frontal courtyard walls of the Mithombeni homestead in Dlawulale, Limpopo. Photo: C. J. van Vuuren

pare food and beverages, and dispose of domestic waste. This section, which includes the house, symbolizes a female and private domain, whereas the front section of the courtyard, or *isirhodlo*, is regarded as male and public space.

Interlinking courtyard walls between houses are accessed by several corridors and thoroughfares, called *imikgothana* (fig. 3). To the ordinary person, these corridors obviously provide mobility for residents between sectors. From an intangible perspective, these corridors arrange for the flow and maintenance of the *ukuhlonipha* rule in Ndebele society. According to the *hlonipha* principle in Nguni society (Krige



FIGURE 3 Example of a corridor (*umkgothana*) between the front and rear courtyards. The woman who kneels in the frontal section is applying cow dung to the floor. Photo: C. J. van Vuuren

1957: 30–31), a bride honors and respects her father-in-law by observing a range of rules of avoidance; for example, she should not face him, address him, or enter the same room or a restricted space where he sits and stands. If during her daily movements around the homestead she comes into close proximity to him, she utilizes these courtyard corridors to avoid him, even if it involves walking through a neighboring courtyard to her destination (Van Vuuren 1983: 64) (fig. 4).

During the 1980s Ndebele men blamed the decline in *hlonipha* respect on a lack of “proper” homestead design, in other words, a design that did not have corridors to allow for the “flow” of *hlonipha* principles. In this regard, Moore (1986: 162) argues that space is “an objectification of the male world view.”

Female initiation ritual (*iqhude*) in Ndebele society challenges these male perceptions and transforms the social rank and status of women, as well as their control of space and resources in that society. Although it is a temporary situation (mostly over weekends), the ritual nevertheless empowers women to reverse the male/female dichotomies in settlement space. During the girls’ initiation male space becomes female space, which is dominated by female relatives and age mates of the initiate. Women outnumber men, and men are marginalized to outer areas around the core homestead. Men are invited back during ritual occasions and announcements, and even the girl’s father is “told where to sit.”

Women occupy central positions in the frontal courtyard (*isirhodlo*), the interior of the house and the public space

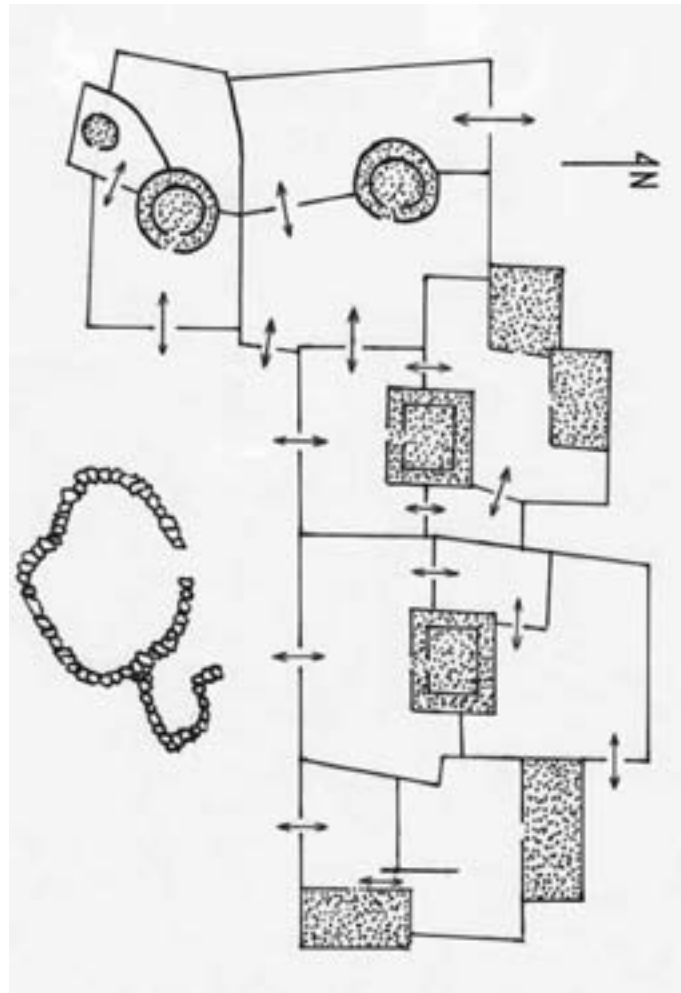


FIGURE 4 Plan of the nine-house homestead of the late Jonas Mthombeni, on the farm Kafferskraal, near Stoffberg. Arrows indicate thoroughfares. Principal access is from either side of the stone-walled cattle byre.

between the front of the homestead and the cattle enclosure (Van Vuuren 1993: 7) (fig. 5). The claiming of male space during the girls’ initiation ritual becomes a victory in what Lincoln (1969: 93) has termed “the battle of the sexes.”

The Intangible in Ndebele Mural Art

The Ndebele of South Africa have captivated the world with their mural art and beadwork. This mostly geometrical, multi-colored and visually inspiring style of wall painting has since the 1950s drawn the attention of both the popular media and scholars (Bakker and Van Vuuren 2006: 124). The national

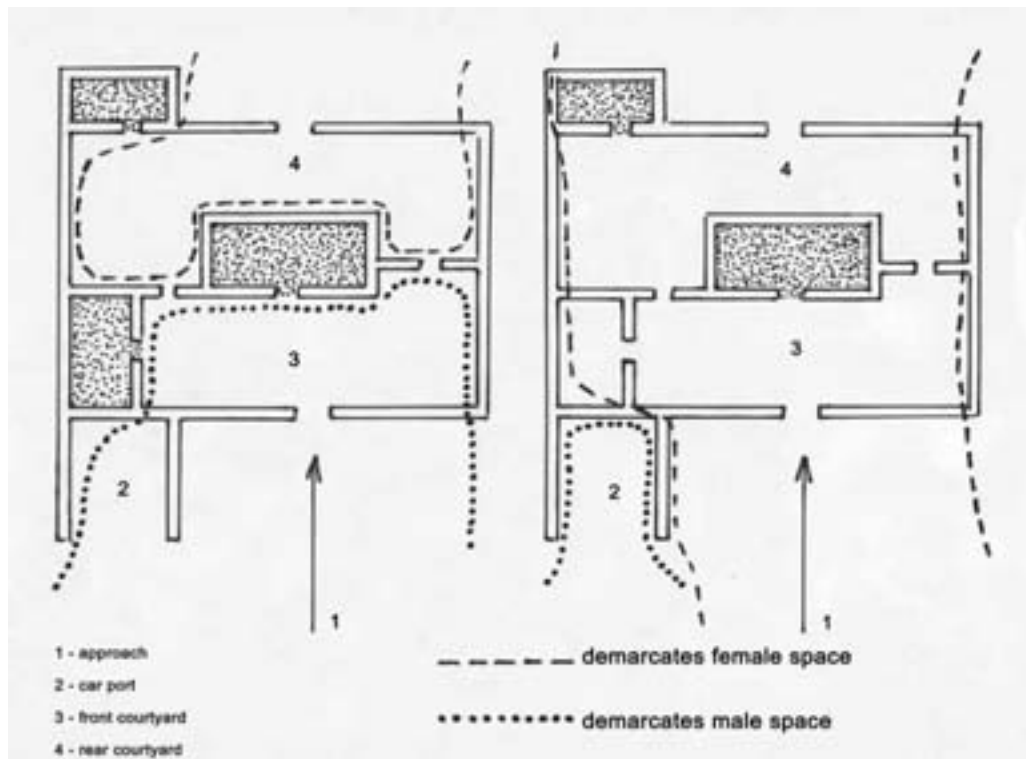


FIGURE 5 Diagram of the three-house homestead of the Mnguni family in KwaNdebele, Mpumalanga province. The diagram on the left indicates the routine gender division. The diagram to the right indicates the ritual division.

and African identity of the Ndebele mural art is the dominant narrative.

Ndebele mural art has earned this community a distinguished cultural identity (Schneider 1985: 62). Ndebele women and their daughters paint their houses and courtyard walls according to their *isikhethu*, that is, “ours” or “our culture.” This style has also become contrasted with modern tendencies in style variation mostly advocated by younger Ndebele women. It has become a generation identity. Since the 1883 diaspora of the Ndebele and the introduction of the farm life period (roughly 1883–1970), regionality in style, particularly motif, color, and paint, has become a clear marker of differentiation (Schneider 1985: 62–63; Van Vuuren 1983: 60–68). Modern acrylic paints were introduced in areas closer to the urban fringe, while earthen pigments are still used in rural areas (Van Vuuren 1983: 165) (fig. 6).

Apart from traditional geometric designs (steps and triangles), Ndebele women introduced a range of themes that they incorporated into their geometric designs. These included the shaving blade (*itjhefana*), airplanes, automobiles, urban icons such as lampposts and facades, motor registration letters, potted plants, and many others. It is suggested that these designs inform one very specific gender-related



FIGURE 6 Modern mural art accommodates both earthen pigments and commercial paints. Note the lamppost design on the corner wall. Photo: C. J. van Vuuren

issue. According to Lina Matjiya (age fifty-eight), Ndebele women have established social networks in urban areas since the early 1900s, mainly by kinship ties: “I visited my aunt in

Pretoria, and we walk around church square and I see the buildings and I paint these when I return.” It gives her freedom and enhances her creativity, and she notifies the (male) world where she has been.

The frontal courtyard might be male and public space, but its dominating visual impact is entirely female. Ndebele women paint the outer frontal wall freely and in an elaborate style. They might add further lower walls to the front (see fig. 6) and model a bridge with anthropomorphic figurines at the entrance, without any interference from the male household head. In brief, the homestead reflects how the Ndebele woman projects herself.

Conclusion

Traditional earthen building styles and the associated knowledge base in Ndebele society have not survived modern developments and trends. The corresponding intangible elements of the earthen settlement have also thus been largely eradicated. Ironically, earthen building techniques have been sustained within economically marginalized and mostly rural Ndebele families. Fortunately, some of the nonobvious, invisible and intangible elements of socio-Ndebele earthen architecture were accessed using the indicated research techniques.

In order to establish an inventory of both the tangible and intangible components of earthen architecture, one needs to bring the holders and custodians of the local knowledge into the fold. Conservation efforts by the organized heritage industry will be rendered fruitless unless these craftspeople are included in any conservation project.

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PART FOUR

**Conservation and
Management of
Archaeological Sites**

**Conservation et gestion
de sites archéologiques**

Une collaboration exemplaire pour la conservation et la mise en valeur du site archéologique de Mari (Syrie)

Mahmoud Bendakir, Jean-Claude Margueron et Michel Dayre

Résumé : Depuis 1989, date de la signature de la convention de collaboration entre la Mission archéologique de Mari, CRATerre-ENSAG et la Direction générale des Antiquités et des Musées de Syrie, des efforts considérables ont été engagés pour la préservation et la mise en valeur des vestiges millénaires de Mari. Lancées sur une voie nouvelle, des étapes importantes ont été atteintes selon une démarche scientifique rigoureuse qui a permis d'explorer de nouvelles pistes de recherche pour mieux comprendre les processus de dégradation de l'architecture de terre dans un contexte archéologique. Elle a aussi permis d'expérimenter, puis d'appliquer, des solutions inédites pour sauver les ruines d'une disparition lente qui paraissait jusqu'alors irrémédiable.

Abstract: Since 1989, when a cooperation agreement between the Mari archaeological mission, CRATerre-ENSAG, and the Department of Antiquities and Museums of Syria was signed, considerable efforts have been deployed for the preservation, presentation, and interpretation of Mari's millenary vestiges. With this innovative approach, important steps have been taken in keeping with a rigorous scientific methodology. This approach has enabled new areas of research to be explored to understand the degradation processes of earthen architecture in an archaeological context. It has also enabled experimentation and application of novel solutions to save the ruins from gradual loss that was previously thought unpreventable.

L'exploration archéologique du site de Mari, entreprise depuis 1933, a permis de remettre au jour un nombre considérable de monuments de l'une des premières civilisations urbaines en Mésopotamie. Certains de ces monuments,

en particulier deux palais successifs du III^e et du début du II^e millénaire avant notre ère, sont à juste titre considérés comme des exemples uniques dans les annales de l'archéologie orientale.

Cependant, la nature du matériau de base de cette architecture, la brique de terre crue, fait que les ruines exhumées sont d'une grande fragilité ; les édifices retrouvés sont souvent méconnaissables à la suite des effets de la dégradation naturelle. L'absence de politique de conservation et de mesures de protection préventive a entraîné une dégradation rapide et brutale des ruines.

Avec l'arrivée de M. Jean-Claude Margueron à la direction de la Mission archéologique française de Mari en 1979, la nécessité de mettre en place une véritable stratégie de conservation a été instaurée comme un outil de gestion complémentaire à la recherche archéologique. C'est dans cette logique qu'une collaboration étroite a été nouée entre la Mission archéologique de Mari, CRATerre-ENSAG et la Direction générale des Antiquités et des Musées de Syrie. Depuis 1989, des efforts ont été engagés dans cette nouvelle voie et des étapes importantes ont été atteintes pour la préservation et la mise en valeur des vestiges millénaires de Mari.

Mari, exemple vivant des premières cités de l'histoire de l'humanité

Située dans la moyenne vallée de l'Euphrate, à la frontière entre la Syrie (fig. 1) et l'Irak, Mari est une ville entièrement nouvelle fondée au début du III^e millénaire avant notre ère, suite à une réelle volonté de créer un grand centre urbain. Cette fondation est née d'une volonté politique accompagnée d'une triple stratégie :

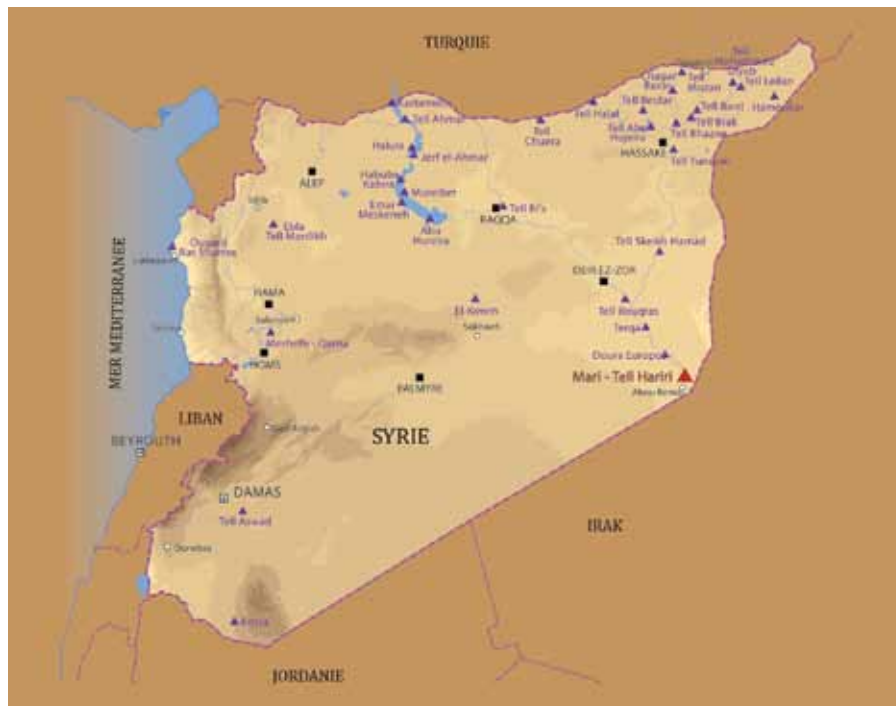


FIGURE 1 Localisation de Mari et des plus importants sites archéologiques en Syrie. Carte de la Syrie d'après Hélène David, IFAPO, 2003 retravaillée par Arnaud Misse

1. le contrôle du commerce par voie fluviale ;
2. le développement de l'agriculture ;
3. la maîtrise du phénomène urbain.

Parmi les premiers foyers de civilisation qui ont permis l'émergence et le rayonnement d'une architecture de terre originale et d'une culture constructive singulière, Mari occupe une place de premier choix. L'essor de la ville de Mari s'accompagne de la mise en œuvre d'une architecture citadine monumentale bien ancrée dans la tradition constructive mésopotamienne dont l'ampleur des palais, des temples et des résidences confère à cette ville un caractère exceptionnel.

Lors de son dégagement en 1935 par André Parrot (fig. 2a), le Grand Palais Royal (fig. 2b) du II^e millénaire avant notre ère (ville III) était dans un état de conservation unique. Ses murs encore haut de 4 à 5 m, ses 260 majestueuses salles et cours, sa salle du trône et son architecture monumentale, ses installations rituelles, sa décoration et ses peintures murales singulières, ses objets d'art et ses archives, font de ce monument une référence unique et un témoignage exceptionnel de la civilisation syro-mésopotamienne. Construit sur une superficie de deux hectares et demi, cette résidence royale est sans aucun doute l'une des plus belles leçons d'architecture de terre du début du II^e millénaire avant notre ère.

La découverte en 1964 du palais du milieu du III^e millénaire avant notre ère (ville II), dont la hauteur conservée des murs était aussi impressionnante que ceux du Grand Palais Royal, a persuadé André Parrot de la nécessité d'engager des travaux de protection afin de prévenir les futures détériorations. C'est ainsi qu'en 1974, l'ensemble des murs de l'Enceinte Sacrée du palais a été mis à l'abri sous une couverture (fig. 3), les protégeant ainsi des méfaits des précipitations atmosphériques. Avec le temps, cette couverture s'est révélée insuffisante car, si elle a efficacement ralenti l'érosion, elle ne l'a pas complètement arrêtée.

La problématique de la conservation du site archéologique de Mari

Le tell de Mari se trouve dans une région subdésertique dominée par un climat aride qui, sans apport d'eau par irrigation, rend impossible toute culture et ne permet que le développement d'une végétation pauvre. La forte évaporation, liée aux faibles précipitations, supprime toute possibilité de lessivage des sols et favorise la précipitation des sels qui s'accumulent en surface. Ce phénomène est commun à beaucoup de terres des régions semi-désertiques ou arides. Il est à prendre en considération car il constitue un facteur important dans les processus de dégradation des architectures en briques de



(a)

FIGURE 2 Dégagement du Grand Palais Royal de Mari par André Parrot en 1937 et Plan du Grand Palais Royal de Mari, projet de restauration du secteur de la salle du trône.
© Mission Archéologique Française de Mari



(b)

Le Grand Palais Royal de Mari

FIGURE 3 Secteur de l'Enceinte Sacrée du palais du III^{ème} millénaire av. J.-C. protégée par une couverture. © Mission Archéologique Française de Mari





FIGURE 4 Travaux de fouille dans le chantier L avec apparition de l'eau de la nappe phréatique. © Mahmoud Bendakir. CRATerre-ENSAG

terre crue. Or, depuis une trentaine d'année, pour remplacer un système plus ancien et moins performant, un grand projet d'irrigation de la vallée a été lancé par le gouvernement syrien à des fins agricoles. Ce projet a engendré de profonds changements dans le paysage de la plaine, qui malgré le système de drainage mis en place, est encore plus affectée par les dépôts de sels. Il en va de même pour le tell.

L'étude hydrologique a révélé que le principal facteur d'érosion à Mari est lié à la présence permanente d'humidité dans le sol et le sous-sol du tell (fig. 4). Sa localisation non loin de l'Euphrate, dans une vallée actuellement très irriguée, explique cette omniprésence d'humidité. De plus, l'élévation du tell à 14,5 m au-dessus du niveau de la plaine, son exposition au soleil et au vent, offrent les conditions idéales pour l'évaporation des eaux ascensionnelles.

Les murs dégagés par la fouille augmentent la surface d'évaporation du tell et fonctionnent selon le même principe que les lampes à pétrole où les mèches servent de conduit à la remontée de l'huile. On imagine donc que les murs constituent ces conduits capillaires dans lesquels les eaux de la nappe phréatique montent et s'évaporent au contact de l'air.

En l'absence de soubassements opposant une barrière aux remontées capillaires, l'humidité du sol atteint directement le cœur des murs et s'évapore sur les surfaces exposées à l'air, en déposant au passage tous les sels qu'elle a pu dissoudre durant son séjour dans le sol. Ces migrations d'humidité diminuent la cohésion des argiles, altèrent les propriétés mécaniques du matériau et constituent un facteur d'érosion déterminant.

Principes et éthiques d'intervention

En l'absence de principes et de règles éthiques spécifiques à la conservation des architectures de terre, et notamment à la conservation des sites archéologique en terre, les références utilisées furent celles précisées dans les grandes chartes de références, tout en prenant en compte les recommandations émises lors des précédentes conférences internationales Terra.

En premier lieu, nous avons décidé que la priorité devait être donnée à une connaissance approfondie de l'environnement du site, de l'état des ruines et de leur exposition aux différents facteurs de dégradation. Les méthodes et les procédés de conservation appliqués à Mari se réfèrent le plus souvent au potentiel technique et architectural antique. Un des principes qui a guidé notre intervention consistait à conjuguer la connaissance et la technique moderne avec les savoir-faire millénaires.

Les critères suivants furent déterminants pour la définition des méthodes et des techniques de traitement :

- connaissance maximale de l'architecture (documentation) ;
- respect de l'authenticité et de l'intégrité du site ;
- intervention minimale ;
- utilisation de techniques et de matériaux non intrusifs ;
- réversibilité ;
- emploi de matériaux locaux ;
- amélioration des techniques antiques de réparation ;
- appel aux savoir-faire traditionnels ;
- respect de l'environnement du site.

Enfin, les méthodes et procédés de conservation n'ont pu être introduits qu'après une période d'expérimentation suffisamment longue. Les solutions devaient aussi être imaginées en prenant bien en compte le contexte économique de Mari, en faisant appel aux matériaux disponibles localement et aux techniques de mise en œuvre connues dans la région. Il avait aussi paru évident que la priorité devait être donnée à des traitements plutôt « doux » car le risque de provoquer des désordres graves, par l'application de procédés mal adaptés, est particulièrement présent dans le cas des constructions en terre crue. Toutefois, il avait été reconnu qu'en contrepartie, la sensibilité à l'eau du matériau terre permettait d'évaluer, sur des périodes relativement courtes, les effets des procédés de préservation et d'envisager un programme d'expérimentation à l'échelle de quelques années.

Les phases du projet

Phase 1 : Programme d'étude pour la compréhension des processus d'érosion des ruines (observer, diagnostiquer, faire le suivi)

Notre projet s'est développé selon une méthode scientifique rigoureuse visant à approfondir tout d'abord la connaissance du matériau terre et de sa dégradation dans un contexte archéologique. Dès lors, il était impératif d'étudier tous les phénomènes de la dégradation des ruines, liés d'une façon directe à leurs conditions d'exposition. La connaissance du milieu naturel et environnemental du site est une phase déterminante permettant de dresser le fonctionnement hydrologique du tell. Ce travail fut basé essentiellement sur les mesures d'humidité, l'analyse de la nature du sol et le repérage du niveau de la nappe phréatique.

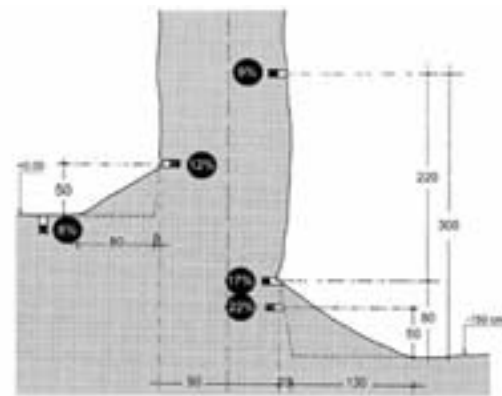
D'autre part, le travail d'observation des ruines a permis de repérer les signes d'érosion les plus significatifs et de dresser une typologie des phénomènes caractéristiques. Un protocole de mesures approprié a été mis au point afin d'enregistrer le suivi des migrations d'humidité dans le sol ainsi que dans les murs, et la cristallisation des sels en surface (fig. 5). Les données obtenues ont permis d'établir des corrélations entre les signes d'érosion observés et l'état humide des murs. La réalisation de procédés expérimentaux destinés à la conservation des ruines s'est ainsi fondée sur la compréhension des causes, des mécanismes et des effets de l'érosion.

Phase 2 : Programme d'expérimentation

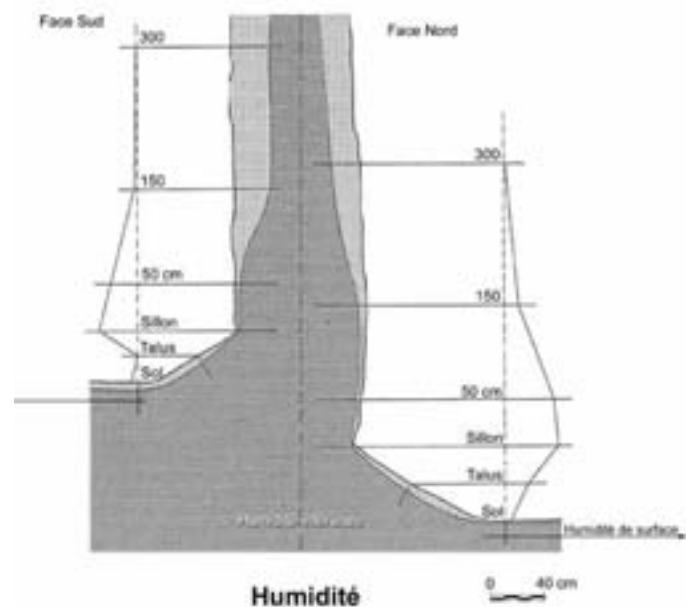
Une fois obtenus les premiers éléments permettant la compréhension des processus d'érosion, des procédés de préservation capables d'atténuer ou de réguler ces processus furent imaginés. Ces procédés ont été installés avec un minimum d'intervention sur une sélection représentative de murs. La base de données recueillie au cours de la première étape a permis d'évaluer l'incidence des procédés sur les effets de l'érosion. Ces expériences ont été conduites *in situ* sur une période de temps significative avec, pour compléter les travaux de terrain, des essais au laboratoire CRATERRE-ENSAG et au CSTB de Grenoble.

Cette phase a permis :

- de sélectionner sur le site les zones d'expérimentation (murs tests) (fig. 6) ;
- d'introduire à petite échelle les procédés expérimentaux de conservation ;



Teneur en eau



Humidité

FIGURE 5 Protocole de mesures et de suivi de l'humidité et des teneurs en sels dans les murs. © Mahmoud Bendakir. CRATERRE-ENSAG

- de faire un suivi de tous les procédés expérimentaux sur une période de temps significative ;
- d'évaluer l'efficacité des procédés et leur faisabilité technique et économique.

Phase 3 : Application des procédés et des techniques de conservation

En 1994, après avoir dressé un premier bilan des recherches et des expérimentations, un programme d'action prioritaire



FIGURE 6 Zone d'expérimentation, 1993. © Mahmoud Bendakir. CRA Terre-ENSAG

pour la sauvegarde des monuments les plus menacés a été ébauché. Ce programme visait la mise au point d'un plan de sauvetage des deux monuments fouillés par A. Parrot suivant une action concertée et durable entre les archéologues, les conservateurs et les architectes. Ce plan de conservation proposait trois types d'action :

- *Une action préventive* consistant à aménager l'ensemble du site par la mise au point d'un plan de gestion des eaux pluviales afin de prévenir l'érosion. Cette action comporte un plan de drainage, un plan de gestion des déblais provenant des fouilles et un plan de conservation préventive comprenant les travaux de protection des fouilles neuves, d'entretien et de maintenance du site.
- *Une action sur les éléments d'architecture* : Elle représente l'étape la plus importante et la plus délicate à mener car elle nécessite une intervention directe sur les ruines. Cette action comporte l'application des techniques de traitement et des procédés de préservation, selon un cahier des charges préalablement défini.
- *Une action par la « mise à l'abri » des ensembles d'architecture* : Elle consiste à protéger les ruines des agents atmosphériques d'érosion par l'installation d'une couverture légère, tout en respectant le paysage du site et l'environnement des ruines.

La définition des techniques de restauration et de préservation utilisées pour la conservation de l'Enceinte Sacrée

du palais du III^e millénaire avant notre ère et du secteur de la salle du trône du Grand Palais Royal du II^e millénaire avant notre ère (fig. 7) a été élaborée selon un cahier des charges précisant et spécifiant les caractéristiques de chaque procédé. Ce cahier des charges tient compte à la fois du mode et du domaine d'application de chaque procédé, de leur degré d'efficacité contre tel ou tel effet d'érosion, des recommandations de leur mise en œuvre, des matériaux qui les composent, des critères d'intégration à l'architecture des ruines, des limites et des risques de leur utilisation, ainsi qu'une estimation des coûts.

Pour ces deux monuments majeurs du site, un plan de conservation prioritaire a été élaboré comprenant :

- un plan de conservation préventive ;
- un plan de gestion et d'évacuation des déblais ;
- un plan de fouilles de sauvetage dans les secteurs à conserver ;
- un plan de gestion et de drainage des eaux de pluie ;
- un plan de remblaiement et de *backfilling* des zones à protéger ;
- un plan d'entretien et de maintenance ;
- un plan de restauration des murs.

Phase 4 : Préparation du plan de gestion et de mise en valeur du site

La préparation d'un plan général de sauvegarde du site prend en considération des éléments d'ordre social, politique, économique, culturel et environnemental liés au contexte de la région de Mari. Le travail de sensibilisation et de formation des populations locales est un paramètre qui a été pris en compte depuis le lancement de cette collaboration. Au cours de chaque campagne de restauration, vingt ouvriers en moyenne ont été engagés et formés aux différentes techniques de construction et de conservation des bâtiments en terre crue. La formation d'une main d'œuvre qualifiée, de techniciens, d'architectes et de conservateurs locaux permet d'assurer un relais adéquat et dynamise la mise en place du projet de sauvegarde.

Un schéma général de gestion du site a été établi en collaboration avec les archéologues et en relation directe avec les autorités syriennes compétentes.

Trois actions majeures ont été engagées :

- l'élaboration et la mise en œuvre d'un plan de conservation prioritaire des ruines ;



(a)



(b)



(c)

FIGURE 7 La tribune de la salle du trône du Grand Palais Royal du II^{ème} millénaire av. J.-C. État avant et après les travaux de restauration. (a) Mission Archéologique Française de Mari ; (b) et (c) © Mahmoud Bendakir. CRATerre-ENSAG

- l'élaboration d'un plan de gestion et de mise en valeur du site, acceptable par toutes les parties prenantes ;
- la préparation du dossier de proposition d'inscription du site sur la Liste du patrimoine mondial de l'UNESCO.

Conclusion

Engagée sur une voie nouvelle et innovante, cette coopération de près de 19 ans entre la Mission archéologique de Mari, CRATerre-ENSAG et la Direction générale Antiquités et des Musées de Syrie, avait pour objectif de mettre en place une véritable stratégie de conservation afin de sauver les monuments archéologiques mis au jour, et de prévenir la dégradation des ruines en cours de dégagement.

Cette collaboration a permis de poser les premières bases d'une réelle connaissance des problèmes liés à la dégradation des vestiges archéologiques en briques de terre crue. Elle a également permis la mise au point et l'expérimentation de nouvelles techniques de conservation qui ont pu déboucher sur la mise en œuvre effective de travaux de conservation d'envergure avec la sauvegarde et la restauration de deux des monuments majeurs du site. Enfin, cette collaboration a constitué un socle pour la préparation d'un premier plan de conservation des ruines, et au-delà, l'élaboration en cours du plan de gestion et de mise en valeur du site de Mari.

The Use of Historic Photographs for the Study of Earthen Architecture

Louise Cooke

Abstract: *Historic photographs are an important resource for the study, survey, assessment, documentation, and ongoing monitoring of earthen architecture. This paper discusses the benefits and problems associated with using historic photographs as a site management tool in the Archaeological Park of Ancient Merv, Turkmenistan. In the case studies presented, historic photographs have been used to assess the condition of select architectural monuments in a more complete state (primarily for interpretation and reconstruction purposes) and to document and monitor the extent and rate of their deterioration and better understand the causes of damage.*

Résumé : *Les photographies historiques constituent une ressource importante pour l'étude, les relevés, l'évaluation, la documentation et le suivi permanent de l'architecture en terre. Cette communication évoque les avantages et les problèmes liés à l'utilisation des photographies historiques comme outil de gestion dans le Parc archéologique de l'ancienne Merv, Turkménistan. Dans les études de cas présentées, des photographies historiques ont été utilisées pour évaluer l'état de conservation de certains monuments architecturaux en meilleur état (principalement pour servir à l'interprétation et à la reconstruction) et pour documenter et suivre l'ampleur et le rythme de détérioration et mieux en comprendre les causes.*

Contemporary conservation and management planning models emphasize monitoring as a fundamental component (Clark 1999), and this is particularly relevant for those sites preserving earthen architecture. At many sites this is problematic, as there are invariably neither baseline data nor the resources to undertake the detailed survey needed to properly document this type of structure. While developing technologies such as 3-D

scanning offer the potential to secure the necessary baseline data, the approach is costly and time-consuming and requires specialist application. In contrast, historic photographs survive for thousands of earthen monuments and can give valuable insight into temporal change with minimal investment.

The use of historic photographs has generally been applied to the conservation and management of earthen architecture for the following two purposes:

1. To assess the condition of monuments in a more complete state and to assist in interpretation and reconstruction, often “back” to their historical appearance (Othman 2003); and
2. To document, monitor, and understand the factors affecting the survival and deterioration of monuments using quantitative methods such as cross-section analysis of walls and to perform predictive modeling of erosion (Stevens 1983; Caperton 1990; Oliver and Hartzler 2000).

A survey of the historic photographs was undertaken for selected monuments in the Archaeological Park of Ancient Merv, Turkmenistan (Cooke 2006). The purpose of the survey was to replicate historic photographs and to create point-in-time references for a selection of the earthen architectural monuments within the park. Assessment of their condition through photographic comparisons gives us unparalleled insight into the factors affecting the survival and deterioration of these standing earthen structures. This type of easily replicable survey should be an essential part of any site's documentation and monitoring program and is especially appropriate as a means of collecting baseline data.

Ancient Merv

Ancient Merv is a site that invites hyperbole: it is a rich and evocative archaeological landscape that stirs the imagination (Herrmann 1999; Williams 2002). We are fortunate to have extensive photographic coverage of some of the monuments, some dating to as early as 1890 and many from the present day (Herrmann et al. 2002). As is common elsewhere, these photographs have been used to (1) guide restoration (such as the rebuilding of elements of Abdullah Khan Kala), (2) increase our understanding and interpretation of the site, and (3) gain understanding of the factors affecting the monuments' deterioration and survival.

In 2003 and 2004 the use of historical photographs to study, survey, assess, document, and regularly monitor the earthen architecture was carried out through the Institute of Archaeology's Ancient Merv Project. A formal survey of the historic photographs of a selection of monuments was completed, and new images were taken that replicate the initial field of view as precisely as possible to create point-in-time reference images. By visually comparing the monuments' current condition with that recorded in the historic photographs, we are able to identify and analyze deterioration factors affecting the monuments. This survey has shown that some of the larger monuments survive in a surprisingly good condition, while others have suffered much more dramatic loss in the past approximately one hundred years.

The survey produced forty new photographs of six different monuments, each replicating an important historical image. The photographs were taken using both conventional and digital cameras. They were assigned monument numbers (from the Merv GIS) and photographic numbers. Physical positions were recorded in the field using a GARMIN® Handheld GPS as a supplement to the spot locations recorded in the Merv GIS. Some of the images were adjusted in Adobe Photoshop®, to compensate for light levels and so on. Rectification of the views was done using Irwin Scollar's AIRPHOTO program (part of a nonprofit software program developed for archaeologists).¹ Original photographs have been archived and are included in this paper.

As part of the survey, qualitative observations about the monuments' condition were recorded in the field on a handheld computer, and more detailed investigation and quantitative analysis of physical changes were completed in the United Kingdom. As a result of this investigation, we have a better understanding of the earthen architecture and how it is changing over time. This synthesis has been supplemented

with general observations about park management processes acquired in discussions with the park director, park staff, and people living nearby.

Given the constraints of this paper, only a selection of photographs is presented. Some illustrate the poor survival of the monuments; others show surprisingly high levels of preservation.

Little Kyz Kala

Little Kyz Kala is a corrugated structure constructed of mud bricks, earthen mortars, and plasters (Herrmann 1999). Although the monument is in fairly poor condition, there is still evidence of the multistory original construction, a variety of different roof types, a stairwell, and vaults. As is the case with a majority of the monuments at Merv, Little Kyz Kala is characterized by deep and extensive undercutting at the wall base.

Figures 1a and 1b show the eastern facade. Comparison of these two photographs from 1954 and 2003, respectively, illustrates the dramatic deterioration and collapse of the east side. The 1954 photograph shows a void in the southeast corner caused by erosion, as well as extensive undercutting below the corrugations on the east wall. The 2003 photograph also shows collapse of the eastern wall, which exposed the structure within (stairs and a vaulted roof). This left an extensive deposit of debris that buried what remained of the wall and altered surface runoff and drainage patterns surrounding the monument. The photographs also show significant alteration in vegetation types and extent in the surrounding area.

The Kepter Khana in Shahriyar Ark

The Kepter Khana in Shahriyar Ark is one of the best preserved corrugated earthen buildings at Merv. The structure is built on a low earth mound: it is rectangular in plan and is oriented north to south. The structure comprises a *paksha* building platform, with the lower portion built of fired brick masonry and the upper portion of mud brick (Herrmann 1999). As with all of the monuments in the oasis, the northern face of the structure is adversely affected by weathering. Preservation of the corrugated buildings is usually poor on the northern faces; the corrugations are often eroded and truncated from weathering and windblown particle abrasion.

Figures 2a and 2b show the east facade of the Kepter Khana. Comparison of the 1958 and 2003 photographs shows an overall loss of definition. Also, the void covering the first



(a)



(b)

FIGURE 1 (a) Eastern facade of the Little Kyz Kala in 1954, photographed by a member of the YuTAKE team. Courtesy of the Ancient Merv Project, Institute of Archaeology, University College London; (b) Eastern facade of the Little Kyz Kala in 2003. Photo: L. Cooke



(a)



(b)

FIGURE 2 (a) Eastern facade of the Kepter Khana in 1958. Photo: G. Pugachenkova. Courtesy of the Ancient Merv Project, Institute of Archaeology, University College London; (b) Eastern facade of the Kepter Khana in 2003. Photo: L. Cooke

to fourth corrugation from the southeast corner has grown between 1958 and 2003 and corresponds to an area of wall collapse and mounding on the exterior. The 2003 photograph also shows repairs carried out on the undercut north and east sides of the monument. General changes in the monument setting can also be noted: the monument looks higher and more exposed in 2003.

The Great Kyz Kala

The Great Kyz Kala is the largest *köshk* in the Merv oasis and one of the most iconic structures in the Archaeological Park. The date of construction (though not established by archaeological excavation) remains conjectural, from the sixth to eighth century (Herrmann 1999). The enormous structure



(a)



(b)

FIGURE 3 (a) The southern and eastern facades of the Great Kyz Kala in 1971. Photo: V. Pilyavsky. Courtesy of the Ancient Merv Project, Institute of Archaeology, University College London; (b) The southern and eastern facades of the Great Kyz Kala in 2003. Photo: L. Cooke

is characterized by its unusual corrugations, with the longer western and eastern ends originally composed of twenty-two corrugations and the shorter northern and southern sides eighteen. The monument's relatively good state of preservation is due in large part to its original massive construction, which has made it capable of withstanding considerable erosion and deterioration.

Figures 3a and 3b show the southern and eastern facades. The greatest apparent change is the collapse of the middle section of the east wall, which reduced the number of corrugations on the east side of the monument from twenty-two to sixteen (as seen in the 2003 image). The 1971 photograph also shows the tops of the corrugations having a pointed, more highly defined appearance than in 2003. This thinning and shortening of wall tops and general loss of detail in the wall surface is the result of continued erosion associated with rainwater runoff. By and large, the corrugations have contributed to overall erosion by acting as gullies that channel water down the monument face.

It is important to note that the early photographs of the Great Kyz Kala dating to 1890 show the monument significantly undercut, even at that time. This suggests that the cause of the undercutting and deterioration, which is presumed to be due to fluctuating groundwater levels from the Karakum canal, may be oversimplified. Rather, the undercutting is likely to be associated with more general changes in land use throughout the monument's history.

The Palace in Shahriyar Ark

The Seljuk Palace lies in the center of Shahriyar Ark. It is constructed of mud brick, earthen mortars, and plasters. Surviving

elements reveal the plan, variety of different roof types, and decoration (Herrmann 1999). The monument is in fairly poor condition, and very little of it survives relative to the more massive corrugated buildings in the archaeological park. Large piles of eroding mud-brick rubble on the northwest, northeast, and southeast corners of the building are from relatively recent collapses. Very little of the palace remains, which makes photographic comparisons difficult.

Figures 4a and 4b are of the west wall of room 23 (taken in 1990 and 2003, respectively). These images demonstrate how rapidly and dramatically the palace's checkerboard-patterned mud brick deteriorated over a period of just thirteen years. The delicately constructed palace stands in contrast to the park's other mud-brick monuments, not only in its form, but also in its state of preservation. The other freestanding structures have been far more resistant to long-term erosion because of their original massive construction. Nonetheless, all the structures in the park have suffered considerable loss of the finer details such as coursing, shape, and form.

Summary

Using photographic comparisons to show change over time is not groundbreaking technology, but, as in the case of Merv, it clearly shows how rapidly structure loss and erosion can occur and also how remarkably resistant some of the massive structures are to centuries of abandonment. The survey also illustrates the nonlinear pattern of erosion and deterioration affecting these earthen structures. After an initial period of abandonment, the rate of deterioration and loss is gradual until a threshold is reached. At that point, so much of the

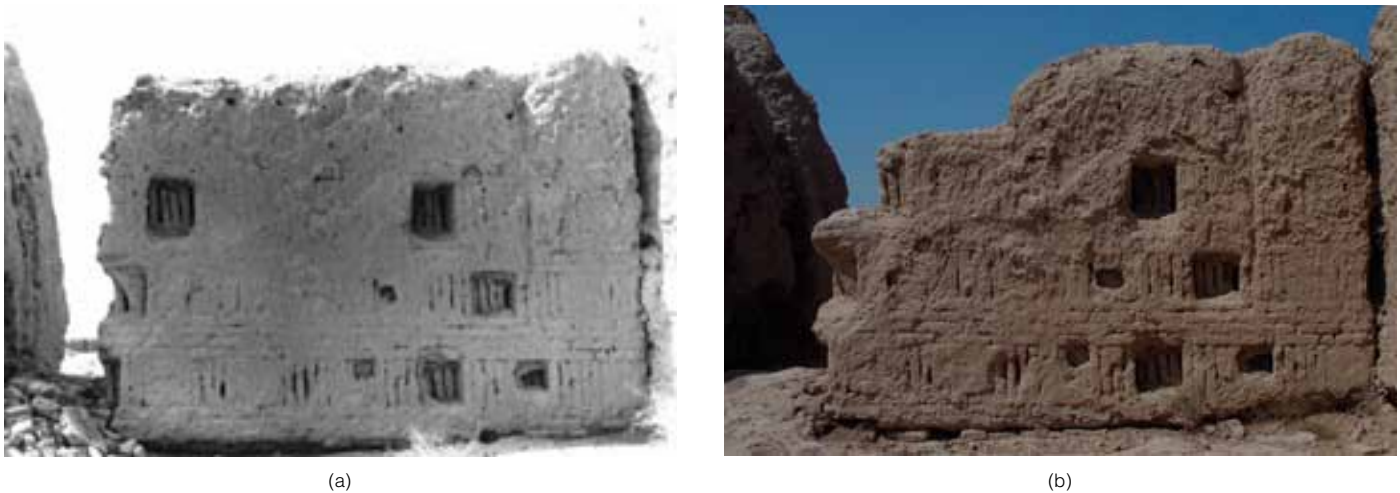


FIGURE 4 (a) The west wall of room 23 of the Palace in Shahriyar Ark in 1990. Photo: IMP team member. Courtesy of the Ancient Merv Project, Institute of Archaeology, University College London; (b) The west wall of room 23 of the Palace in Shahriyar Ark in 2003. Photo: L. Cooke

structure has deteriorated that accelerated and eventual catastrophic destruction occurs.

Historic photographs provide a fixed temporal reference to use in determining the nature and range of factors affecting the condition of the monuments over time. This technique, combined with other forms of data collection, provides a useful, relatively simple, and easily transferable way to evaluate and monitor earthen archaeology and earth-built monuments, regardless of the management context of the site. In terms of the larger issue of site management and conservation, historical photographs can be used to prioritize actions and interventions as they help indicate those structures most at risk. In 2005 photographic comparisons were used as part of the World Monuments Fund training program at Merv.

Some problems do exist with photo comparisons, however. Often it is difficult to “match” the images, especially where extensive erosion has occurred and a portion of the structure is no longer comparable in the two images (such as at Little Kyz Kala). Also, landscape changes, such as the cutting of irrigation channels around the monument, have made image replication difficult.

As a discipline, archaeological and conservation approaches to documentation and monitoring are often concerned with the collection of usable and reusable quantifiable data sets. Consequently, emphasis has recently been placed on high-tech approaches such as 3-D scanning. This approach is, without doubt, significant; however, these high-tech approaches are costly and are not readily transferable

to all management contexts. They should be used alongside simple and replicable survey methods, such as the use of historical photographs, especially at sites that need to acquire baseline data.

The photograph comparison methods used in the Merv survey are transferable to every site and provide useful and relevant data sets. This technique should become a formal component of documentation programs in any management planning framework. Establishing a set of standard images that can be used for monitoring the condition of standing monuments and/or areas of an archaeological site is key for successful management and preservation of earthen architecture and sites.

Acknowledgments

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Notes

- 1 Irwin Scollar's AIRPHOTO program is available at www.uni-koeln.de/~a1001/basp.html.

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Préparation d'un plan de gestion et de sa mise en œuvre : Le cas de Joya de Cerén, El Salvador

Françoise Descamps et Carolina Castellanos

Résumé : Cet article présente les points clefs de la préparation et de la mise en œuvre d'un plan de gestion de site archéologique. L'analyse critique de l'application du processus de planification participatif, basé sur les valeurs du site, a permis d'évaluer les conditions nécessaires et les facteurs à prendre en compte pour la mise en place d'un processus de planification, son développement et son exécution. Le plan se conçoit comme un système de gestion intégrale pour le site et son contexte. Les conditions indispensables et leurs alternatives sont présentées afin de proposer une réponse adéquate aux contraintes et problématiques locales de planification.

Abstract: This paper presents the key elements in the preparation and implementation of a management plan for an archaeological site. A critical analysis of the application of a participative planning process, based on the values of the site, made it possible to evaluate the conditions and factors that need to be considered in the establishment, development, and implementation of a planning process. The plan is designed as an overall management system for the site and its context. The essential conditions and their alternatives are presented in order to propose an adequate response to local constraints and planning issues.

Joya de Cerén : Un site particulier

Joya de Cerén est un site d'architecture de terre de la région mésoaméricaine daté d'environ 600 ap. J.-C. Cet ensemble, qui occupe aujourd'hui une superficie de 5 hectares, a été accidentellement découvert en 1976, lors de la construction d'infrastructures agricoles, mais n'a été fouillé que dans les années 1980 (fig. 1). Les structures en terre, les éléments bota-

niques pétrifiés et les multiples objets abandonnés par les habitants dans leur fuite, ensevelis sous plus de 7 mètres de cendres, ont été bien conservés malgré les effets de la catastrophe volcanique. Le site, image d'un temps arrêté, constitue une extraordinaire source d'informations qui a attiré l'attention d'équipes de chercheurs. Ces vestiges permettent mieux que partout ailleurs de redécouvrir les pratiques et usages domestiques des habitants à cette époque. Ils procurent des informations précieuses pour la compréhension des relations entre les groupes établis dans cette région de la périphérie du monde maya, et mettent en évidence la continuité de ces pratiques domestiques jusqu'à nos jours, renforçant ainsi le caractère symbolique et identitaire du lieu pour les communautés d'Amérique centrale.

Reconnu pour son caractère unique et exceptionnel et pour ses valeurs universelles, le site a été inscrit sur la Liste du patrimoine mondial en 1993, et a attiré une attention particulière à l'échelle nationale et internationale. Bien que situé hors des grandes routes mayas, le site est aujourd'hui fréquenté par de nombreux visiteurs. À l'échelle nationale et locale, il est considéré comme une attraction potentielle pour le tourisme et un facteur de développement économique pour la communauté civile du Salvador.

Problématique du site

Le site s'inscrit dans un cadre naturel et socio-économique proche de celui de son époque d'occupation, bien que soumis à l'évolution rapide du cadre de vie. Le climat de caractère tropical humide et la nature luxuriante constituent un environnement naturel similaire à celui qui existait lors de



FIGURE 1 Structure dégagée dans son carré de fouille. Photo : Richard Ross. © J. Paul Getty Trust

l'éruption volcanique. Par contre, l'exploitation des sols et les usages de la terre se sont transformés depuis la réoccupation datée aux environs de 800 de notre ère. De plus, le développement d'infrastructures de communication, l'expansion urbaine et le développement industriel génèrent aujourd'hui des altérations fondamentales du cadre social, paysager et environnemental (fig. 2).

Les structures sont soumises aux actions destructrices de la nature et de l'homme. Leurs formes, leurs matériaux et textures se sont modifiés : tout d'abord dès leur construction, en étant exposées aux intempéries, utilisées et transformées peu à peu ; ensuite lors de l'éruption volcanique, quand elles ont été soumises aux effets telluriques et à la chaleur des matières projetées, et enfin lors des fouilles où, privées de leur environnement protecteur, elles ont de nouveau été exposées à l'environnement naturel et aux actions des hommes, soucieux de remédier à ces nouvelles altérations de leurs conditions.

La conservation des structures et objets – botaniques et céramiques – présents dans le site, est particulièrement délicate à analyser. Chacune des structures est unique et les conditions de fouilles sont peu connues. La topographie a été complètement modifiée et les conditions microclimatiques actuelles sont différentes dans chacune des aires fouillées, ce qui rend difficile l'isolement des paramètres nécessaires à l'identification des facteurs de détérioration et l'établis-



FIGURE 2 Vue aérienne du site illustrant les conditions et l'environnement du site. Photo : Irene Sen. © J. Paul Getty Trust

sement des relations de causes à effets. La planification doit prendre en compte cette complexité et intégrer les besoins de la recherche pour la conservation dans la programmation des interventions sur le site (fig. 3).

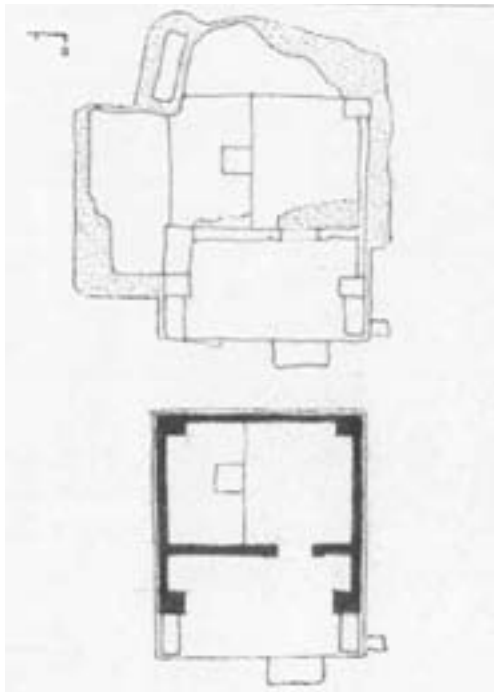


FIGURE 3 Analyse des techniques, des matériaux de construction et de l'état de conservation. Photo : Payson Sheets. Graphique : Elvia Arango. © J. Paul Getty Trust

Origine et objectifs du projet

En 1999, le Salvador sort d'une guerre civile particulièrement destructrice. Dans ce pays pauvre, souvent affecté par des catastrophes naturelles, la notion de patrimoine est à construire afin de promouvoir les valeurs identitaires, vectrices d'appartenance et de fierté nationale. Le projet de reconstruction nationale est basé sur la mise en place d'alliances qui favorisent les collaborations interministérielles et interinstitutionnelles et la promotion des valeurs culturelles (création de musées, promotion de traditions, et autres).

Le site de Joya de Cerén est l'un des éléments majeurs du patrimoine national et est inscrit sur la Liste du patrimoine mondial de l'UNESCO. Cette inscription et l'engagement subséquent de l'État partie, la fragilité du site et ses problèmes de conservation ont amené les autorités en charge du patrimoine à se préoccuper de la gestion du site et des problèmes engendrés par le développement socio-économique et contextuel et les modifications rapides de son environnement physique. En réponse, Concultura, avec l'appui du Getty Conservation Institute (GCI), s'est proposé de développer une approche de planification intégrée fondée sur la reconnaissance des valeurs du site et l'association de la société à la prise de décision pour sa gestion¹. Conçue pour ce site parti-

culier, cette approche est la première expérience de ce type au Salvador. Elle constitue un modèle à transposer à d'autres sites et sert de base à l'élaboration d'une nouvelle politique de gestion du patrimoine.

Le projet

Les valeurs qui sont attribuées au patrimoine ne peuvent être comprises et promues sans tenir compte des acteurs qui animent cette approche ou s'en désintéressent, ni sans anticiper les modifications des modes de vies et les besoins des communautés dans lequel vit ce patrimoine. C'est sur cette conception que se fonde l'approche intégrée de la conservation et de la gestion du patrimoine, qui propose de favoriser un développement durable basé sur la conservation du patrimoine culturel (fig. 4).

Le processus

Le processus de planification proposé dans le cadre du projet dérive de ce précepte et s'établit sur deux principes fondamentaux : 1. L'approche pluridisciplinaire et l'intégration participative de tous les groupes d'intérêt ; et 2. La reconnaissance des valeurs de ce patrimoine, qui serviront

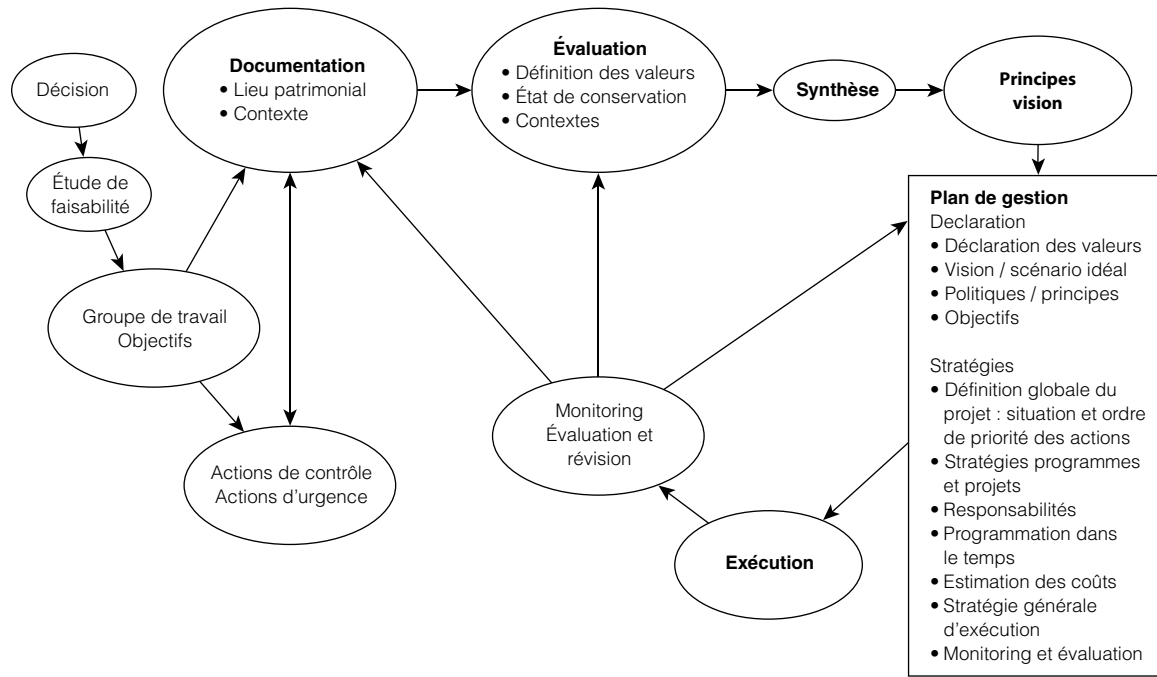


FIGURE 4 Processus de planification. Graphique : F. Descamps, C. Castellanos. © J. Paul Getty Trust

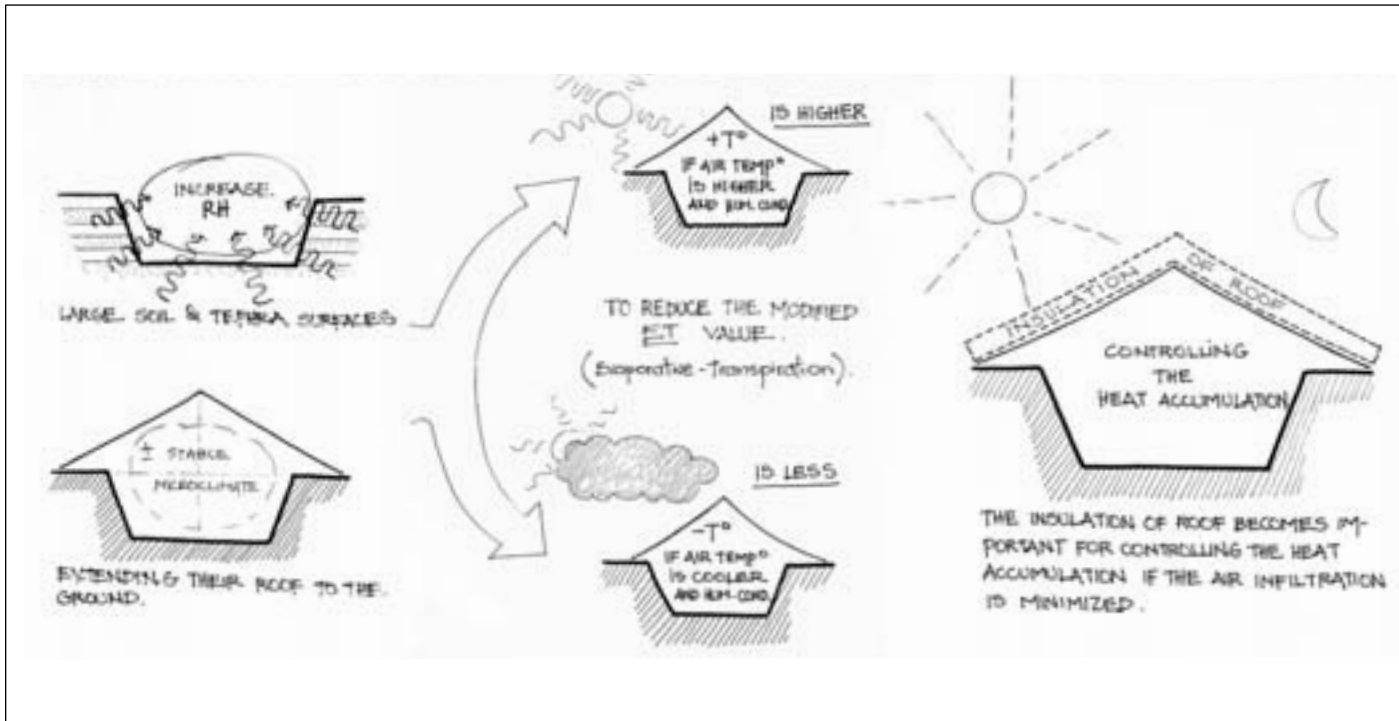


FIGURE 5 Analyse de l'influence des facteurs climatiques. Graphique : Elvia Arango. © J. Paul Getty Trust

de références pour la prise de décision. Ce processus comprend les étapes communes à toute proposition d'action : la phase d'étude, la phase d'analyse et de diagnostic, et la proposition. Ces phases s'articulent ainsi : la collecte de données permettant de comprendre le lieu² (considéré ici comme le site et son contexte géographique et humain), le diagnostic des composantes déterminées dans l'évaluation préalable de l'état du bien et des risques qui le menacent, la synthèse de ces diagnostics, l'établissement de la déclaration des valeurs et de la vision, base de la réponse, et enfin, l'élaboration de la réponse proposée dans son schéma opérationnel, ses programmes et projets détaillés.

La charte ici présentée inclut des étapes qui permettent d'évaluer les actions proposées dès leur exécution ou ensuite. Ce principe cyclique d'évaluation et d'adaptation des actions vise à mesurer la qualité et l'efficacité des mesures proposées et les incidences nouvelles sur le site.

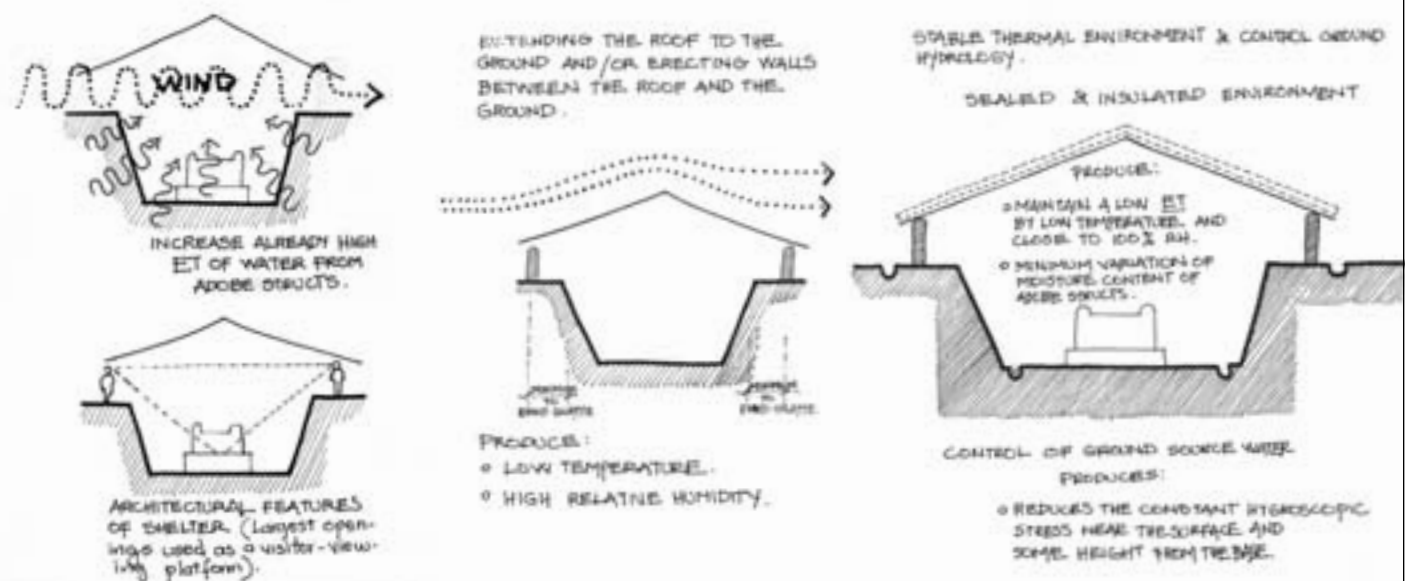
Les composantes

Les instruments consistent à créer et gérer un système de connaissance du site et de son contexte. Toute décision doit être basée sur l'analyse détaillée, la confrontation et la syn-

thèse d'un grand nombre d'informations existantes ou produites sous diverses formes. Cette documentation doit être collectée et organisée de manière flexible et structurée pour répondre aux besoins et usages. Le degré de détail et la forme selon laquelle cette documentation du site sera abordée et organisée varient en fonction de la nature de l'information à collecter et des possibilités opérationnelles :

- état de connaissance du site et de son évolution, du contexte naturel (modifications géologiques et climatiques), du contexte humain (voisinage, visiteurs, développement des activités agricoles et économiques, éducation et structures sociales) ;
- état de conservation du site, des structures, évolution de l'état des vestiges, recherche des facteurs et phénomènes de détérioration (fig. 5).

Mais toute documentation d'un site nécessite une étude cartographique de référence. La compatibilité de cette documentation du site à d'autres sources d'information et de gestion du territoire ou du patrimoine est fondamentale – plan d'aménagement, plan d'urbanisme, système d'identification et classification du patrimoine – afin d'assurer la



bonne coordination entre les différents niveaux de décision et d'atteindre le degré de détail nécessaire à la prise de décision dans le respect des valeurs du bien.

Responsabilités, collaborations et interactions

La responsabilité du patrimoine n'est pas limitée aux seuls professionnels du patrimoine, la conservation est trop souvent perçue comme une « affaire d'experts ». Il a pourtant été reconnu que la préservation du patrimoine nécessite aussi l'appréciation et l'appropriation de celui-ci par la société civile (fig. 6).

Les phases, tant d'étude que d'exécution, requièrent avant tout l'action d'un groupe de professionnels de la conservation qui assure et coordonne la qualité technique et les actions de divers spécialistes. Cependant, le succès d'un projet de gestion réside aussi dans sa promotion et dans l'association de groupes institutionnalisés ou non à la prise de décision est une des étapes clés du processus. Ceci exige de la part des initiateurs du projet des qualités de communication et une grande flexibilité pour répondre aux différents aspects de la gestion : exécution technique, gestion des visiteurs, gestion administrative, coordination et négociation avec les ministères chargés de l'aménagement du territoire et des infrastruc-

tures, coordination avec les groupes d'intérêt, promotion et recherche de fonds, et autres.

Ressources humaines et financières

Ces deux aspects sont à prendre en compte dès la mise en place du projet. La présence d'un personnel qualifié et disponible durant la durée du processus, et lors de son application, c'est-à-dire la création d'un système permanent de gestion, est très problématique. Les qualités requises dépassent les seules compétences techniques de conservation, bien que ces dernières soient indispensables. La capacité d'harmoniser les besoins, d'articuler des options, requiert des qualités de visionnaire et de négociateur.

Les ressources financières ne peuvent être un obstacle qui justifie l'inertie ou le manque d'action, mais elles sont toujours un paramètre fondamental à prendre en compte dès la conception du projet. La mise à disposition des ressources financières adaptées pour mettre en place, démarrer et soutenir les actions de préservation et conservation du lieu est un facteur déterminant du processus décisionnel pour assurer la viabilité et l'efficacité de l'exécution du plan. Il est faux de considérer que ces ressources doivent seulement procéder de l'institution de tutelle, ou que celle-ci doit acquérir l'entière propriété du patrimoine. L'allocation de fonds peut être en partie résolue par la coresponsabilité et l'articulation de projets qui appuient et supportent la préservation du patrimoine sous l'angle, entre autres, de projets sociaux ou de développement.

Le travail dans la durée fait partie de cette projection mais le succès du plan sera plus convaincant et susceptible d'être répété si des avancées et bénéfices visibles et tangibles peuvent être rapidement perçus par le public et les investisseurs privés ou publics.

Résultats

Instrumentalisation

La cartographie et les plans sont les instruments de la planification. Ils permettent de reporter les informations afin d'en assurer une synthèse visuelle et spatiale à l'échelle du site et de ses objets, dans son environnement immédiat ou au niveau territorial. Ils permettent aussi une visualisation des espaces de responsabilités. Ainsi, les projets identifiés et localisés sur ces plans mettent en évidence les zones de responsabilité partagée et de collaboration indispensable entre institutions, comme cela a été précisé dans le document descriptif de chacun des projets, qui accompagne le plan de gestion (fig. 7).

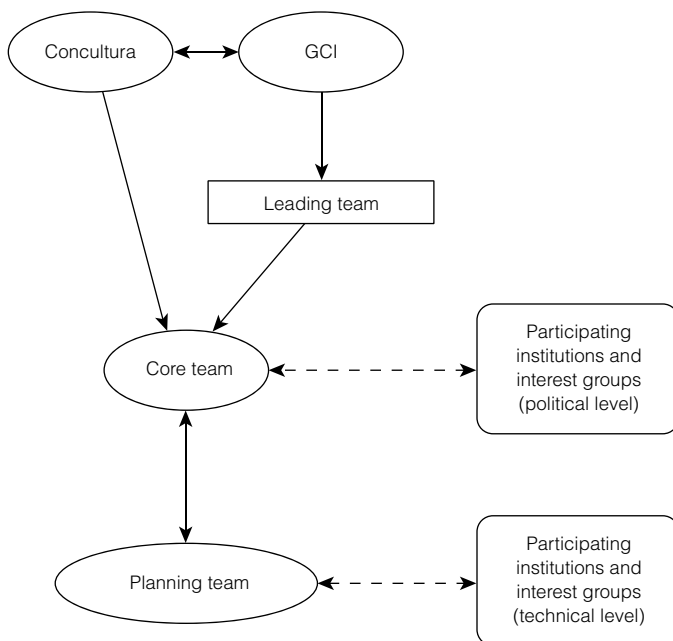


FIGURE 6 Schéma de la structure de travail. Graphique : F. Descamps, C. Castellanos. © J. Paul Getty Trust

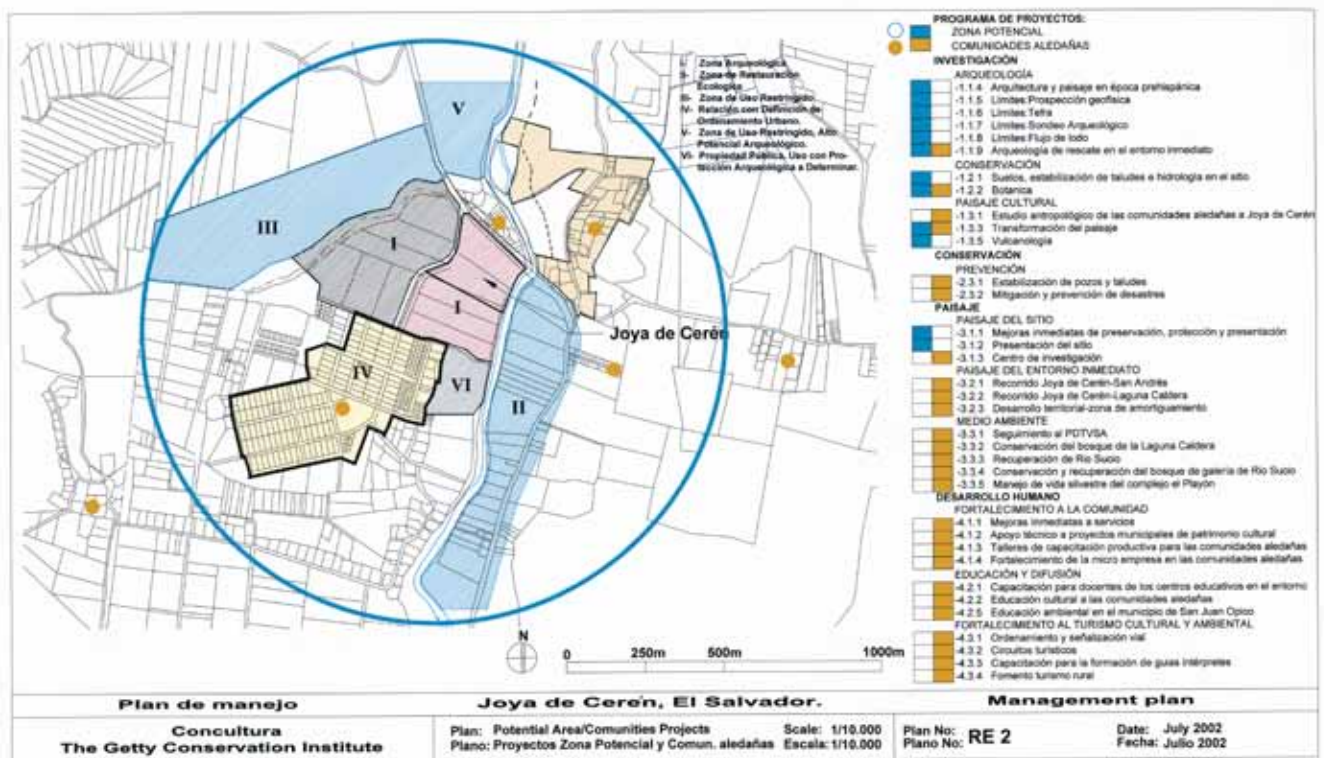
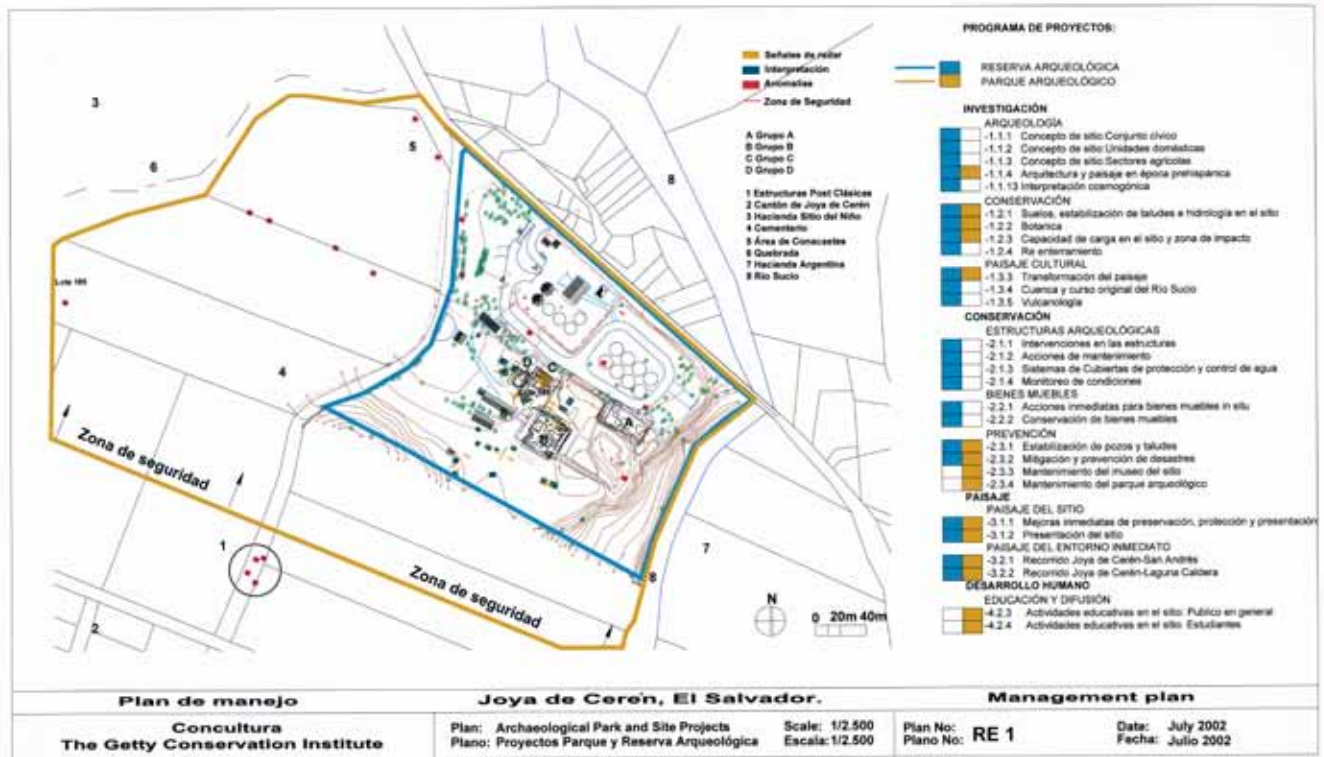


FIGURE 7 Localisation des projets et attribution des responsabilités, aux trois niveaux de décision : le site, son environnement immédiat et le territoire. Document original du plan rédigé en espagnol. Graphique : F. Descamps, R. Eppich, L.Valero. © J. Paul Getty Trust

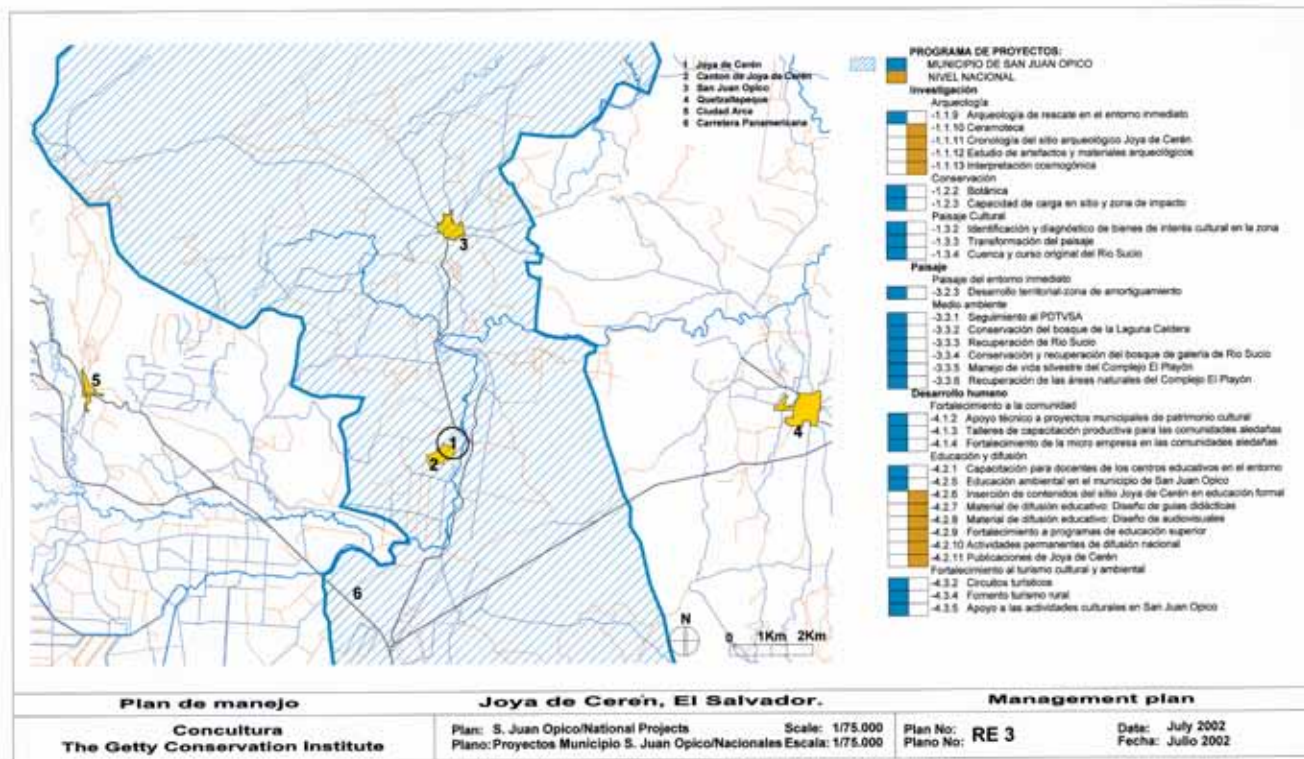


FIGURE 7 (continued)

L'élaboration de la documentation et la qualité de son contenu sont des éléments essentiels à la gestion du bien. Les modes de collecte et l'organisation de cette documentation ne sont pas déterminants en eux-mêmes. Réalisé par ordinateur ou à main levée, le plan de délimitation, s'il est établi à partir de données géographiquement et spatialement contrôlées, donne un même résultat : une situation clairement définie du bien, sa surface d'occupation, l'étendue des zones d'influences qui, confrontées à un état de propriété, serviront de base pour l'établissement de mesures de préservation adaptées.

Processus

Le processus en soi reste logique et de bon sens. C'est peut-être le résultat ou la perception que l'on a du résultat qu'il convient de mettre en question. Le résultat du processus n'est pas seulement le produit final, c'est-à-dire le plan de gestion. C'est aussi, et surtout, les mécanismes qui sont mis en place pour élaborer ce produit car ils sont le moteur des actions futures. Sous cet angle, les trois composantes nécessaires à l'appli-

cation du processus – documentation, groupe de travail et ressources – doivent être analysées dans le contexte politique, économique, culturel et administratif national, voire régional. Plusieurs questions essentielles se posent alors :

- Où réside l'autorité politique ? Qui définit et met en place la politique ? Où résident les institutions et organismes les mieux habilités à articuler des actions intégrées et participatives ? Quelle sera la place des autorités locales et comment concilier les différents niveaux de décision dans l'intérêt de la préservation du patrimoine ?
- Quels sont les besoins et les ressources disponibles ?
- Enfin, sur ces bases, comment initier un projet de site du patrimoine ?

Dynamique institutionnelle

L'interaction institutionnelle et l'acceptation de la notion de « responsabilités partagées », ne sont pas toujours spontanées et, même si elles sont parfois intégrées à une vision de



FIGURE 8 Sessions de travail pour la définition du projet paysagé.
Photo : Lucia Valero. © J. Paul Getty Trust

politique nationale, elles ne sont pas forcément appliquées ou applicables sur le terrain. La planification intégrée nécessite la continuité des actions de concertation et l'articulation de celles-ci dès les phases préparatoires jusqu'aux phases de réalisation et cela à tous niveaux, de manière transversale ou hiérarchique, afin de générer une « grille » où, depuis le technicien jusqu'au plus haut niveau politique, les décisions qui auront un impact sur le site, son paysage, sa gestion et sa conservation seront articulées et coordonnées.

Les alternatives

Générer une structure qui favorise la conservation et la gestion intégrée

Parfois la « planification » n'est pas intégrée dans la culture sociale ou administrative, cependant un site peut être « géré » par divers moyens bien connus et utilisés dans des systèmes plus statiques, tels que le classement, la création de zones de protection, etc. Une gestion quotidienne du site opérée de la manière la plus conservatrice possible, et la préparation d'opérations ponctuelles à haute visibilité qui ne mettent pas le bien culturel en péril mais améliorent ses conditions environnementales ou de présentation faciliteront son appréciation comme bien d'intérêt collectif.

Concilier conservation et développement

L'implication directe ou indirecte des communautés locales, en particulier dans des zones défavorisées, peut favoriser le développement socioéconomique nécessaire sans compromettre l'avenir du patrimoine. Ainsi, la formation de techniciens, de personnel d'accompagnement ou la génération d'activités dérivées, sont des possibilités à explorer (fig. 8).

Communication

Le « patrimoine » est encore souvent considéré comme élitiste et, souvent, le langage trop technique des chercheurs ou des conservateurs rend ce concept inaccessible au plus grand nombre. Un travail de communication doit mettre en valeur les liens entre « patrimoine » et « vie quotidienne » pour chaque citoyen, et le rendre accessible à tous.

« Pourquoi ce patrimoine est-il important pour vous en tant que personne, professionnel ou responsable au sein d'une institution ? » Telle fut la question clef de la réunion multisectorielle à laquelle furent conviés les responsables locaux, les représentants des diverses administrations et des porte-parole représentatifs des communautés avoisinantes. La réponse à cette question a permis d'établir la vision partagée par tous les participants.

Conclusion

Deux points sont incontournables et non négociables en matière de gestion d'un bien patrimonial : une structure de gestion et un principe.

Une structure de gestion

- Une autorité responsable présente sur le site :
Au-delà de l'autorité de tutelle à l'échelle nationale, c'est à une personne ou à un petit groupe de professionnels qualifiés et disposant d'une certaine autonomie que doit être confiée la responsabilité du site. Ce groupe ne détient pas la complète autorité sur le site, mais exécute les actions selon une politique clairement définie, développée et structurée dans le plan. Ce groupe est le pivot de la coordination des actions entreprises sur le site et son environnement, quels qu'en soient les promoteurs ou les acteurs. Il doit constituer le lien et l'agent fédérateur entre tous les groupes d'intérêt.
- Une délimitation claire et précise du bien à gérer :
Quel que soit le bien patrimonial, il est indispensable d'identifier de manière précise l'étendue et la nature de ses composants et, éventuellement, de leur articulation avec d'autres biens patrimoniaux. Cette délimitation est indissociable de l'état de propriété (parcellaire, plan cadastral) et des mesures de protection prévues par la législation. De même, la protection du site doit être coordonnée à tous les autres niveaux de planification et de gestion du territoire (zonage).
- Un projet réalisable et efficace :
Tout projet se construit par étape et les résultats à atteindre devront être définis de manière réaliste à partir des connaissances et des ressources disponibles. L'inertie résulte souvent de la manière dont les actions sont envisagées. Préparer un plan d'urgence, une réponse à des catastrophes naturelles, un plan « d'améliorations immédiates » peut se faire de manière réaliste et exécutable avec les ressources internes de l'institution. Par ailleurs, des interven-

tions nécessaires, mais plus délicates ou dépendantes d'une recherche plus approfondie, seront programmées à moyen et long terme. Quoiqu'il en soit, la crédibilité du plan réside dans sa mise en œuvre par l'application des mesures et des actions proposées.

Un principe

Agir dans le respect des principes de la conservation à partir de la connaissance du comportement des matériaux et des structures, limiter les interventions lorsqu'on n'en connaît pas les effets, anticiper des dégradations provoquées par l'imprudence ou l'inconscience des visiteurs, assurer l'entretien et l'intégrer dans les plans et le budget de fonctionnement, informer et éduquer les visiteurs, mais aussi les citoyens, sont les responsabilités essentielles des gestionnaires de site. Elles constituent la base et la garantie d'une gestion saine, responsable et durable.

Notes

- 1 Le plan de gestion de Joya de Cerén a été préparé dans le cadre d'une collaboration entre le Consejo Nacional para la Cultura y el Arte et le Getty Conservation Institute.
- 2 Le mot « lieu » s'emploie de façon à déterminer le site et son contexte.

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Conservation and Documentation of the Buddhist Monastery of Ajina Tapa, Tajikistan: Heritage of the Silk Road

Enrico Fodde, Kunio Watanabe, and Yukiyasu Fujii

Abstract: *This paper describes the documentation and conservation activities carried out at the site of Ajina Tapa in Tajikistan. Project activities included condition and damage assessments, laboratory analysis for the selection of repair materials, archaeological cleaning and consolidation, 3-D mapping of earthen structures, and presentation of the site to the public. The project was developed by UNESCO and the Japanese Funds-in-Trust for the Preservation of World Cultural Heritage (2005–8) and is part of a wider involvement of UNESCO in the conservation of the earthen heritage of Central Asia.*

Résumé : *Cette présentation décrit les activités de conservation et de documentation menées sur le site d’Ajina Tapa au Tadjikistan. Les activités du projet comprenaient des évaluations de l’état de conservation et des détériorations, des analyses de laboratoire pour la sélection des matériaux de réparation, des opérations de nettoyage et de consolidation, la cartographie en 3-D des structures en terre et la présentation du site au public. Le projet a été élaboré par l’UNESCO et les Fonds-en-dépôt japonais pour la préservation du patrimoine mondial culturel (2005–2008), dans le cadre d’un engagement plus large de l’UNESCO dans la conservation du patrimoine en terre d’Asie Centrale.*

The monastery of Ajina Tapa (seventh–eighth century C.E.) is located in southern Tajikistan along the Vahsh Valley about 13 kilometers from the modern city of Kurgan Tybe (fig. 1). Despite the site’s great significance for the spread of Buddhism in the area, it has been neglected and left to decay (fig. 2). The Moscow Institute of Oriental Studies of the Russian Academy of Sciences has carried out extensive documentation since the



FIGURE 1 Map of Central Asia showing location of Ajina Tapa.

site was excavated (1961–75), and the resulting publications (Litvinskij and Zejmal 1971, 1973) have contributed to the site’s current popularity. The site is also well known for the Buddha that was discovered during excavation of one of the corridors (fig. 3). After the destruction of the Bamiyan Buddhas in Afghanistan (2001), this statue became the largest known statue of the Buddha in Central Asia.

This paper describes the UNESCO/Japan Trust Fund project Preservation of the Buddhist Monastery of Ajina Tapa, Tajikistan (Heritage of the Ancient Silk Roads). There are five project goals:

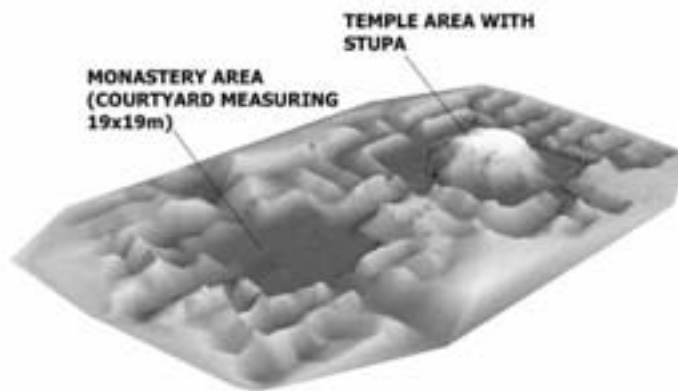


FIGURE 2 Three-dimensional view of the site showing location of monastery and temple area (total area about 50×100 m). Drawing: Fujii Yukiyasu



FIGURE 3 The 13 m long Buddha in *paranirvana* was discovered in one of the corridors of Ajina Tapa. The statue, made of soil, was cut into pieces and transported to the National Museum of Antiquities in Dushanbe, where it was conserved by experts from the Hermitage Museum of St. Petersburg. Spring 2005. Photo: Enrico Fodde

1. scientifically document the site;
2. establish a management system to ensure proper functioning and maintenance of the site, as well as prepare a master plan;
3. apply appropriate conservation treatments and implement a monitoring and maintenance schedule;

4. promote the site within the local community, as well as at the national and international levels; and
5. train staff in site management, monitoring, and maintenance.

Representatives from the Tajik Ministry of Culture, the Academy of Sciences (Institute of History, Archaeology, and Ethnography), the National Museum of Antiquities, and the Tajik Technical University (Faculty of Architecture) were trained in documentation and conservation activities.

Ajina Tapa is on UNESCO's list of cultural properties proposed for inclusion in the serial World Heritage nomination of the Silk Road. Other Tajik proposed sites include Panjikent, Shakhristan (Kalai Kakhkaka), Khulbuk, and the Pamir Fortresses. The Ajina Tapa project is one in a series of Central Asian projects launched by UNESCO in the past decade. These include several earthen sites, for example, Otrar Tobe in Kazakhstan (Fodde 2003, 2007a), the Chuy Valley sites in Kyrgyzstan (Fodde 2007b, 2008a), Merv in Turkmenistan (Williams 2003), and Fayaz Tapa in Uzbekistan.

Description of the Ajina Tapa Monastery

The monastery of Ajina Tapa is a typical seventh- to eighth-century C.E. combination of *vihāra* (monastic area) and *caitya* (temple area). Figure 2 shows that the plan is clearly organized in two distinct parts: the monastery, characterized by an open courtyard measuring 19 by 19 meters, with cellae facing four access passages; and the temple, with a similar arrangement of four passages facing the cellae but with a massive terraced mud stupa in the courtyard.

Study of the walls revealed a sophisticated construction system. Mud brick and *pakhsa* (Tajik: "rammed earth," "cob") were both used to construct the monastery walls. Pakhsa is seldom found at the lower levels. Walls were built by alternating several courses of mud brick with pakhsa. Doorways were made with mud-brick arches. Roofing was constructed with barrel vaults, without formwork. Litvinskij and Zejmal (2004) explain that at the time of excavation the pakhsa blocks measured 0.70 by 0.78 by 0.80 meter, and the mud bricks measured 0.10–0.12 by 0.25 by 0.50 meter. Other mud bricks surveyed by Litvinskij and Zejmal measured 0.05 by 0.20 by 0.50 meter. Fired brick, with nominal dimensions of 0.035–0.06 by 0.31–0.54 by 0.26–0.40 meter, was found in the core of the stupa and as paving in the main courtyard path.

Condition of the Site

Before the start of the project, the condition of the monastery was similar to that of other Tajik sites excavated in the Soviet period (figs. 4, 5). The earthen walls were left to decay without conservation, which also occurred at Qhulbuk (ninth–eleventh



FIGURE 4 Vegetation is one of the main deterioration factors for the earthen walls of Ajina Tapa. Deep roots (up to 1.5 m) expand while growing and cause collapse of parts of the wall. Spring 2006. Photo: Enrico Fodde



FIGURE 5 One of the tallest earthen walls after removal of vegetation showing decay caused by bird nesting. Spring 2006. Photo: Enrico Fodde

century C.E., Kulyab City) and the pre-Islamic city of Panjikent (Marshak 1990). In 2004 these sites, including Ajina Tapa, were inscribed in the ICOMOS Heritage at Risk list (Turekulova and Turekulov 2005). Today the sites are still in need of proper conservation.

In Ajina Tapa building decay was attributed to several factors: man-made damage (illegal quarrying), animal activity (uncontrolled livestock grazing on walls), salts attack (see table 2 for soluble salts content compared to that of other Central Asian sites), vegetation growth, and erosion. Quantification and analysis of the decay factors were undertaken through frequency distribution (Fodde 2008b).

Analytical Work

A field laboratory purchased specifically for the project was set up in the National Museum of Antiquities, and two experts were trained in soil analysis. The aim of the analysis was to select the best-performing repair/conservation material that was physically compatible with the historic fabric, yet reversible. The following analyses were carried out on both the pakhsa and the mud brick (twenty samples each): Munsell soil color; grain size distribution with granulometry curves; calculation of grading envelopes; Atterberg limits; soluble salts and carbonates content; wet/dry cycling, erosion, and shrinkage testing; and evaporation measurements by using a newly developed portable evaporation meter (Watanabe et al. 2008). The Geosphere Research Institute, Saitama University, Japan, conducted advanced, instrumental analysis that included mineralogical composition of soil, X-ray diffractometry, and soluble salts composition. Freeze and thaw tests were not performed.

Field testing was also carried out. Similar to experiments that were conducted in the Chuy Valley project in Kyrgyzstan (Fodde 2007b), eight test walls were constructed near the site to determine and select the best-performing repair material (Fodde 2008a, 2008b). The test proved extremely useful for assessing not only mud brick but also mud plaster (fig. 6).

The methods employed for the majority of the laboratory and field tests followed protocols established in other Central Asian projects, such as at Otrar Tobe in Kazakhstan (Fodde 2003) and the Chuy Valley in Kyrgyzstan (Fodde 2007b). Detailed results of the analysis and testing carried out in Ajina Tapa are presented in Fodde, Watanabe, and Fujii (2007). Due to the scarcity of information on the earthen heritage of Central Asia, it is interesting to compare the results from Ajina Tapa with those of other sites studied (tables 1, 2).



FIGURE 6 Test wall construction. Fall 2006. Photo: Enrico Fodde

Conservation Work

Before the conservation work started, the area around the earthen structures was cleared of debris that had accumulated from decades of erosion. Experts from Tobunken (National Research Institute for Cultural Properties, Tokyo) carried out the archaeological cleaning (removal of soil buildup) and training of local archaeologists. Emphasis was given to exposing the stupa area, which was done in tandem with the documentation and conservation work. Conservation activities then concentrated on the leaning and heavily eroded walls.

Leaning walls were stabilized by building mud-brick buttresses against them and covering them in mud plaster (fig. 7). The buttresses were not mechanically connected to the original walls in order to keep the intervention reversible and to minimize disruption of the original fabric. The mud-brick buttresses are easily removed without harming the monastery walls. Earthen buttresses were used instead of timber props because it was thought that the timber would have accelerated erosion at the junction between the timber prop and the earthen wall.

Heavily eroded walls were protected with a mud-brick shelter wall (fig. 8). Prior to this, the ground was positively graded to drain rainwater away from the base of walls. A shal-

Table 1 Comparative analysis of grain size distribution of three Central Asian sites

Description	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
Mud brick, Buddhist Temple II, Krasnaya Rechka, Kyrgyzstan	7.4	29.0	63.4	0.2
Mud brick, Otrar Tobe city wall, Kazakhstan	6.2	12.0	81.5	0.3
Mud brick, Ajina Tapa, Tajikistan	14.7	64.9	19.9	0.5
Pakhsa, Ajina Tapa, Tajikistan	14.2	57.3	16.1	2.4

Table 2 Comparative analysis of carbonates and soluble salts content of three Central Asian sites

Description	Carbonates (%)	Soluble Salts (%)
Mud brick, Buddhist Temple II, Krasnaya Rechka, Kyrgyzstan	15.2	2.8
Mud brick, Otrar Tobe city wall, Kazakhstan	34.8	5.6
Mud brick, Ajina Tapa, Tajikistan	24.7	3.7
Pakhsa, Ajina Tapa, Tajikistan	24.6	6.6



FIGURE 7 Construction of buttresses for the consolidation of leaning walls. Spring 2007. Photo: Enrico Fodde



FIGURE 8 Construction of shelter wall against erosion. Spring 2007. Photo: Enrico Fodde

low trench (20 cm deep) was dug along the wall and filled with a conglomerate of gravel and sterile soil. This mix was rammed in place to give a solid ground for the shelter wall masonry. The shelter wall was constructed so that the mud brick is clearly legible as a modern intervention. The gap between the mud-brick skin and the historic fabric was filled with dry soil, and then the area was fully plastered with a mix of soil and straw. In some cases, “windows” were left to expose the historic fabric; this was done for a didactic purpose, to demonstrate our approach to shelter walling.

Documentation Activities

Total station recording of the ground surface and photogrammetric documentation of earthen structures were undertaken as a joint venture between the University of Saitama and the Fukada Geological Institute (Fujii, Watanabe, and Murakami 2007). A 3-D map was produced from three pairs of stereo

photographs and from the photogrammetry. Other documentation activities included the following:

1. Digitization of archival materials that are kept in the National Museum of Antiquities (Dushanbe). This consists of b/w negatives and prints, original excavation reports, isometric drawings, plans, sections, and elevations. The digital copy was catalogued in specially designed databases, and the original archival materials were stored in fireproof filing cabinets. The information provided in the archive was essential for the proper conservation of the earthen walls.
2. Photographic documentation of wall elevations before conservation and cataloguing of the images in specially designed databases.
3. Graphic and written damage assessments of structures using specially designed proformas and symbols (in both English and Russian).
4. Documentation of the conservation interventions (in both English and Russian).
5. Study of local earthen building techniques by interviewing craftsmen and by studying the available (albeit scarce) literature.
6. Collection of climate data.

Both training and capacity building were essential components of all documentation activities.

Presentation of the Site to the Public

In 2006 a fence was built around the site to protect against animal intrusion, and a new access bridge was built since the site is partially surrounded by a modern canal. One of the final aims of the project is to develop promotional materials, such as pamphlets and sign boards, that tell the history of the site and provide site maps, all translated into Tajik, Russian, English, and Japanese.

Conclusion

The Ajina Tapa project will conclude at the end of 2008, but, as this paper has shown, several successful results have already been achieved. Apart from the conservation and documentation work, a critical outcome was national capacity building. Tajik experts were fully involved in the archaeological work, as well as the documentation and conservation activities. Furthermore, they were active in the field research, data

collection, database design and input, laboratory analysis, and conservation treatment, all under the supervision of an international team of experts. It is hoped that this project, the first of its kind in Tajikistan, will have broad application in the conservation of the country's built heritage.

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Conservation et gestion des sites archéologiques en Asie centrale : Mise en place d'une stratégie adaptée aux structures en terre

David Gandreau, Sébastien Moriset et Mahmoud Bendakir

Résumé : Suite aux recommandations établies dans le cadre du programme *Central Asian Earth* par les représentants des cinq pays d'Asie centrale impliqués, plusieurs projets de conservation ont été réalisés ou sont en cours de réalisation sur des édifices en terre dans un contexte archéologique. Les résultats observés sur cinq sites (Merv et Nisa au Turkménistan, Fayaz Tepa et Ayaz Kala en Ouzbékistan et Sarazm au Tadjikistan) attestent des progrès réalisés en termes de techniques de conservation et de gestion des sites. Le travail engagé sur ces sites pilotes témoigne aussi d'une meilleure coopération entre les archéologues et les conservateurs et d'une plus grande ouverture vis-à-vis des acteurs concernés. Pour autant, ces efforts de coopération méritent d'être encore renforcés. De même, de nouveaux rapprochements comme ceux déjà établis entre les personnes et institutions en charge du patrimoine archéologique au niveau régional doivent être encouragés.

Abstract: Following recommendations made in the context of the *Central Asian Earth* Program by the representatives of the five Central Asian countries involved, several conservation projects concerning earthen buildings in an archaeological context were carried out or are in progress. The results observed on five sites (Merv and Nisa in Turkmenistan, Fayaz Tepa and Ayaz Kala in Uzbekistan, and Sarazm in Tadjikistan) illustrate the progress made in terms of conservation techniques and site management. The work undertaken on these pilot sites reveals improved cooperation between archaeologists and conservators and a greater openness to stakeholders. Yet cooperation efforts need to be stepped up. Similarly, the establishment of closer ties between individuals and institutions in charge of archaeological heritage on the regional level should continue to be encouraged.

Les pays d'Asie centrale sont riches d'un patrimoine archéologique exceptionnel, constitué de centaines de sites construits en terre pour lesquels les fouilles très répandues et quasi exclusives des dernières décennies laissent place, peu à peu, à des stratégies de gestion impliquant des partenaires de divers horizons.

L'activité de fouille archéologique est progressivement accompagnée d'une politique de conservation, si bien que les différentes disciplines impliquées sont amenées à mettre en place une collaboration effective tout en engageant les différents acteurs sociaux ayant un intérêt sur le site et les décideurs politiques, au niveau local, national et même régional.

Cette nouvelle situation exige une harmonisation des visions et des moyens et une planification concertée et durable des activités. Or, dans les pays d'Asie centrale, malgré d'importants efforts engagés sur plusieurs sites pilotes, la mise en application d'un processus régional de gestion des sites archéologiques en terre demande d'être renforcée et plus structurée.

Dans cet article, nous faisons une synthèse des premières expériences réalisées dans le cadre du programme *Central Asian Earth*¹ sur des sites archéologiques en Ouzbékistan, Turkménistan et Tadjikistan. L'étude de ces projets vise à mesurer les avancées réalisées, mais aussi les difficultés rencontrées, afin de mieux accompagner cette démarche nouvelle de conservation et gestion des sites archéologiques en terre.

Projet cadre *Central Asian Earth*

En mai 2000, une réunion d'experts visant à établir une stratégie globale pour le patrimoine en terre d'Asie centrale rassemblait des représentants de cinq pays, Kazakhstan,

Kirghizistan, Tadjikistan, Turkménistan et Ouzbékistan (Asghabat, 14–17 mai 2000). La signification culturelle du patrimoine archéologique en terre d'Asie centrale, sa variété et son caractère unique y furent unanimement reconnus. Dans un même temps, les experts ont manifesté leurs craintes face aux problèmes de conservation et de gestion qui menacent ce patrimoine et ont souligné les manques de capacités au niveau de chaque pays pour en assurer la préservation.

À la demande des représentants des cinq républiques, le programme *Central Asian Earth* a été réalisé par le Centre du patrimoine mondial de l'UNESCO, en collaboration avec des institutions nationales d'Asie centrale responsables de la conservation du patrimoine culturel immobilier. Ce programme reçoit l'appui des bureaux de l'UNESCO en Asie centrale (Almaty, Tachkent et Téhéran), d'autres divisions de l'UNESCO, du Centre international d'études pour la conservation et la restauration des biens culturels (ICCROM), du Conseil international des monuments et des sites (ICOMOS), et des institutions spécialisées dont CRATerre-ENSAG. Le programme *Central Asian Earth* vise à renforcer les capacités des gestionnaires de sites et des experts techniques en Asie centrale en matière de conservation, présentation et gestion du patrimoine culturel, grâce à une étroite collaboration aux niveaux international, régional, et national.

De nombreux projets de gestion et conservation ont été depuis engagés sur des sites archéologiques. Certains pour lesquels CRATerre a été impliqué font l'objet de cette étude :

Merv, Turkménistan

Les vestiges des cités qui se sont succédé à Merv (fig. 1) subsistent sur plus de mille hectares, depuis Erk Kala, le premier site fortifié de période achéménide jusqu'à Bairam Ali, la ville actuelle. Les murs d'enceinte de ces cités sont restés visibles et certains édifices – les plus monumentaux – demeurent encore en élévation (mosquées et mausolées, palais, résidences fortifiées, citernes et glaciers). L'état de ruine de ces bâtiments est toutefois devenu alarmant : après plus de 100 ans d'interventions archéologiques qui ont permis l'ouverture de plusieurs centaines de sondages laissés ouverts, de nombreux vestiges restés à l'air libre sont menacés de complète disparition. Le projet de conservation et gestion du site a été mis en place suite à sa nomination sur la Liste de patrimoine mondial en 1999, afin de faire face à cette situation.

Nisa, Turkménistan

Le site archéologique de Nisa (fig. 2), à 12 km au sud-ouest d'Asghabat, se compose de deux centres voisins d'époque



FIGURE 1 Merv, Turkménistan (Great Kiz Kala). Partenaires du projet depuis 2000 : Direction du patrimoine national turkmène, University College of London, Centre du patrimoine mondial de l'UNESCO, World Monuments Fund, CRATerre-ENSAG. © CRATerre-ENSAG / David Gandreau



FIGURE 2 Nisa, Turkménistan. Partenaires du projet depuis 2005 : Direction du patrimoine national turkmène, Académie russe des Sciences, Université de Turin, Centre du patrimoine mondial de l'UNESCO, CRATerre-ENSAG. © CRATerre-ENSAG / Sébastien Moriset

parthe : à l'ouest la ville dite « nouvelle Nisa » et à l'est, la citadelle royale appelée « ancienne Nisa » ; seule cette dernière a été fouillée. Il s'agit d'un ensemble de bâtiments liés à la représentation de la cour parthe, construits sur plus de 14 hectares au sommet d'une colline naturelle. Ces bâtiments, protégés

par un mur d'enceinte de 1,6 km de circonférence comportant 43 tours de garde, sont répartis en deux zones, l'une au nord et l'autre au sud. La zone nord continue d'être fouillée chaque année par deux équipes archéologiques : l'une russe, dirigée par Victor Pilipko (Académie russe des Sciences), l'autre italienne, dirigée par Carlo Lippolis (Università degli Studi di Torino) qui chacune, en collaboration avec la direction du patrimoine national, prévoit des actions de conservation après les fouilles. Le montage du dossier de nomination, réalisé en 2005, a permis de définir une stratégie plus effective de conservation, inscrite dans le plan de gestion du site. Le site a été inscrit sur la Liste du patrimoine mondial en 2007)

Fayaz Tepa, Ouzbékistan

Datant du I^{er} siècle av. J.-C., les ruines du site bouddhiste de Fayaz Tepa (fig. 3) se situent près des remparts de l'ancienne ville de Termez. L'édifice, constitué de briques de terre crue, s'organise autour d'un stupa et d'un complexe monastique, composé de trois parties : la cour centrale, les cellules monastiques au nord, le réfectoire et les cuisines au sud. Depuis l'achèvement des fouilles en 1977, seuls de très élémentaires travaux de préservation ont été entrepris avant qu'un projet de plus grande envergure ait permis sur cinq ans de sauvegarder les vestiges anciens tout en facilitant la compréhension du site.



FIGURE 3 Fayaz Tepa, Ouzbékistan. Partenaires du projet 2002–2007 : Unesco/Fonds-en-dépôt japonais, Bureau de l'UNESCO à Tachkent office, Conseil des Monuments d'Ouzbékistan, CRAterre-ENSAG. © CRAterre-ENSAG / Mahmoud Bendakir

Ayaz Kala, Ouzbékistan

Les trois forteresses d'Ayaz Kala (fig. 4), construites entre le IV^e siècle av. J.-C. et le VII^e siècle après J.-C., font partie d'un ensemble d'architecture militaire de la région du Khorezm, au nord de l'Ouzbékistan. L'érosion progressive de ces forteresses et des monuments associés a atteint un point critique qui menace les valeurs du site. Dans le cadre d'une formation régionale sur la conservation des structures en terre organisé sur place en septembre 2006, des actions d'urgence ont été mises en œuvre pour prévenir des dégradations majeures diagnostiquées en 2005. Cette formation réunissant des professionnels de quatre pays d'Asie centrale et d'Afghanistan a posé les bases d'un projet visant à élargir les interventions de conservation, non seulement à l'ensemble du site, mais aussi aux autres forteresses de la région.

Sarazm, Tadjikistan

Le site proto-urbain de Sarazm (fig. 5), dans la vallée du Zerafshan, non loin de la frontière actuelle entre le Tadjikistan et l'Ouzbékistan a été occupé sur au moins 50 hectares depuis le IV^e millénaire jusqu'au II^e millénaire avant notre ère. De nombreuses constructions en terre se sont succédé durant cette période et une partie a été révélée par les fouilles archéologiques de ces dernières décennies. Cinq couvertures métalliques de 120 m² chacune ont été installées pour protéger les



FIGURE 4 Ayaz Kala, Ouzbékistan. Partenaires du projet depuis 2005 : Unesco/Fonds-en-dépôt japonais, Bureau de l'UNESCO à Tachkent, Conseil des Monuments d'Ouzbékistan. © CRAterre-ENSAG / David Gandreau



FIGURE 5 Sarazm, Tadjikistan. Partenaires du projet depuis 2005: Archaeological Base of Panjikent of A. Donish Institute of History, Archaeology & Ethnography, Academy of Science, et UNESCO. © CRA Terre-ENSAG / Thierry Joffroy

vestiges de cette installation proto-urbaine unique dans la région. Le plan de gestion, finalisé en 2006, largement tourné vers la conservation et la mise en valeur du site, est progressivement mis en œuvre.

Composantes développées et principales avancées

Techniques de conservation préventive et éthique

Avec le lancement du programme *Central Asian Earth*, une réflexion sur les approches de conservation et l'éthique d'intervention a été ouverte. Il s'agissait de rendre compte des pratiques passées et encore d'actualité au début du XXI^e siècle utilisant largement les matériaux rajoutés tels que le béton et la brique de terre cuite, procédés inadaptés à la conserva-

tion des structures en terre. Une modification de ces pratiques s'opère actuellement avec l'introduction du principe de conservation préventive – à la fois volontairement minimale, réversible, fidèle au matériau d'origine, et peu coûteuse. Il s'agit désormais de freiner autant que possible l'érosion des structures, sans pour autant en modifier l'aspect. Les activités menées ces sept dernières années via le programme *Central Asian Earth* ont permis de déterminer ce palier minimal d'intervention spécifique à la terre. En effet, l'érosion relativement rapide de la terre crue par rapport à la pierre ou la brique de terre cuite impose cette approche différente, ou la notion d'intervention minimale ne peut être aussi radicale qu'avec les matériaux durs.

Du point de vue méthodologique, une étude poussée des pathologies est un préalable à chacun des projets cités. Cette observation systématique des facteurs de dégradation est accompagnée d'un programme de monitoring qui permet d'en mesurer la vitesse. En fonction des données ainsi acquises, des techniques de conservation appropriées pour chaque site sont mises au point et testées à petite échelle, sur plusieurs années, avant d'être progressivement utilisées plus largement (fig. 6). Parallèlement, des recherches sur les terres disponibles et sur les processus de transformation pour préparer les matériaux (briques de terre crue, terre compactée, terre façonnée, et enduits) sont réalisées. Des laboratoires d'analyse des terres ont même été installés sur deux sites archéologiques au Turkménistan, à Merv et à Nisa.



FIGURE 6 Différents procédés de conservation préventive mis en œuvre à Merv. © CRA Terre-ENSAG / David Gandreau

Les techniques les mieux connues et répandues désormais sont :

- les interventions minimales de maintenance ;
- les procédés de ré-enfouissement (*backfilling*) ;
- les enduits de protection en terre ;
- les couches de terre sacrificielles en tête de murs (*capping*) ;
- les drainages de surface ;
- les drains enterrés ;
- la reconstruction des bases de murs déchaussées ;
- la maçonnerie des zones ponctuelles d'érosion.

Des équipements spécifiques ont été réalisés ou fournis sur chacun des sites pour la mise en œuvre de ces nouvelles techniques.

Mise en valeur des sites

Les traces archéologiques du riche passé historique de l'Asie centrale représentent généralement un formidable support pour l'éducation et la sensibilisation au patrimoine des jeunes générations d'élèves et étudiants. Elles ont aussi un attrait considérable pour les visiteurs locaux ou étrangers. Aux yeux de nombreux partenaires concernés, la préservation de ces évidences parfois ténues du passé et leur mise en valeur peuvent contribuer très sensiblement au développement local (fig. 7). Les expériences se multiplient dans ce sens, allant du



FIGURE 7 Élèves visitant le site de Nisa au Turkménistan.
© CRATerre-ENSAG / David Gandreau

simple feuillet explicatif distribué à l'entrée des sites laissés en l'état, à la restitution des murs anciens et des aménagements comme à Fayaz Tapa où le complexe bouddhiste a été partiellement restauré. Un centre d'information a également été construit en matériaux locaux à proximité du monastère.

Le classement récent du site turkmène de Nisa sur la Liste du patrimoine mondial en 2007 témoigne d'une meilleure reconnaissance de la signification culturelle de ce patrimoine archéologique. D'autres dossiers en cours d'élaboration confirment cette avancée (Sarazm, Tadjikistan).

Formation des professionnels

La transmission des connaissances est un axe essentiel du programme. Les projets sont avant tout des lieux de formation où des ouvriers locaux s'entraînent aux techniques de conservation. Des sessions théoriques et pratiques pour les responsables de site sont également organisées au niveau national (Merv, 2007 ; fig. 8). Une formation régionale réalisée à Ayaz Kala, Ouzbékistan, a même pu être organisée, mais celle-ci reste exemplaire et trop rare.

Établissement de plans de gestion

La gestion des sites archéologiques mettant en perspective leur conservation est une approche récente, particulièrement appropriée en Asie centrale où les vestiges archéologiques en terre constituent une majorité du patrimoine immobilier. Les expériences de Merv et de Sarazm montrent que l'aide



FIGURE 8 Formation organisée à Merv en juin 2007 pour les responsables des huit parcs archéologiques du Turkménistan.
© CRATerre-ENSAG / Sébastien Moriset

des riverains est un précieux atout pour cette tâche que les trop rares employés des gouvernements affectés à la gestion du patrimoine ne peuvent assumer à eux seuls. La collaboration de chacun dans l'effort de protection et de gestion passe par des phases de sensibilisation, qui peuvent nécessiter la construction de centres d'interprétation (Fayaz Tepa), la préparation de kits pédagogiques à distribuer dans les écoles (Merv), ou la présentation des activités de conservation à la télévision (Turkménistan). Si la sensibilisation est essentielle pour fédérer les populations autour de leur patrimoine, elle permet également de récolter des financements qui souvent suffisent à mettre en œuvre les actions préventives de conservation.

L'efficacité de cette collaboration dépend du degré d'implication des parties prenantes dans le processus de planification de la gestion. Les impliquer dès les phases initiales de constat des problèmes, jusqu'à la formulation d'un plan d'action visant à atteindre des objectifs partagés, se révèle comme le meilleur moyen d'associer un large groupe d'acteurs aux efforts de conservation.

Par ailleurs, les premières expériences de collaboration entre archéologues et conservateurs menées au Turkménistan (Nisa, Olug Depe, Merv) montrent de réelles avancées en termes de gestion. À Nisa par exemple, l'équipe italienne d'archéologues (Università degli Studi di Torino) discute avec les conservateurs turkmènes des travaux de conservation à effectuer après les fouilles. Cela permet de prévoir un budget pour payer les matériaux et la main-d'œuvre de conservation. Ce budget qui est en général dérisoire par rapport au budget de transport de l'équipe internationale. La même chose se produit à Merv, où les plans de conservation se discutent sur le site même, en présence des architectes qui supervisent les travaux de conservation, et des archéologues qui donnent leur avis. Cela permet une meilleure compréhension mutuelle, un plus grand respect des règles éthiques et une meilleure conservation des structures à long terme.

Difficultés rencontrées

La formation nationale organisée à Merv en 2007 a montré que l'expérience n'est pas encore assez répandue à l'intérieur même des pays, et qu'il serait très utile d'organiser des sessions nationales rassemblant des responsables de sites différents, partageant les mêmes problèmes techniques mais n'ayant pas d'occasions de collaborer. Les professionnels témoignent aussi de l'inadaptation des enseignements universitaires actuels à la problématique de la conservation. La plupart des enseignants en conservation d'Asie centrale basent leurs cours sur des projets réalisés du temps de l'administration soviétique, à une époque où l'intervention sur les structures en terre n'existait quasiment pas, et où l'intervention sur des structures en terre cuite consistait généralement à restaurer entièrement les bâtiments. L'adaptation des programmes universitaires fait partie des priorités, afin de sensibiliser les jeunes conservateurs aux techniques de conservation préventive des architectures de terre, ainsi qu'aux normes et règles éthiques internationales de la conservation. Dans cette perspective, il convient de renforcer la coordination mise en place au niveau régional pour assurer une meilleure diffusion des informations, une plus grande visibilité des actions et une réelle capitalisation des informations.

Enfin, les premières expériences de collaboration engagées par les archéologues et les conservateurs afin d'imaginer ensemble des mécanismes de gestion ouverts à une large gamme de partenaires concernés, révèlent toute la pertinence de cette approche. Souhaitons que ces rapprochements entre disciplines se généralisent et que tous les moyens soient mis en place pour y parvenir.

Note

- 1 Pour plus d'informations sur le programme Central Asian Earth, consulter les liens Internet suivant : <http://terre.grenoble.archi.fr/documentation/downloads/central-asian-earth.pdf> et <http://unesdoc.unesco.org/images/0013/001322/132213e.pdf>.

The Archaeological Site of Konar Sandal, Jiroft, Iran: Conservation of Earthen Architecture

Manijeh Hadian Dehkordi, Rasool Vatandoust, Youssef Madjidzadeh, and Mohsen G. Kashi

Abstract: *New discoveries from five seasons of excavations at the archaeological site of Konar Sandal in southeastern Iran (2003–7) have revealed evidence of a civilization dating to the third millennium B.C.E., one of the oldest civilizations in the East. The principal deterioration mechanisms on the site are rapid erosion of the earthen remains after excavation, extensive washout from heavy rains, creation of deep ridges and waterways, and soluble salt efflorescences. Based on the results gained from scientific studies, we recommend that the earthen structures be preserved by coating the exposed surfaces with earthen materials to protect against rainwater washout and to decrease the moisture evaporation rate. Creating suitable drainage systems and sloping would also help decrease erosion and deterioration.*

Résumé : *À la suite de cinq saisons de fouilles sur le site archéologique de Konar Sandal dans le sud-est de l'Iran (2003–2007), des témoignages d'une des plus anciennes civilisations de l'Orient au III^e millénaire avant notre ère ont été mis au jour. Les principaux mécanismes de détérioration qui affectent le site sont l'érosion rapide des vestiges en terre après les fouilles, le ravinement après les fortes pluies, la création de gorges profondes et de cours d'eau, et des efflorescences de sels solubles. Sur la base des résultats des études scientifiques, nous recommandons de préserver les structures en terre en appliquant un revêtement en terre sur les surfaces exposées pour les protéger contre les effets de la pluie et diminuer le taux d'évaporation et d'humidité. L'aménagement d'un système de drainage adapté en créant des pentes permettrait aussi de ralentir l'érosion et la détérioration.*

The Jiroft plain is situated south of the province of Kerman in southeastern Iran. It is located in a flat, low-lying region that

is surrounded on the north, west, and east by relatively high elevations. The plain slopes down from north to south. It has a 60 kilometer north-south length and a 10 to 15 kilometer east-west breadth. The Konar Sandal region lies 30 kilometers outside and to the south of the city of Jiroft on the banks of the Halil Rood River. The majority of the region's orchards, farms, and villages are located in this area, which is agriculturally rich and fertile from the extensive layers of alluvial topsoil left behind from repeated overflowing of the river.

The artifacts recovered from Konar Sandal's northern and southern archaeological sites belong to an ancient civilization dating to the third millennium B.C.E. (fig. 1). Five seasons of excavations at the two sites have produced a wealth of archaeological finds, as well as remnants of adobe architecture that include two huge structures and both residential and industrial (metalwork) units.

The conservation of ancient architecture is of utmost importance. Immediately after the start of the project in 2002, we approached and later collaborated with the Research Center for the Conservation of Cultural Relics to conduct preliminary studies on the composition and physical/mechanical characteristics of the adobe structures. In addition, we asked them to determine the type and extent of damage and the best methods to conserve and restore the buildings.

Decay and Damage

Some of the damage to the structures may have occurred in the interim period between the two seasons of excavations and even during excavation when the walls were not adequately protected. Factors contributing to the rapid erosion of exposed adobe walls are the local soil's extraordinary ability to absorb



FIGURE 1 Northern main hill of Konar Sandal. Photo: Nader Soleimani, Archaeological Research Base, Halil Rood region



FIGURE 2 Rapid erosion of exposed adobe. Photo: Manijeh Hadian, RCCCR



FIGURE 3 The use of adobe plaster on jute textile. Photo: Manijeh Hadian, RCCCR

water (hygroscopicity), extensive water runoff that has caused soil erosion and the formation of deep furrows and water conduits, and the efflorescence and dissolution of soluble salts on and just below the wall surfaces (fig. 2).

Previous Conservation Methods

In the first and second seasons of excavation, archaeologists experimented with various methods to protect the architecture found in multiple layers. These methods included covering the walls with adobe plaster on jute textile (fig. 3), constructing new brick walls covered with adobe plaster to protect the original fabric, and applying temporary plastic sheathing over the exposed areas (figs. 4, 5). Each of these methods suffered certain shortcomings and disadvantages that made them incapable of fully preventing damage to the structures. A critical problem was insufficient adhesion between the new and old materials, a lack of adequate protective covering, and high moisture permeability in the old walls.

Studies and Results

Geology and Climate of the Region

Geological studies indicate that the Jiroft plain consists of clay and newly formed streams on river plains. The clay layers have caused the formation of aquifers in the region. Based on the climate tables, Jiroft is classified as hot and semiarid. Though the



FIGURE 4 The raising of brick walls covered with adobe plaster as a means of protecting the main walls. Photo: Manijeh Hadian, RCCCR

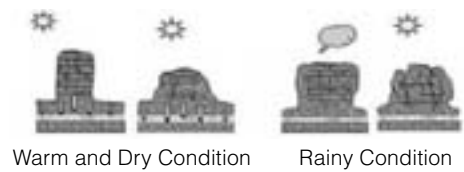


FIGURE 5 Schematic form of the decay process of mud bricks. Photo and drawing: Manijeh Hadian, RCCCR

average annual temperature is 25°C, there are wide differences between summer and winter temperatures. The area is characterized as having high humidity and frequent morning fog, and the average annual evaporation rate is 2,468.9 millimeters.

Analysis of Soil and Water

Chemical tests of the region’s ground and surface water revealed high levels of chlorine, sulfate, sodium, and magne-

sium (table 1). Mineralogical studies of the soil indicated the presence of quartz, albite, and muscovite. Montmorillonite and illite were found in the mud bricks from the northern and southern hills of Konar Sandal (table 2). Chemical tests of these samples showed lesser amounts of calcium and higher amounts of sodium, chlorine, and sulfur, as compared with the soil of western Iran (tables 3, 4). The region’s soil may be classified into two categories: clay-sand and clay.

Table 2 Mineralogical studies of Konar Sandal mud bricks

Sample	Mineral
Konar Sandal north mud brick	Quartz, albite, calcite, montmorillonite, chlorite, muscovite, gypsum
Konar Sandal north mud brick	Quartz, albite, calcite, montmorillonite, chlorite, muscovite, gypsum

Table 1 Chemical analysis of the ground and surface waters of the Konar Sandal region. Samples were taken from a local well and at different locations along the Halil Rood River.

Row	Water Source	pH	Cation and Anion Concentration (mEv/lit)							
			K ⁺	Na ⁺	Mg ⁺²	Ca ⁺²	SO ₄ ⁻²	Cl ⁻	HCO ₃	CO ₃ ⁻²
1	Well	7.3	—	28	12.8	4.8	25	13.6	6.6	—
2	River (Halil)	7.9	—	5.4	2.3	2.6	5.2	2.4	2.4	—
3	River (Halil)	7.9	—	3	1.5	2.3	2.8	1.2	2.7	—
4	River (Halil)	8	—	4.2	1.0	2.3	3.0	1.5	3.1	—
5	River (Halil)	7.8	—	25.8	3.6	8.8	22.8	11	4.1	—
6	River (Halil)	7.8	—	26.5	4.8	8/0	24	11	3.8	—
7	River (Halil)	8	—	4.8	1.4	2.2	2.5	2.4	3.7	—

Table 3 Chemical analysis of Konar Sandal mud bricks

Sample	% SiO ₂	% Fe ₂ O ₃	% Al ₂ O ₃	% CaO	% MgO	% K ₂ O	% Na ₂ O	ppm S	ppm Cl
Konar Sandal north mud brick	49.20	6.19	9.54	10.96	4.42	2.89	2.04	5291	4989
Konar Sandal north mud brick	48.27	7.29	11.15	12.27	4.58	1.75	1.43	4461	426

Table 4 Chemical analysis of Chogha Zanbil mud bricks in western Iran

Sample	% SiO ₂	% Fe ₂ O ₃	% Al ₂ O ₃	% CaO	% MgO	% SO ₃
Chogha Zanbil mud brick 1	35.79	2.6	9.83	22.75	2.97	5.12
Chogha Zanbil mud brick 2	25.47	3.77	6.123	22.59	3.43	9.07

Decay Process

Our studies indicate that the erosion of adobe structures is partially attributed to montmorillonite minerals and chlorine and sodium sulfate salts in the soil. These expandable clays and soluble salts accelerate disintegration of the adobe, especially at the wall tops and bases, which are exposed to rain and high groundwater levels respectively. In dry weather a high degree of surface evaporation transports soluble salts through the earthen wall, leaving efflorescences on and just below the adobe surface.

Conservation Strategy

The following measures are recommended to minimize erosion and protect the earthen structures:

- Insulate the structures against moisture and temperature fluctuations and reduce surface evaporation by protecting the exposed surfaces with materials such as geotextiles, soil, mud brick, and adobe plaster.
- Regrade the site to eliminate standing water and divert surface water runoff.
- Reduce groundwater levels by drilling wells in the vicinity of the site (this method requires detailed geological studies).

Conservation Operation

A work area was set up on-site to make mud bricks. Prior to mass production, bricks made from locally available soil were assessed for suitability, and the most important factors were determined to be cohesion, wet and dry strength, water

permeability, and shrinkage. Their dimensions were half the size of the original bricks, nominally measuring 10 × 20 × 40 centimeters. The smaller size and composition of the replacement bricks was chosen for the following reasons: (1) physical compatibility between the original and the restored sections; (2) sufficient thickness of the new adobe to protect the originals from erosion; (3) increased pace of bricklaying; and (4) distinction between the original and replacement building materials.

Conservation work on the six archaeological trenches of Konar Sandal proceeded in the following stages:

1. Leveling and sloping of the ground and diversion of surface water away from the site.
2. Creation of protective layers for the floors and walls.
3. Covering of all surfaces with adobe plaster (*kah gel*).

These activities were carried out by teams that completed all stages of the work, including acquiring the materials, transporting them to the site, preparing the trenches, and conducting the actual construction and conservation work.

Walls

Conservation of the walls within the trenches began with new mud bricks set in mud mortar laid approximately 5 centimeters from the original wall. The space between the new and the original walls was filled with compressed earth (fig. 6). It should be noted that the soft nature of the adobe bricks enables the mason to cut them to the required dimensions as the work proceeds. The tops of the walls were covered with a layer of geotextile and a layer of compressed earth 10 centimeters thick, followed by another layer of mud bricks and compressed earth. This was covered with adobe plaster sloped at an incline to shed water.



FIGURE 6 The conservation method of treating the walls within the trenches. Photo: Manijeh Hadian, RCCCR

Brick Floors

The same materials and methods were used to protect the brick floors (fig. 7). First, the surface of the floors was leveled using compressed earth. This was covered with a layer of geotextile and an additional layer of bricks. A thin layer of soil was used



FIGURE 7 The conservation method of treating the brick floors. Photo: Manijeh Hadian, RCCCR

to fill the gaps and create the required slope for the adobe plaster. One-centimeter-diameter holes were pierced through the geotextile material to allow airflow and reduce condensation.

Floors of the Trenches

The trenches were leveled with compressed earth to protect them. When possible, positive slopes were created to divert surface water; otherwise, the floors were leveled flat. Geotextiles were sandwiched between two layers of compressed earth and covered with adobe plaster. The plaster was applied to prevent the edges of the trenches from collapsing and to divert surface water flow away from them.

Monitoring

Close monitoring of the repairs over a three-year period showed some success. Important factors contributing to this were (1) careful application of plaster to the adobe and (2) precise leveling of the surfaces to shed water. Other treatments were also tested and monitored. These included laying new bricks at the wall corners to increase structural stability. Differences in settlement between the compressed earth and the bricks resulted in cracks on the upper surfaces of the walls. In addition, the walls of some trenches were unstable and collapsed owing to poor adhesion of the adobe plaster. To address this, the walls were covered in geotextile prior to being covered with earthen plaster. The outcome of this method is yet to be determined.

Conclusion

In conclusion, the following points are worthy of note:

- Both stabilization and restoration measures taken on the trenches have been accomplished using traditional materials such as adobe and earthen plaster to reduce the rate of erosion and with minimal intervention to retain the architectural characteristics of the structures. Treatment measures were designed to be reversible and retreatable. Considering the environmental conditions of the region—high groundwater levels, soluble salt-rich soils, and rapid surface evaporation, together with related wet/dry and salt phase cycling (efflorescence/deliquescence) that rapidly disintegrates adobe bricks—geotextiles are recommended to help reduce surface evaporation and moisture absorption.

- Conservation and restoration materials and methods adopted at Konar Sandal differ based on the condition of the buildings and the site, as well as the physical environment. The treatments adopted at one site may prove destructive for another that has a different climate and deterioration conditions.
- There are many issues that drive conservation and restoration activities on archaeological sites. Some of the environmental complications at Konar Sandal are the high levels of salinity in the water and the prevalence of expandable clay minerals in the soil. These conditions cannot be eliminated and require considerable research to mitigate on a sitewide basis. In some cases new and high-tech treatment solutions that address these issues are prohibitive due to insufficient resources, and the prospect of their potential success can cause delays in carrying out critical and often simple emergency conservation work. Therefore, our best course of action is to continue using traditional and practical repair materials and methods while advanced analysis and treatment testing continue. A critical part of the process, though, is the ability to distinguish between the issues that are compelling and immediate and those that can be addressed over time as the necessary research and resources are acquired.

The complex environmental conditions of Konar Sandal, as well as its extensive size and archaeological importance, require development and implementation of a carefully considered, long-term conservation and management plan. In the interim, our recent conservation and restoration activities at Konar Sandal have helped reduce the extent of erosion, and our efforts to increase public awareness, train locally stationed staff, and vigilantly guard the site have helped prevent serious damage.

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Conservation of the Enclosure of Khasekhemwy at Hierakonpolis, Upper Egypt: Investigation, Experimentation, and Implementation

Richard L. Jaeschke and Renee Friedman

Abstract: *The ceremonial enclosure of King Khasekhemwy (ca. 2686 B.C.E.) at Hierakonpolis, Upper Egypt, is the oldest free-standing mud-brick structure in the world. The structure was constructed in two phases, and the building methods and materials used have left it vulnerable to weathering and erosion. Its fragile condition has been exacerbated by archaeological excavations and mining for adobe bricks. The building's corners, the key to its stability, have also collapsed. In 2004 a program to investigate, document, and conserve the enclosure was begun. This paper discusses the project results to date, including treatment materials and methods, issues of identification and interpretation, and adaptation of treatments in response to increasing knowledge of this historic structure and its continued use.*

Résumé : *L'enceinte cérémonielle du roi Khâsekhemoui (vers 2686 avant notre ère) à Hiérakonpolis, Haute-Égypte, est la plus ancienne structure indépendante en briques de terre crue au monde. Elle a été construite en deux phases. Les méthodes de construction et matériaux employés ont rendu la structure vulnérable aux facteurs de détérioration et à l'érosion. Cette fragilité a été encore aggravée par les fouilles et l'extraction de terre pour fabriquer des briques. Les angles du bâtiment – qui en assuraient la stabilité – se sont effondrés. En 2004, un programme d'étude, de documentation et de conservation de l'enceinte a démarré. Cette communication fait état des résultats, y compris des matériaux et méthodes utilisés, des questions d'identification et d'interprétation et de l'adaptation des traitements compte tenu du progrès des connaissances sur cette structure historique et son utilisation continue.*

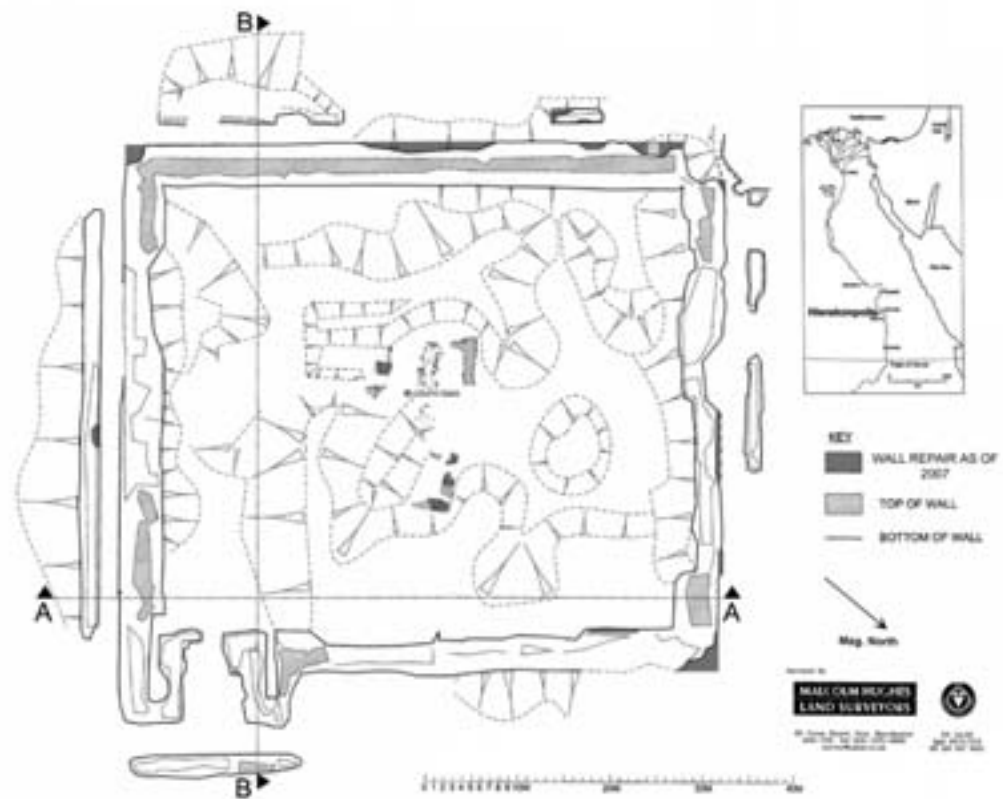
Egypt is best known for its ancient stone monuments, but it also has a long and rich tradition of using mud brick, extend-

ing back into prehistory to at least 3500 B.C.E (Spencer 1979). Due to various environmental and cultural factors, little of this early earthen architecture survives aboveground. Today the oldest mud-brick structure still standing (to almost its original height) is the ceremonial enclosure attributed to King Khasekhemwy of the Second Dynasty, at the site of Hierakonpolis in Upper Egypt. Built near the middle of this king's lengthy and influential reign and dating to approximately 2700 B.C.E., it is the oldest freestanding mud-brick structure in the world (Friedman 2007) (figs. 1, 2).

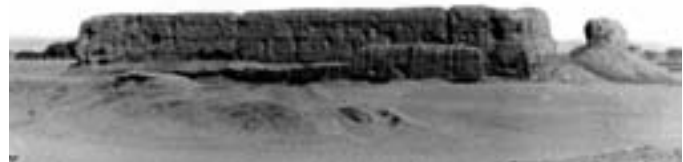
Although the enclosure continues to be called the Fort, as it was first described over one hundred years ago (Quibell and Green 1902), there is no evidence that it had a military function (Kemp 1966). Its purpose remains a mystery, but it is clearly related to the mud-brick enclosures erected to house the funerary cults of Egypt's earliest kings at the site of Abydos, 150 kilometers to the north (O'Connor 1989; Adams and O'Connor 2003). Here Khasekhemwy also built a funerary enclosure that is almost two times the size of the Hierakonpolis structure. His reason for building two large edifices is not clear. Political fragmentation and subsequent reintegration of the nascent Egyptian state has been suggested as a possible explanation; all the same, the architectural history of the Hierakonpolis enclosure suggests it was constructed at a time of much change (Friedman 2005).

At nearly 4,700 years old, this impressive edifice consists of a rectangular, unroofed structure, 67 meters long and 57 meters wide. The slightly tapering walls are 5 meters thick at their base and still well preserved in places to a height of 9 meters, with probably less than 1 meter lost to erosion. Surrounding the main enclosure is a thinner perimeter wall that measures about 2.5 meters high (see fig. 1).

FIGURE 1 Plan of the enclosure at Hierakonpolis as surveyed in 2000, with location of repairs as of 2007.
© Hierakonpolis Expedition



(a)



(b)

FIGURE 2 (a) View of the south and west walls of the enclosure and repairs made in 2006. Photo: R. Friedman; (b) View of the south and west walls of the enclosure in 1905. Photo: © Garstang Museum of Archaeology, Liverpool University; Garstang Archive Negative H102

The exterior of the main enclosure was originally ornamented with a regular pattern of raised pilasters (fig. 3), and around its projecting entrance there was a more complex pattern of niches and pilasters. This type is familiar from contemporary depictions of the so-called palace-facade, which was used to display the names of Egypt's early kings. These decorative pilasters are well preserved only on the south side, but traces of their distinctive brick pattern can be found on the exterior of every wall. Near the base of the walls there are remains of the thick, mud scratch coat and the gypsum plaster that once made it a

gleaming white. In its day it must have been a dazzling statement of royal power that was visible for miles across the desert and valley, and it is still a dominating landmark today.

Aside from the loss of the north and south walls due to the prevailing northerly winds, archival photographs show that the structure survived in fairly good condition until a little over a century ago (see fig. 2b). It has since deteriorated at an accelerating rate, with collapse of the corners, loss of the perimeter wall, and the growth of numerous gaps in the wall matrix. This damage has been due in large part to removal of



FIGURE 3 Decorative pilasters preserved on the south wall of the enclosure. Photo: James Rossiter

the archaeological treasures of the ancient site, especially in and around the enclosure, which was built on top of an earlier, predynastic (3400–3000 B.C.E.) cemetery.

The enclosure has been a target for uncontrolled digging by robbers looking for salable antiquities, as well as a focus for Western archaeologists conducting excavations in and around the structure in 1905, 1934, and 1978 (Garstang 1907; Kemp 1963; Adams 1987; Lansing 1935; Fairservis 1978). As a result of these activities, the ground level was lowered by as much as 2 meters below the wall footings, leaving them exposed and extremely vulnerable to erosion and weathering. Graves found under the walls were excavated but inadequately backfilled; the walls above them are now subsiding and have collapsed

entirely in some places, leaving the area open to brick mining, which has caused further damage.

Since 2004, with the financial assistance of the World Monuments Fund, the Annenberg Program for Endangered Cultural Heritage in the Developing World, and private donations from the Friends of Nekhen, the Hierakonpolis Expedition has been engaged in a program to conserve, document, and study the enclosure. The damage that destabilizes the monument also provides a view into its interior and allows a better understanding of how the structure was built and how best to treat it. As is the case with most large mud-brick constructions in Egypt, its walls are composed of transversely bonded stacked headers, with a veneer of headers and stretchers. This type of construction allows the long walls of the structure to flex and settle but relies on the corners to provide longitudinal support. With loss of the corners, the walls begin to separate and lean outward, causing large cracks to form through the matrix. These conditions increasingly worsen with water flow and animal infestation. One of the priorities of our work has been to repair the corners. First, deep pits cut into the ground by treasure hunters were reinforced with compacted earth to form a firm base, and then new masonry was laid following the ancient brick pattern. The bricks were placed at a slight incline inward to join the new and old segments together (Jaeschke 2006).

The collapse of the corners, though tragic because of the extensive damage it caused, allowed us to detect two distinct building phases. At the core there is an inner and obviously earlier phase of construction, which was finished with pilasters (fig. 4). It had only reached a height of about 2.4 meters when plans apparently changed. In a subsequent second phase, an additional 1.5-meter-thick cover of mud brick was added on the exterior and 1.2 meters on the interior. The upper walls were then built up to their full height of over 9 meters as one fully bonded construction. The bricks used in the first phase of construction are slightly paler in color and are about 2 centimeters thinner than those from the second phase that cover them, making them easy to detect in all four walls of the main enclosure (Friedman 2007).

Aside from the historical significance of this earlier construction phase, its discovery has helped us better understand the taphonomy of the structure and how to more appropriately address its repair. For example, the second-phase mud-brick additions only abut the earlier construction and are not keyed into it; therefore, the lower 2.5 meters of the walls are composed of three independent walls standing side by side. When there is damage or weakness in the foundation, this lack of



FIGURE 4 The pilasters and exterior facade of the first-phase construction visible within the core of the west wall and partly repaired foundations in 2007. Photo: R. Jaeschke

bonding not only causes the outer walls to fall away, exposing the vertical face of the inner core wall, but also leaves the monolithic masonry of the upper walls teetering on a small base. This can be seen clearly at the northeast corner, which collapsed in 2002, leaving a precarious section of brick overhanging and threatened with further collapse (fig. 5).

In light of this construction style, we not only physically supported the damaged areas but also reinforced the wall bases and foundations around the monument by raising the ground level to the appropriate height. To protect the fragile walls, this compensation is done manually and not by heavy machinery. Several hundred cubic meters of infill have been laid by hand basket, which is then compacted with a little water after every 15- to 20-centimeter lift.

To implement the structural repairs, suitable new mud bricks are made, which has proved to be a challenging operation. Though analysis of the ancient bricks has not been possible, we assume they were made of fine silt gathered from the nearby floodplain. This organic-rich silt is still used today to make new bricks and is in high demand for building purposes; however, due to construction of the hydroelectric barrages at Esna, 30 kilometers to the north, the water table is now permanently high, and mining of field earth is forbidden so as to protect the farmlands from oversalinization. Unfortunately, this restriction has increased interest in mining the ancient mud bricks as a source of building material. The excellent preservation of the ancient bricks has clearly demonstrated their viability and superiority as a building material for use in this area.

Since more than 200,000 new bricks are needed for the repairs and we have only limited access to field earth obtained legally from intermittent building activities and canal dredging, we experimented with soil from fossil terraces of the Pleistocene Nile in the low desert. Bricks made from this soil exclusively had inadequate strength and were a poor color match to the ancient bricks. We eventually developed and tested an acceptable soil formula composed of a 1:1 ratio of Pleistocene silts to field earth, mixed with a small amount of straw chaff as a binder. The new mud bricks are close to the original in durability, weight, and color but still distinct. Each new brick is made to the dimensions of the second-phase bricks and stamped with our code to identify it in the future (Jaeschke 2005).

Overall, repairs to the enclosure have been made incrementally. In each collapsed area the foundation is reinforced and filled with water-compacted desert silts. Only a 2-meter area, approximately 60 to 70 centimeters deep, is treated at a time. After drying, new masonry is laid as necessary. In the large areas of collapse along the west side, the overhanging walls are first buttressed to temporarily stabilize them and provide a safe working space. The collapsed areas are subsequently repaired in the same manner, and the new masonry is interbonded (fig. 6). In all cases, the new bricks are laid according to the ancient pattern, with some concessions to allow the new masonry to be keyed into the old (Jaeschke 2007).

While the major focus of our work has been to stabilize the structure against further deterioration, in so doing we have also restored some of the monument's original grandeur. New walls have been built flush with the original facade, and the decorative pilasters have been reconstructed, but only where evidence



FIGURE 5 View of the northeast corner, which collapsed in 2002, and ongoing repairs in 2007. Photo: R. Jaeschke



FIGURE 6 Repair of the exterior west wall with a series of buttresslike constructions that were later interbonded. Photo: R. Friedman

for their placement is clear and where the conservation work would otherwise have obscured their presence. This compatible integration of the old and new materials imparts both physical and visual strength and facilitates future monitoring and maintenance of the monument. The enclosure is still actively visited by the local community on holidays and weekends, a practice we seek to encourage, as only local interest and respect for the structure will help safeguard it from illicit brick mining and ensure its long-term survival.

To ensure durability of the enclosure while it is actively used by the local community, as well as to protect the exposed surfaces from erosion by windblown particles and facilitate effective monitoring and maintenance, the modern repairs have not been inset but have been built flush to the surviving wall plane. We have chosen not to duplicate the disturbed appearance of lacunae in the lower walls by laying the bricks in a jagged manner, although this method may be useful in the higher reaches where the wall plane is highly irregular.

As this is the oldest surviving monument of Egypt's rich tradition of mud-brick construction, we feel it is important not only to stabilize the structure against further deterioration but also to preserve the scientific and cultural information that it holds, as well as its distinctive form and character. To this end, we have installed a window in the walls to view the pilastered facade of the first phase, which also supports the structure around it.

Our work at the Enclosure of Khasekhemwy at Hierakonpolis is just beginning. In the near future we will also

focus on issues of presentation, recovery, and preservation of important historical and architectural evidence, as well as long-term safety for both the structure and the people who enjoy it.

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Huacas de Moche, Peru, Archaeological Project: Management, Research, Conservation, and Results

Ricardo Morales Gamarra

Abstract: *The Huacas de Moche archaeological complex (100–800 C.E.) is situated on the northern coast of Peru. Huaca de la Luna, the most important of the four buildings at this pre-Hispanic site, consists of six superimposed temples with over 12,000 square meters of mural paintings and reliefs. The buildings were constructed in the same architectural pattern with recurring dimensions and a system of modulating spaces, surfaces, and iconography. The Archaeological Project at Huaca de la Luna is essentially a conservation program under the shared direction of an archaeologist and a conservator. Together they have planned and carried out this interdisciplinary research program since 1991.*

Résumé : *L'ensemble archéologique de Huacas de Moche (100–800 C.E.) est situé sur la côte nord du Pérou. Huaca de la Luna, le plus important des quatre bâtiments de ce site préhispanique, comprend six temples superposés avec plus de 12 000 m² de peintures murales et de reliefs. Les bâtiments ont été construits selon le même modèle architectural, avec des dimensions similaires et le même système d'agencement de l'espace, des surfaces et de l'iconographie. Le projet archéologique réalisé à Huaca de la Luna est essentiellement un programme de conservation, sous la direction conjointe d'un archéologue et d'un conservateur-restaurateur qui ont ensemble planifié et mis en œuvre ce programme de recherche interdisciplinaire depuis 1991.*

The Moche

At the beginning of our era, on the narrow and semiarid northern coast of Peru, the Moche Kingdom developed (fig. 1). It was a theocratic society with advanced technologies in water man-

agement, agriculture, roads, pottery, metallurgy, architecture, and mural art. The political and religious center of the north coast was located in the Moche valley. First formed was the ceremonial center, called Huaca de los Reyes (1500 B.C.E.); then the urban and ceremonial center, Huacas de Moche; later Chan Chan, the great Chimu metropolis; and finally the Spanish colonial city of Trujillo, founded in 1534. The Moche maintained technological continuity through their use of earth as the main material for constructing temples, houses, walls, and aqueducts.

Huacas de Moche, the sacred capital of this kingdom, is spread over 175 hectares and is located between the totemic Cerro Blanco and Río Moche. It is composed of four temples, or *huacas*, a city, and a geoglyph. In this archaeological complex Huaca de la Luna is the major temple of the Moches, organized in three platforms and four ceremonial patios. Platform I, where we have concentrated our work, is the product of six buildings superimposed over one another, spanning six centuries of occupation (fig. 2a). The recurring iconographic pattern, which is executed as plain paintings and modeled reliefs (fig. 2b), covers approximately 12,000 square meters of architectonic surfaces. They are complex, extraordinary, and colorful (fig. 3).

Causes of Deterioration

The monument exhibits four levels of deterioration. These are associated with environmental impact and vulnerability of the building, fragility and fatigue of the earthen structures and architectural surfaces, poor adhesion of the plasters and reliefs on the walls, and extreme fragility and fatigue of the paint. The geographic and topographic location of the archaeological



FIGURE 1 Moche Valley. Moche Archaeological Site, Trujillo Colonial City, and Chan Chan, a technological continuity in the use of earth as the main architectural material.

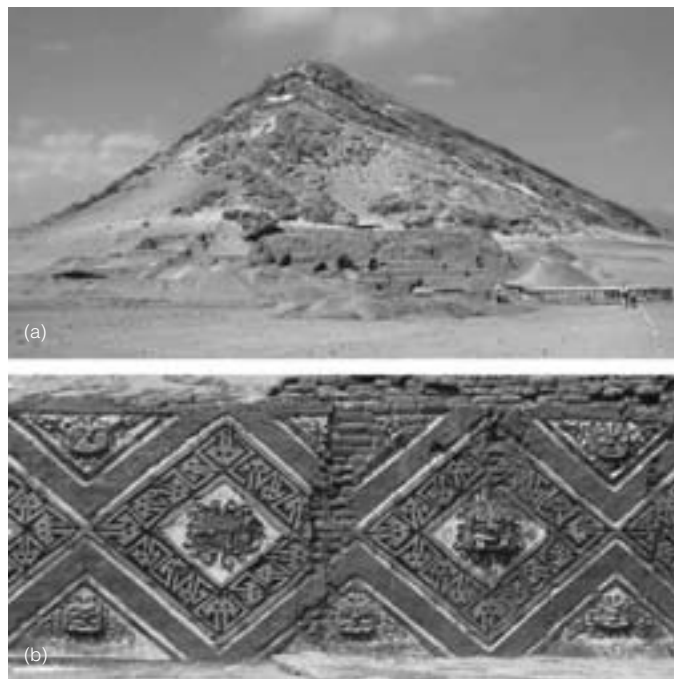


FIGURE 2 Huacas de Moche: Temple of the Moon and sacred hill (a) and reliefs in polychrome earth on ceremonial patios (b).



FIGURE 3 Facade of the Temple of the Moon, with complex iconographic narrative in relief. Red, white, black, yellow, brown, and blue are inorganic pigments mixed with organic binder, of exceptional artistic expression.

complex (in the desert plateau near the sea and without trees and exposed to strongly abrasive and contaminated winds from the south) plays a decisive role in the site's complicated pathology, as do the harsh meteorological agents (wind and sunlight) and human activity (tourism, industrial activities, and livestock).

Sustainable social use of these monuments, especially under such adverse environmental conditions, is guided by the Management Plan of Environmental, Monumental, and Public Use. It is organized and executed by an interdisciplinary team in which the conservator plays a decisive role and where intervention is not exclusive to the archaeologist. In this context our primary goals are to improve environmental conditions as a way to conserve the monument, use minimally invasive conservation practices, and expose only one diagnostic sector of the archaeological evidence at a time (Chanfón 1996).

The Management Program

Preservation of this fragile, fatigued, and vulnerable monument is focused on five management priorities: environmental, social, touristic, monumental, and entrepreneurial.

Environmental management. Environmental management is geared to protecting the immediate physical environment (soil, water, and air) in and around the archaeological site, called the buffer zone, from predation and pollution. The threshold levels maintained are based on national laws, technical standards, and international agreements. Maintaining a sustainable environmental balance is a complicated task due to strong economic interests in the area that can be in conflict with park goals, as well as the bad habits of the rural populations, which have, in some cases, destroyed the neighboring agricultural land and altered the local ecosystem (Convesa 2003).

Social management. Social management seeks to strengthen the cultural identity and the quality of life for native inhabitants on their ancestral lands. The local population is directly involved in the preservation and conservation of the environment and its cultural heritage, and has been organized under the signature aphorism, "We are also Heritage."

Tourism management. Tourism management is crucial because it has a direct impact on the preservation of the exposed archaeological complex and an indirect impact as a vital source of funding. Current management has established pathways and transit areas; installed signs and information panels; and built shelters, windbreaks, and drains to

protect the site, all without affecting the original floors. Visitor control is permanent and responds to criteria that reduce visitor impact on the monument and the microclimate in the exposed areas.

Monument management. Monument management is a shared planning process between archaeologist and curators that defines areas for excavation based on both research needs and the opinion and operational capacity of the conservators. This is why the Huaca de la Luna Project is considered a highly conservation-based endeavor. Thanks to management, we have transformed a classic archaeological project into an interdisciplinary research and training program. We developed two courses/workshops in 2004 and 2007 to educate thirty-seven archaeologists, architects, and conservators from Peru and others from Poland, Spain, Colombia, and Ecuador in our conservation and site management techniques.

Entrepreneurial management. Entrepreneurial management is supported by generous donations from international institutions such as the World Monuments Fund, national companies such as the Backus Brewery Company, and bilateral agreements such as the Peru-France Value Fund. Funding from these and other sources, as well as the income generated by tourism, supplements the project budget. Thanks to these contributions, we have transformed an abandoned monument into a center for social and economic development in the area.

The Conservation Program

The Huaca de la Luna Project has planned its interventions based on the criteria of minimum intervention and respect for the authenticity of the site. We have protected excavated areas and exhibited them under temporary roofs. The project has also focused heavily on interdisciplinary conservation research, with special emphasis on monitoring both treated and untreated areas and test walls. We publish reports on the work and the results annually. In this project, study and conservation of the painted surfaces is paramount. Treatment of the polychromy is done in four levels: registration, documentation, and database recording of the walls; preventive conservation parallel to excavation; integral conservation and exceptional interventions, such as anastylosis and stacco; and finally monitoring and systematic maintenance (Morales 2003) of all exposed and treated areas.

Conservation Processes

Documentation

Walls are registered graphically through plans, elevations, and cross-section drawings. Then they are photographed and filmed to record the state of conservation prior to intervention and to document the conservation measures. This report is vital for subsequent monitoring, evaluation, and maintenance of the monument and the conservation treatments.

Structural Stabilization

Our highest priority is structural stabilization (consolidation) of the walls at risk of collapse to avoid damage and loss of the polychrome surfaces. Here at Huaca de la Luna structural stabilization is usually completed prior to conservation of the surfaces. In addition, windbreaks and provisional roofs made with traditional materials have been constructed to avoid the effects of wind and weather.

Discovery and excavation of the walls consists of removing the rubble and various other materials that cover the structures and the polychrome surfaces. There is a considerable buildup of soil and clays as a result of abandonment, erosion, and vandalism. Removal of these earthen materials is challenging because the debris is often tenaciously adhered to the fragile surface of the polychrome murals, requiring delicate and deliberate intervention to avoid loss of original paint and plaster (fig. 4a).

Structural movement from seismic activity as well as movement of the masonry within the platform has put the buildings and their decorated surfaces at risk. Damage is seen in the form of cracks, both large and small, and detached fragments of plaster and polychrome reliefs, which are found scattered about at the time of excavation. Fragments to be re-adhered are wetted with a solution of water and alcohol, which is introduced between the surface and the supporting wall.

Conservation of the Painted Surfaces

Structural stabilization is a priority in the treatment of these architectural surfaces because wall movement causes cracks and potential detachment of the decorated surfaces. Reinforcement of the foundations and walls to eliminate movement generally consists of removing and replacing fractured adobes. In special cases wooden structural reinforcements are used at corners and other connections to strengthen walls and improve their biomechanical resistance.

For aesthetic reasons and to best present the architectural spaces with their iconographic values, the clay materials



(a)



(b)



(c)

FIGURE 4 Sequence of wall treatment: (a) discovery, (b) cleaning and consolidation, and (c) aesthetic presentation.

adhered to the polychrome surfaces are removed manually (fig. 4b). They are also removed because the clay can expand and contract with hygrothermic fluctuations and cause irreversible damage (Stubbs 1984). This intervention is carried out with cotton swabs dipped in distilled water and ethyl alcohol, binocular magnifying glasses, scalpels, and soft paintbrushes. The last step of this process is to use breadcrumbs (which have been successfully used since 1977) to remove the thin clay layer remaining on the polychrome surface, leaving it in optimal condition for consolidation (fig. 4c).

Consolidation of the earthen surfaces is carried out by spraying a solution of Ethyl Silicate 40 and absolute ethyl alcohol on the relief. The proportion used is a half-liter ethyl silicate to one liter of absolute ethyl alcohol for each meter of treated surface. This consolidant has proven effective in similar cases, for instance, at Chan Chan, where it has been used since 1975. With this treatment the entire wall and decorated surface behave uniformly, that is to say, show improved resistance to erosion, capillarity, high humidity, and weathering (Alva and Chiari 1984).

The mural paintings at Huaca de la Luna have serious detachment problems, such as flaking paint. This is due in part to the fragility of the painting technique and the fatigue of the original organic binder (cactus juice). We stabilize the paint by consolidating the pigments with a 3 percent solution of acrylic resin (Paraloid B-72) in a solvent, applied with soft paintbrushes.

The earthen surfaces consolidated with the ethyl silicate form a thick crust that must be attached to the irregular surface

of the adobe wall. Since the silicate does not bond fractures or fissures, an earthen grout is used to fill the voids and reattach the ends. This mixed consolidation technique is carried out by injecting a semiliquid clay mortar into the spaces between the reliefs or the plaster and the surfaces of the walls until they are completely filled.

Other Interventions

Anastylosis consists of removing architectural elements affected by structural movement, fractures, or settling of the wall and restoring the missing elements. To do this, the sector to be treated is first documented with instant photographs and drawings to facilitate the subsequent task of repositioning the feature without affecting its previous appearance. Then the deteriorated adobe masonry is physically removed until a stable sector of the wall is reached. After the structural problem has been solved, the wall is reconstructed with previously consolidated and/or selected adobe blocks (fig. 5).

FIGURE 5 Structural reinforcement in walls affected by seismic activity in archaeological times.



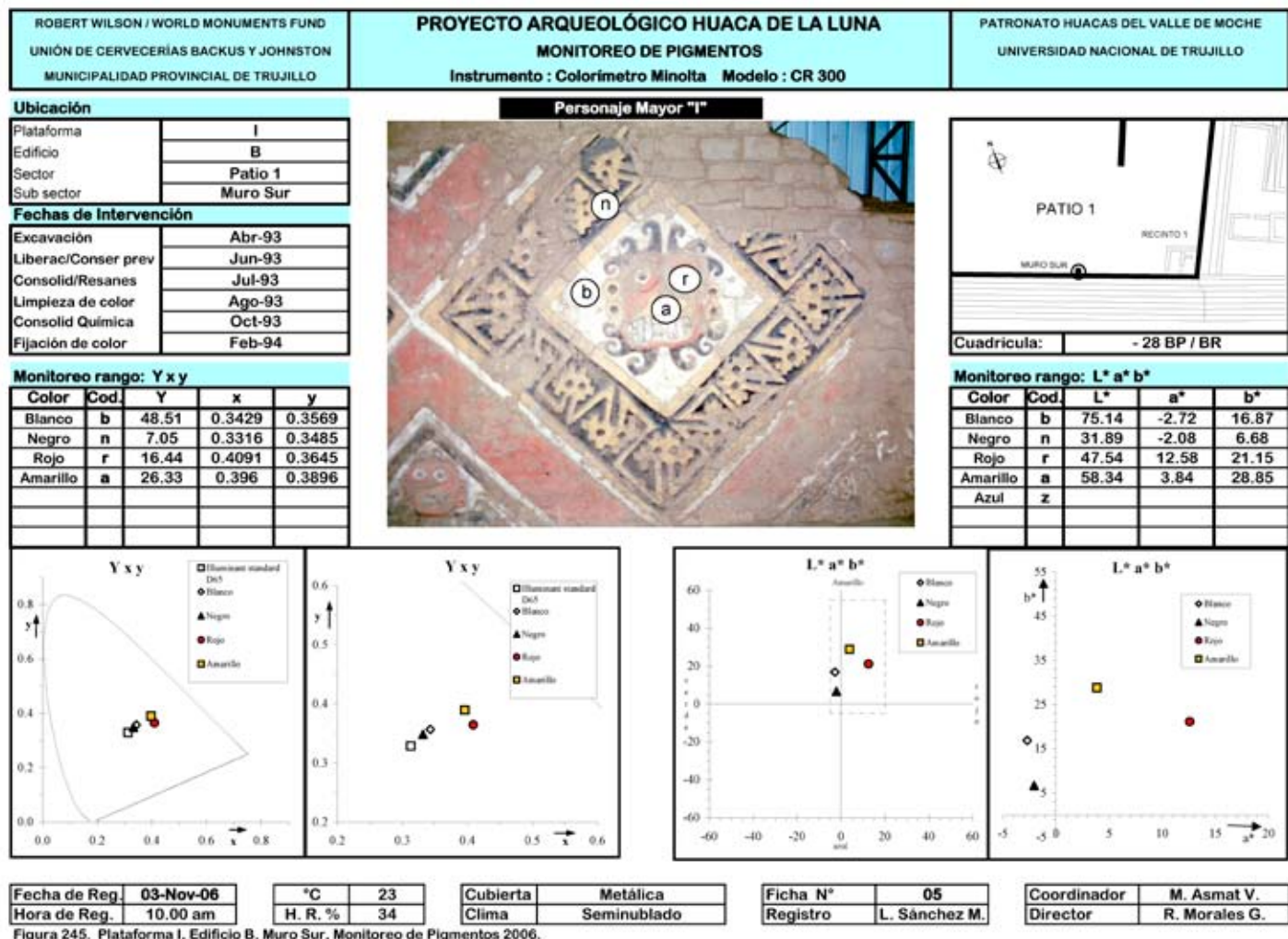


Figura 245. Plataforma I, Edificio B, Muro Sur, Monitoreo de Pigmentos 2006.

FIGURE 6 Color monitoring form: periodic evaluation of the color's stability when exposed to ultraviolet light, change of microclimate by tourism, and wind with sand.

When the wall and polychrome surfaces are wet due to rain infiltration, we dry them in a way that does not affect the polychrome surface. Adobes are placed in a line 5 centimeters from the wall, and the space is filled with hot sand. This is repeated until the wall is completely covered. After four to five days, the adobes are removed, as is the sand, which is completely humid and full of salts. This process is repeated for approximately two months.

Monitoring and Maintenance

Treated areas are systematically observed and their behavior recorded and compared with that of nontreated areas. The

evaluation focuses on continued stabilization of the pictorial layer, performance of the conservation materials, and monitoring of the weather behavior. Evaluations are conducted on an annual basis, and the results are noted on specially designed index cards and entered into the database (fig. 6).

Considering the fragility, uneven texture, and need to permanently display the polychrome surfaces to visitors, periodic and systematic maintenance is carried out. This includes removal of sand, dust, and excrement from livestock, birds, and insects on the surfaces. Finally, the reinforced sectors previously damaged by earthquakes or structural movement are also strictly monitored and maintained when needed.

Conclusion

The most significant result of this project is the implementation of an interdisciplinary scientific research program that focuses on two areas: *intrinsic* issues, such as color stability, architectonic and decorated surface material identification and interpretation, salts analysis, phreatic (groundwater) level behavior, and monitoring of the conservation materials applied to the walls and surfaces; and *extrinsic* issues, such as meteorological conditions, seismic resistance, aeolic and pluvial erosion, tourism, and environmental pollution due to economic activities of the population in the surrounding areas that directly affects the condition of the monuments. Huaca de la Luna is a field laboratory for investigating and resolving the many and diverse earthen architectural problems on the northern coast of Peru.

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Treatment of Late Roman Mural Paintings on Mud Plaster in the Dakhla Oasis, Egypt: Conservation Problems and Continuing Challenges

Constance S. Silver

Abstract: Rich in all periods of human occupation, the Dakhla Oasis in the desert of southwestern Egypt is notable for its large Greco-Roman settlements built primarily of mud brick. Since 2004 excavations at the site of Amheida, the Roman city of Trimithis, have revealed remarkable tempera mural paintings and literary inscriptions in Greek, all executed on mud plaster. For several reasons, conservation of these works has proved very challenging. This paper describes the complicated conservation problems and both satisfactory and unsatisfactory conservation treatments. It concludes by discussing the need for conservation research to address two wide-ranging problems: insect damage at sites and a need for reliable inorganic consolidants.

Résumé: Ayant connu toutes les périodes d'occupation humaine, l'Oasis de Dakhla, dans le désert au sud-ouest de l'Égypte, est remarquable pour ses deux vastes cités gréco-romaines édifiées essentiellement en briques de terre. Depuis 2004, les fouilles du site d'Amheida, la cité romaine de Trimithis, ont mis au jour des peintures murales exceptionnelles ainsi que des inscriptions littéraires en grec, toutes exécutées sur les enduits en terre. Pour plusieurs raisons, la conservation de ces œuvres s'est révélée très délicate. Cet article décrit les problèmes complexes de conservation, ainsi que leurs traitements plus ou moins couronnés de succès. Il conclut en évoquant la nécessité pour la recherche en conservation d'aborder deux vastes problèmes : la lutte contre les dommages causés par les insectes sur les sites, et la disponibilité de consolidants inorganiques fiables.

The Dakhla Oasis of southwestern Egypt is rich in all periods of human occupation but is especially remarkable for two large Greco-Roman settlements constructed of mud brick, Kellis

and Amheida. Under the Supreme Council of Antiquities and through the collaborative Dakhla Oasis Project, excavations have taken place at Kellis for more than two decades. In 2001 Columbia University began a program of integrated research and excavation of Amheida.¹ A desert metropolis of late antiquity, the Roman city Trimithis, it occupied an area at least 2.5 kilometers by 1.5 kilometers. Both Kellis and Amheida were abandoned by the beginning of the fifth century.

The site and mural paintings of Amheida have presented conservation challenges that are far more complex and unusual than those encountered at other sites in the oasis; indeed, many of these problems were totally unexpected. Consequently, the excavated mural paintings of Amheida provide an instructive cautionary tale for conservators and site managers. However, the difficulties encountered at Amheida also illuminate substantial gaps in protocols for important conservation treatments for tempera mural paintings on mud plasters in archaeological settings in Africa and the Middle East. The two objectives of this paper are to detail how the linked constellation of problems encountered at Amheida created serious conservation challenges and to examine how these problems reveal the need for highly directed conservation studies.

Mural Paintings of the House of Serenos

At Amheida a large house has been a focus of excavation (fig. 1). Ostraca have revealed a wealth of information. The owner of the house was named Serenos. He served on the city council. Coins found in the house indicate Serenos resided there in the mid-fourth century.

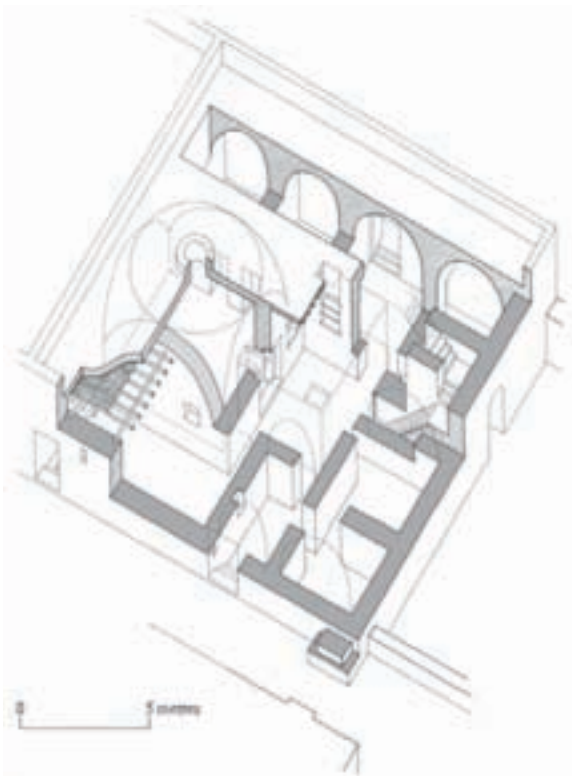


FIGURE 1 Plan of the house of Serenos. © Columbia University, New York University–Columbia University Excavations at Amheida

The house of Serenos has preserved a wealth of mural paintings in the reception hall and parts of the domestic quarters. The reception hall was a convention of high-status Roman domestic architecture covered with a dome. The top register of the wall was painted with scenes from classical mythology, demonstrating the culture of the master of the house. The lower register was embellished with imitation decorative stonework, *opus sectile*. The dome was painted with floral or geometric trompe l'oeil.

The reception hall of the house of Serenos maintains these conventions. It is a rectangle that measures 5.36 meters by 4.46 meters. The dome had collapsed after abandonment, filling the space with rubble and eventually with windblown sand. When excavated in 2004, the walls were standing to a height of over 2 meters. Scenes from classical literature remained on the upper registers and included the adultery of Ares and Aphrodite (fig. 2), the return of Odysseus to Ithaca, and the rescue of Andromeda by Perseus. The lower register is decorated with trompe l'oeil paintings of *opus sectile*. A family



FIGURE 2 Amheida: Reception hall in the house of Serenos. The mural shows a scene from classical mythology, the adultery of Aphrodite and Ares. © Columbia University, New York University–Columbia University Excavations at Amheida

shrine embellished with painted putti had fallen to the floor in a corner.

Three smaller rooms, probably domestic quarters on the west side of the house, were decorated with colorful trompe l'oeil murals of architectural elements and elaborate textiles (fig. 3). A room to the north of the house—originally not part of it but later joined to it—was an unprecedented discovery:



FIGURE 3 Amheida: The house of Serenos. Trompe l'oeil mural painting in the domestic quarters. © Columbia University, New York University–Columbia University Excavations at Amheida



FIGURE 4 Amheida: The classroom in the house of Serenos. The inscription is a unique surviving rhetoric lesson in Greek, executed in tempera paint on mud plaster. © Columbia University, New York University–Columbia University Excavations at Amheida

a classroom with a unique rhetoric lesson in Greek written in red paint on the white plaster (fig. 4).

Conservation Challenges of the Mural Paintings

Unanticipated conservation problems became evident almost as soon as excavation began in 2004. The technique of execution of the mural paintings is remarkably delicate and their state of preservation quite fragile. The mural paintings were made by application of a thin mud plaster to the mud-brick walls. A white ground, no thicker than about 3 millimeters, was applied to the mud plaster.² The paintings were executed on this delicate preparation with thin tempera paints, applied with very fine brushes.

Visual examination indicated that the mural paintings had been affected by rising damp to a height of about 1.5 meters: tide marks, water stains, efflorescence of salts, and reticulated lacunae all were present. Systematic testing of the walls and plaster with a standard moisture meter confirmed that retention of water remained high.³ Subsequent laboratory analysis of the salts identified common sulfates, carbonates, and silicates.⁴ These salts are not hygroscopic and thus did not alter the instrumental measurement of moisture in the walls and plaster.

Ongoing documentation of Amheida has confirmed that the site overall is unusually wet. The house of Serenos was built

in part over the ruins of a bath complex, but the exact source of the infiltration of water into the walls remains unexplained.

Three principal conservation issues were identified initially: in situ conservation of the mural paintings during excavation, consolidation of mural fragments detached from the mud bricks, and conservation and mounting of mural fragments for future presentation.

In Situ Conservation

The principal challenge was to stabilize the mural paintings on the walls during excavation without altering their appearance. Because of the delicate technique of execution, the murals responded poorly to many standard treatments. Specifically, they had a strong propensity to darken or stain when treated with aqueous or resinous fixatives and adhesives. The following conservation treatment was developed. Small areas of the mural paintings were revealed by brushing the sand away from the surface of the painting during excavation. Residual dust was then lightly blown from the painted surface. The painted surface was sprayed from a distance with a 3% solution of Acryloid B67 in acetone. It was found that perfume bottles, purchased locally, provided the gentlest spray. This light fixative did not darken the white preparation and paint but did provide enough protection of the surface and strengthening of the paint and preparation so that the plaster could be readhered.

Readhesion was carried out with a 50% solution of an acrylic dispersion, Lascaux Hydrosealer™, applied between the plaster and the mud-brick wall with eyedroppers. The treated area was gently pressed back on the wall through silicon release paper while the consolidant remained damp.

Mural Paintings Attached to Blocks of Masonry

About fifty-five masonry blocks with mural paintings were removed from the collapse in the reception hall. Some blocks were small, no more than 10 by 12 centimeters. Others were quite large, 1.3 meters by 1 meter. In collaboration with Richard Wolbers of the University of Delaware, a treatment was developed in the laboratory to detach the murals from the blocks. Detachment was considered an option because the blocks can become unstable over time. Moreover, retention of so many blocks creates a substantial and dusty storage problem.

A testing program was carried out using block fragments from the reception hall. These unpainted fragments had been found out of context in the room and thus were considered expendable. The surface of the white plaster was stabilized and held rigid by application of cyclododecane reinforced with silk

crepeline.⁵ The unique properties of cyclododecane make it the only possible choice for a supportive facing. Applied like a wax, it becomes remarkably strong and tenacious when solid but will sublime with time. It leaves no visible residue that can cause discoloration of the surface.

Once the plaster was stabilized with the cyclododecane facing, parallel holes were drilled through the masonry. A hacksaw was inserted in each hole. The masonry was then sawed from hole to hole, allowing the detachment of a uniform section of mud brick, mud plaster, and surface finish about 9 centimeters thick. With the cyclododecane facing still in place, the detached section was consolidated with Conservare OH™, an ethyl silicate-based consolidant.⁶ Conservare OH was placed at the base of the mud brick. Uniform consolidation was achieved by capillary rise through the mud brick, plaster, preparation layer, and paint.

The test results were excellent. Specifically, the plaster and paint were hardened with no change in the color of the constituent materials. However, when this method was used at the site on large blocks, unpredictable and random cracking occurred (fig. 5). Some of the cracking occurred in all layers; other cracking occurred only in the ground layer. In all instances, the cracks are quite clean and sharp, facilitating repairs. Small cracks in the ground layer were treated with injections of an acrylic dispersion adhesive, Jade™. The larger cracks, which go through all the layers, will be treated when the large blocks eventually are mounted for museum display.

Ethyl silicate consolidants have been used successfully to treat similar mud-plaster murals.⁷ However, cracking of mud-based materials using some ethyl silicate consolidants has been noted by researchers.⁸ The exact reason of this negative side effect remains unclear, but there seem to be two probable causes. One cause may relate to inadequate amounts of water in the mud plaster and an insufficiently low relative humidity during consolidation. However, a more likely vector is the clay component in the mud plaster, because some clays can cause shrinkage during consolidation, leading to cracking.⁹

Fragments of Mural Paintings

Thousands of small fragments of mural paintings were retrieved during the excavation. These fragments are very fragile because they generally include only the white preparation layer and the paint (fig. 6). Almost two hundred flat wood trays were constructed for collection of fragments found within discrete areas of the reception hall. In the laboratory, many fragments could be repositioned in these trays, allowing the reconfiguration of significant scenes of the murals.



FIGURE 5 Amheida: A large masonry block with an important mural painting scene. Cracking occurred following consolidation with Conservare OH, an ethyl silicate consolidant. © Columbia University, New York University–Columbia University Excavations at Amheida

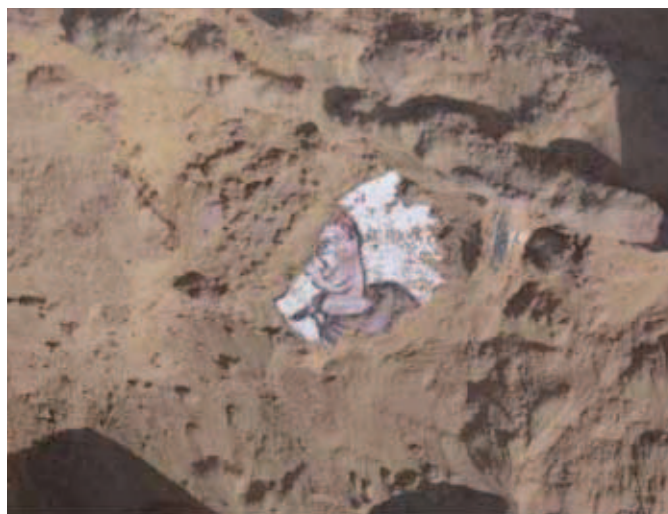


FIGURE 6 Amheida: The house of Serenos. A fragment of mural painting found in and retrieved from the rubble fill of the house during excavation. © Columbia University, New York University–Columbia University Excavations at Amheida

Significant scenes will be conserved and mounted. The envisaged conservation treatment will require three stages. First the cohesive strength of the fragments must be restored by infusion with an inorganic consolidant. Next, the fragments will require additional stabilization by application of a fine backing,

such as silk crepe. Last, the fragments will be configured on and adhered to a reversible museum mounting board.

No fragments will be treated until further research is undertaken on consolidants, to avoid the cracking that occurred during the treatment of the large blocks.

Problematic Backfilling

Because most excavations cannot be completed in one season, reversible backfill systems often must be implemented; this is certainly the case at Kellis and Amheida. At both sites a dry-laid mud-brick wall was constructed parallel to the mural paintings. A space of about 9 centimeters was left between the face of the murals and the mud bricks. This space was carefully filled with protective sand. At the commencement of the next excavation season, the mud-brick wall and sand are removed course by course. This is a safe and effective system of reversible protection.

This backfill system was implemented in the reception hall of the house of Serenos. In addition, a rough roof of wood slats and branches was installed across the top of the walls, to prevent any entrance by visitors or intruders. The conservation problems that ensued indicate how easy it is to create a subtle, unanticipated, and detrimental microenvironment that creates a constellation of unanticipated consequences.

The damp conditions created a relatively cool and moist microclimate in the excavated reception hall, attracting insects, which in turn attracted birds. Because the mud-brick retaining wall did not have mortared joints, substantial amounts of protective sand emptied through cracks, leaving the upper register of some murals exposed behind the retaining walls. Birds and insects thus had access to many areas of the murals and caused substantial damage.

Damage continued following removal of the roof and backfill. Over the course of a few evenings, several tunnels and holes were made in the murals by boring insects. The boring insect was not identified, but a likely candidate is the termite *Anacanthotermes ochraceus* Burs (Hodotermitidae).¹⁰ The insects were repelled by hanging sachets of mothballs around the mural paintings.

It seems probable that the roof cooled the already damp interior of the reception hall, and the backfill wall concentrated humidity and moisture in the mural paintings. Subsequently, some rotting of the straw in the mud plaster occurred, alerting the insects to the presence and location of the straw. The deterrence provided by mothballs appears to confirm this hypoth-

esis: the repellent odor of the mothballs is stronger than the attracting odor given off by the rotting straw.

Subsequently, temporary backfill at the excavation has been created with mud-mortared joints that seal all cracks and retain the protective and deterrent sand fill. No further insect damage has occurred at the site following adjustments in the backfill construction and with use of the mothball sachets on removal of the sand. Mural paintings backfilled in this way have remained in excellent condition.

Conclusion

In spite of careful planning and preparation, two very serious, unanticipated conservation problems arose during the excavation of the house of Serenos at Amheida: negative side effects with a commercial and widely used ethyl silicate consolidant and the rapid reappearance of plaster-boring insects. However, subsequent discussions with conservators in Egypt and at international forums confirm that both problems are not unique to Amheida. Other conservators have described cracking and shrinkage problems when commercially available ethyl silicate consolidants are used to treat mud-based materials. Also, damage from insects is a critical problem at other historic sites in Egypt and probably throughout North Africa and the Middle East.

Both conservation problems—the need for a predictable and readily available ethyl silicate consolidant for mud-based architectural decoration and the threat of boring insects—affect the conservation of many sites and monuments in non-Western countries. Clearly, these are global conservation problems that urgently need solutions. However, any solution also must address the special needs of the non-Western world, which can include difficulties with import of expensive chemicals and trade and patent laws that hamper production of generic chemicals in individual countries. A research program designed to solve these problems would also provide an excellent forum for cross-border cooperation.

Acknowledgments

The excavation and conservation of Amheida occur through collaboration. The author wishes to thank the Supreme Council of Antiquities, Egypt, and its conservators in the Dakhla Oasis for their assistance. Olaf Kemper, University of Leyden, brought invaluable experience to the 2004 excavation and conservation of the house of Serenos. The project benefits greatly from the multifaceted expertise of Paola Davoli,

University of Salento. Roger Bagnall, New York University, is owed a debt of gratitude for his lifelong commitment to the ancient world.

Notes

- 1 The project director is Roger Bagnall, Director, Institute for the Study of the Ancient World, New York University. The field director is Paola Davoli, University of Salento, Italy. In 2008 Amheida became a project of New York University, in collaboration with Columbia University.
- 2 The ground is composed of gypsum and clay. Additional analysis will be needed to identify these components precisely.
- 3 A Delmhorst BD-10 moisture meter was used.
- 4 The salts were analyzed by Richard Wolbers, University of Delaware. Additional interpretation of results was provided by Steven Weintraub, Art Preservation Services.
- 5 Cyclododecane was introduced about ten years ago from Germany. Its protective and adhesive capacities, combined with its unique ability to sublimate, leaving no residue, have made it ideal for many conservation treatments.
- 6 Conservare OH was supplied by the ProSoCo company, Kansas City, Kansas, USA.
- 7 An important Chalcolithic mural on mud plaster from Teleilat Ghassul, Jordan, was treated in 1978 with an ethyl-silicate consolidant, Wacker OH, supplied by the Wacker Company, Germany. It is probable that the Wacker OH and Conservare OH are quite similar. No cracking occurred during treatment with the Wacker OH, and the mural remains in excellent condition in the National Museum, Amman, Jordan. See P. Schwartzbaum, C. S. Silver, and C. Wheatley, "The Consolidation and Remounting of a Chalcolithic Mural Painting on Mud Brick from the Site of Teleilat Ghassul, Jordan," paper presented at the Mud Brick (Adobe) Preservation Symposium, Ankara, September 29–October 4, 1979.
- 8 Cracking during consolidation was observed by Silver in the 1980s during laboratory testing. See C. S. Silver, "Analyses and Conservation of Pueblo Architectural Finishes in the American Southwest," paper presented at the Sixth International Conference on the Conservation of Earthen Architecture, Las Cruces, New Mexico, October 14–19, 1990; published in *Adobe 90 Preprints*.
- 9 Wheeler discusses the effects of clays on consolidation and points out that much more research on this subject is needed. See G. Wheeler, *Alkoxysilanes and the Consolidation of Stone* (Los Angeles: Getty Conservation Institute, 2005).
- 10 The termite *Anacanthotermes ochraceus* Burs (Hodotermitidae) "occurs in Libya, Algeria and continues to the Arabian Peninsula as far as the Persian Gulf. It is mostly found in Lower Egypt, on either side of the Delta. It feeds mainly on wheat or rice straw from green bricks of which rural houses are made. It attacks timbers, or any cellular material. It is restricted to soils with clay or alluvium and low moisture content" (S. I. M. Moein, "Distribution, Danger and Some Habits of the Termites in Egypt and North Africa," in *Report of the UNEP/FAO/Global IPM Facility Termite Biology and Management Workshop, February 1–3, 2000, Geneva, Switzerland* [Geneva: United Nations Food and Agriculture Organization, United Nations Environment Programme, 2000], 39–40).

Conservation of Archaeological *Daga* (Adobe) Structures, Domboshaba National Monument, Botswana

Ashton Sinamai

Abstract: *Domboshaba is a Zimbabwe culture site in eastern Botswana. It had been suffering from neglect until an Africa 2009 documentation workshop was held there. This workshop recommended remedial conservation work to arrest the deterioration of the dry stone walls and daga (adobe) structures at the site. This paper presents some of the accomplishments of the workshop and the methods used to preserve the daga structures at Domboshaba. It also offers recommendations for others managing these types of sites in southern Africa.*

Résumé : *Domboshaba est un site de culture zimbabwéenne, dans l'Est du Botswana. Il était laissé à l'abandon jusqu'à la tenue d'un atelier de documentation Africa 2009 sur place. Cet atelier a recommandé des travaux de conservation et de réfection afin d'arrêter la détérioration des murs de pierre sèche et des structures en daga (adobe) sur le site. Cette communication présente plusieurs résultats de l'atelier ainsi que les méthodes utilisées pour préserver les structures en daga de Domboshaba. Elle propose des recommandations à l'attention de ceux qui gèrent ce type de site en Afrique australe.*

Domboshaba is a dry stone walled Iron Age site occupied toward the end of the Great Zimbabwe period (1250–1450 C.E.). It was a regional center in the Khami phase (1450–1690). The site, which is in the Northeast District, covers more than 8 hectares, with part of the site on a hilltop and part in the lowlands. The Hill Complex has six enclosures; the lowland has one main enclosure divided into several smaller enclosures. The majority of the walls are freestanding with a few platforms that mainly form part of entrances. Most of the walls have areas of collapse that resulted mainly from poor bonding of the stone blocks and vegetation growth.

Over sixteen *daga* (adobe) structures were recorded in some of the enclosures. Unsanctioned excavation in the late 1890s, as well as excavations by a German antiquarian, Frobenius, in the late 1930s, exposed most of them. Some of these *daga* structures are used for presentation purposes, to show visitors how the people at Domboshaba lived (fig. 1).

Domboshaba is revered by the local people and was indirectly protected by cultural taboos until the advent of colonialism. With colonization, the site suffered from treasure hunting and amateur archaeology. To protect the site, the colonial government introduced several acts: the Bushmen and Relics and Ancient Ruins Protection Act of 1911 and the

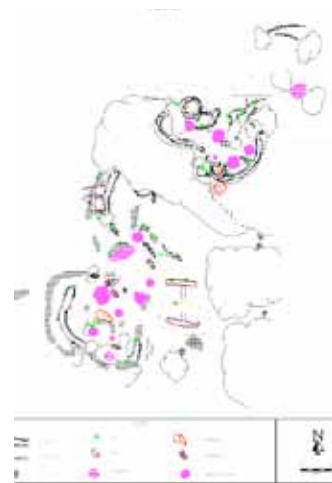


FIGURE 1 Map showing areas with exposed *daga* structures at Domboshaba. Map: Geoffrey Chikwanda, National Museums and Monuments of Zimbabwe

Natural and Historical Relics and Antiquities Act of 1934. The site was declared a national monument under the latter act in 1938.

In 1967 the National Museum and Gallery Act was enacted, leading to the establishment of the National Museum and Art Gallery. The museum was given the responsibility to protect all monuments, including Domboshaba. Inspections of the monument were carried out, but there was no restoration. The first field assistants were employed in 1997 to manage visitors as well as control vegetation. In 2003 a condition survey was conducted to assess site problems. An archaeological survey was also completed to establish the extent of the site (see Africa 2009 Condition Report 2003).

The Daga Conservation Project

The project to conserve daga structures was part of the larger Domboshaba *Projet Situé* and was a follow-up project of the Documentation and Inventory Workshop held in Botswana, July 2–20, 2003. That workshop realized the need for a regional approach to the conservation of dry stone walled structures in southern Africa. We also realized that daga structures had been ignored in previous preservation efforts. To empower those in charge of these sites, it was recommended that Domboshaba National Monument be a *projet situé* in which heritage managers from southern Africa could develop skills in the development of management plans and in the conservation of daga and dry stone structures. The conservation and presentation of daga structures was made a priority as the first phase of the project.

The aim of this project was as follows:

- a. conduct detailed recording of the exposed daga structures and the features associated with them through mapping and photography;
- b. carry out conservation measures to enhance their preservation; and
- c. develop an interpretive plan that promotes understanding of the site and the daga structures without negatively affecting them.

Earth Construction in Southern Africa

Earth is regarded as one of the oldest and most inexpensive building materials in the world. It is readily available and easy to use. Because of this, earthen structures are a significant part of the world's archaeological heritage and are still being

built. Many archaeological structures are made from earth bricks, rammed earth, or a combination of earth and wood (McHenry 1999). In southern Africa most houses are built of earth, including complex state-developed houses whose walls are made entirely from daga. Many of the dry stone walls of the Zimbabwe period enclose remains of daga houses that were constructed for the elite.

Daga construction in southern Africa involves (1) application of daga to a timber framework (the pole and daga technique); and (2) direct shaping of daga by hand to build the walls of the house (solid daga technique, also known as cob). What remains of the older daga houses are parts of walls and floors that are quite durable, especially the floors, which are made with soils that have a high ratio of clay to gravel (Ndoro 1990). Early researchers call this type of daga “granite cement” and speculate that entire houses were fired immediately after construction to strengthen them.

Daga structures have been excavated throughout southern Africa. They have been left exposed because researchers did not backfill their trenches or for tourism, which has led to their accelerated deterioration. Sites with daga structures include Great Zimbabwe, Khami, Tsindi Dhlodhlo, and Danamombe in Zimbabwe. At Vungu, a site in Zimbabwe, the walls of the houses are still standing to a height of over 2 meters. At Domboshaba, excavations by amateur archaeologists and treasure hunters have exposed a number of daga structures.

Excavation and Daga Structures

Zimbabwe sites were among the first to be excavated in southern Africa. Many of these excavations were carried out by treasure hunters whose main concern was to recover gold artifacts that could be melted and sold on the open market. This was an especially serious problem in Zimbabwe, where the Ancient Ruins Mining Company dug up numerous daga structures in its search for precious metals. Sites such as Khami, Regina, Dhlodhlo, and Nalatale suffered extensively from the activities of this company. Individual prospectors also caused havoc at isolated sites such as Domboshaba in Botswana (fig. 2).

Early archaeologists and architects were more interested in monumental architecture and less interested in daga structures. Their excavations removed daga structures from many of the enclosures at sites such as Great Zimbabwe, Khami, and Domboshaba. At Great Zimbabwe, Fredrick Massey, an architect commissioned to assess the condition of the site in 1910,



FIGURE 2 Early excavation by amateur archaeologists at Domboshaba stripped the soil that covered the daga structures. Photo: Ashton Sinamai

recommended the removal of these structures because they were leaning against stone walls (Ndoro 2005).

In later years the daga structures were left open to enhance their interpretation. The structures suffered as the earth fill around them, which played an important structural role, was excavated (these structures are sometimes indistinguishable from the surrounding fill). In many cases, the loss of the supporting fill caused the renderings to collapse. The fill also protected the daga structures from mechanical damage. Many of the houses excavated at Domboshaba were on main walking paths around the site. Once the soil cover was removed the structures eroded quickly from foot traffic as well as from exposure to the elements, including sun, rainfall, wind,



FIGURE 3 Effects of both wind erosion and rain on a daga wall at Nalatale National Monument, Zimbabwe. Photo: Ashton Sinamai

and surface water runoff. Wind carrying dust particles can erode the surface of the walls, as shown by the example from Nalatale (fig. 3). Excess rain runs over the surface, carrying suspended soil particles and causing channeling.

Excavations are among the worst threats to daga structures at archaeological sites like Domboshaba. When buried, a subsurface daga structure is in equilibrium with the surrounding fill in terms of moisture and temperature. When it is excavated, however, rapid change in this microenvironment often results in accelerated deterioration due to stresses imposed by constant wet/dry and temperature cycling. It has been observed that once structures are exposed to the air they develop microcracks and surface flaking within the first ten hours of exposure (Ndoro 1990). Upon drying, daga tends to contract, forming cracks and crusts caused by differential thermal dilation between the surface and the matrix (fig. 4).

Not only excavation but also, sometimes, the inexperience of the excavator can destroy daga structures. When amateurs are unable to distinguish differences between soil layers and architecture, they often dig up daga structures in the process. Occasionally excavators knowingly remove the structures to access underlying layers.

Condition of the Daga Structures at Domboshaba

There are sixteen exposed daga structures at Domboshaba National Monument. Of these, at least ten were recklessly uncovered by both treasure hunters and professional archaeologists and are in varying states of decay, depending on their



FIGURE 4 When daga structures are exposed the surface cracks almost immediately. These cracks, which were not visible on the structure when it was excavated, appeared after one hour of exposure, Kagumbudzi, Zimbabwe. Photo: Ashton Sinamai

level of exposure. There is also evidence of excavation trenches in an area where human remains were discovered by earlier explorers of the site. Two of the daga structures have been exposed by erosion as they were on a slope, and some areas have been dug up by burrowing animals (primarily ant bears). Two houses on the Hill Complex and the lower enclosure have been left open for presentation purposes (for visitors who have difficulty understanding the relationship between the houses and the dry stone walls). Several house floors in the valley ruins were directly on the tourism trails and have been damaged by trampling.

Vegetation has also played a part in the deterioration of these buildings. Roots caused cracks to form on some of the structures. Where possible, roots are removed; in some cases, however, they are embedded in the structures and cannot be lifted without causing extensive damage.

Strategies for Preserving the Daga Structures at Domboshaba

Archaeological daga structures at Zimbabwe cultural sites are among the most difficult to preserve. The difficulty stems from the nature of the earthen materials in a dynamic physical environment and from their variety from site to site, which often requires different conservation approaches. In some cases the soil used to build the structures has been changed by the building process or by abandonment. Many of these structures were fired and thus lost their plasticity. Religious beliefs of the people dictated that structures occupied by elites be burned, which altered their clay components. Preservation treatments can only extend the life of these remains and not stop their deterioration. Since no two sites are exactly the same, each site requires unique conservation solutions based on the type of soil used in construction, the amount of rainfall received, and the type and extent of vegetation in the area. Despite these variables, some basic approaches to the conservation of daga structures can be applied, though the optimum preservation solution is to backfill the exposed structures.

Backfilling and Building Models

Many of the structures are recommended for backfilling since they have deteriorated considerably and are not suitable for display purposes. The backfill stratigraphy consists of an initial shallow layer of salt-free sand to facilitate future excavation, separate the daga structure from the backfill, and allow the structure to breathe. Ideally, the next layer should

be composed of the same soil taken from the excavation since it proved effective at insulating and protecting the structure; however, since this soil was not available because it had been dumped elsewhere, a new soil, closely inspected for termites, was used. The soil was placed by hand; no mechanical equipment was used in an effort to prevent overcompaction, which could have damaged the structures.

Some daga structures regarded as highly important for site interpretation were also recommended for backfilling. To mitigate the loss of information, we are considering building a model of the structure on top of the backfill. This method has been used at one of the houses excavated at Great Zimbabwe and is recommended for one of the structures in the valley. An explanatory panel will accompany the model in an effort to provide as much information about the original site as possible. At Domboshaba it was recommended that one of the house remains in the valley be reconstructed to aid with the interpretation of the site.

Roofing of Structures

Two structures that play a major role in interpretation of the site were roofed, and displays were made explaining the relationship between the stone walls and the daga structures. The roofs designed were to be compatible with the environment as well as rust-proof and fire-resistant (fig. 5).

Embankments

Erosion gullies that channel water toward the structure have been created by reckless excavations. Drainage systems



FIGURE 5 Roofing of the structure eliminates the threat of rain and direct sun but not the problem of humidity. Photo: Ashton Sinamai

have been dug to keep excess water and runoff away from the exposed daga structures. Drainage modifications were also recommended for daga structures in the valley but could not be implemented because the area is archaeologically sensitive and we did not want to disturb archaeological remains.

Interpretation

An interpretation plan was developed for the site so that archaeologically sensitive and fragile areas could be protected. Walking paths were directed away from the daga structures. Since most of the structures had been backfilled, a display panel with a map showing locations of hut floors was recommended, as was adding this and other information on the structures to the site's guidebook. A stone-paved trail was built around the site, and steps leading up the Hill Complex were created to avoid formation of informal visitor paths.

Conclusion

Since many of the daga structures were in poor condition and were difficult to preserve with available resources, we decided the most appropriate treatment was to backfill, which was accomplished during the Documentation and Inventory Workshop held in Botswana in July 2005. A major problem with the daga structures was not just their poor condition but also the general disregard and neglectful approach heritage managers had taken for these sites relative to the monumental stone walls. Also, since there were very few solutions to the problem of saving the daga structures intact, we felt it was important to carry out future research in collaboration with institutions that could provide the necessary technical assistance.

The following recommendations were made at the 2005 workshop, which were adopted by heritage managers in southern Africa:

- Heritage managers must consider daga structures integral parts of the dry stone walled sites that they manage.
- Heritage managers should monitor the activities of researchers to make sure that open trenches are backfilled.
- Trails should go around daga structures to avoid damaging them.

- Daga structures left exposed for interpretation and presentation should be protected from damage by the elements.
- Community participation in the conservation, preservation, and interpretation of all components of Domboshaba should be encouraged.
- Research that would add to our understanding of the behavior of daga structures and materials used should be encouraged and should include study of the vernacular architecture of the region.

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PART FIVE

Advances in Research

Avancées dans la recherche

The Consolidation of Earthen Surface Finishes: Developing a Protocol for Treatment Evaluation at Mesa Verde National Park

Amila Ferron and Frank Matero

Abstract: *In the development of treatment options for disaggregating earthen finishes at Mesa Verde National Park, this research has focused on the behavior of earthen plasters and washes after treatment with ethyl silicate consolidants, especially with regard to hygric and hydric responses. This testing program included on-site observation and assessment of prevalent decay mechanisms and conditions, characterization of existing finish materials, literature reviews, preparation of facsimile samples, and physicomechanical testing of the facsimiles. Promising results were obtained for Silbond® 40 and Funcosil® SAE 300E elasticized consolidants, whereas Conservare® OH 100 performed poorly under wet-dry cycling conditions.*

Résumé : *Pour l'élaboration de solutions de traitement contre la désagrégation des revêtements en terre au Parc national de Mesa Verde, la recherche a été centrée sur le comportement des enduits et badigeons en terre après traitement avec des consolidants à base de silicate d'éthyle, compte tenu notamment des réactions hygriques et hydriques. Ce programme d'essais comprenait des observations sur place et une évaluation des mécanismes et des conditions de détérioration, la caractérisation des matériaux de revêtement existants, une revue des documents publiés, la préparation d'échantillons conformes et des essais physico-mécaniques sur ces échantillons. Les consolidants élastifiés Silbond® 40 et Funcosil® SAE 300E ont donné des résultats prometteurs, tandis que le Conservare® OH 100 s'est avéré décevant dans des conditions d'alternance cyclique d'humidité et de sécheresse.*

Mesa Verde National Park, a World Heritage Site located in the southwestern United States, contains over four thousand Ancestral Puebloan sites, many built within alcoves in the can-

yons' cliff walls during the thirteenth century C.E. The surfaces of these buildings were often covered with plain and decorated earthen finishes, which still survive today. Recent research by the Architectural Conservation Laboratory at the University of Pennsylvania focused on Kiva F of Long House, the second-largest alcove settlement at Mesa Verde. The walls of Kiva F retain an exceptional red finish that is actively disaggregating, possibly due to its composition and exposure. This condition requires new research on the consolidation of earthen surface finishes at Mesa Verde with a focus not only on the anticipated improvements to cohesive strength but also on possible changes to the material's response to moisture, a necessary consideration in any outdoor environment.

The earthen finishes at Mesa Verde typically exhibit interlayer flaking and detachment from the plaster, mortar, and stone substrates to which they were applied. The treatment of these conditions has been a topic of study at Mesa Verde for many years (Bohnert 1990; Silver 1990; Matero 1997; Fiero, Matero, and Bass Rivera 2000). Current treatment, since 1995, involves injection of a warm or cold glycerin-modified gelatin adhesive followed by the application of light pressure with a damp sponge to gently push the flakes back into plane with the wall (fig. 1). The moisture in the damp sponge activates the clays in the finishes and replasticizes the layers, allowing them to be gently pressed into place. When consolidation is considered as a companion treatment, it is critical to know the effects consolidation might have on the plasticity of these finishes, either in terms of current and future treatment or in terms of their natural response to changes in ambient moisture.

The research program began with the analysis and characterization of the original finishes, including stratigraphy, clay mineralogy, and particle size distribution. Representative

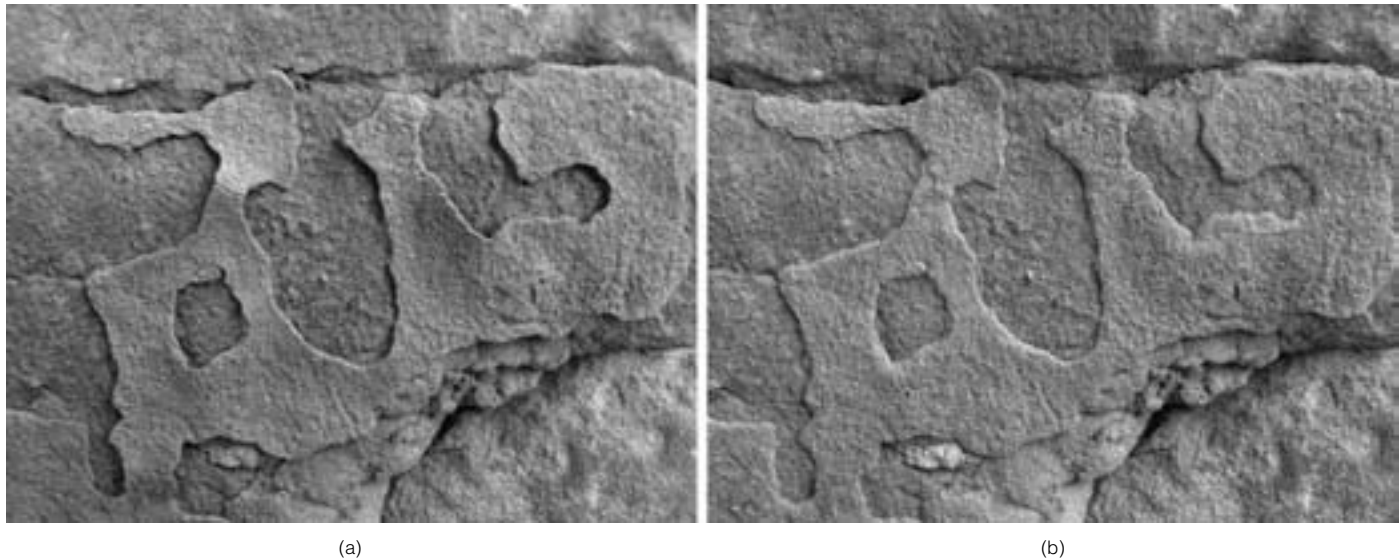


FIGURE 1 Before (a) and after (b) gelatin-glycerin reattachment treatment of earthen surface finishes at Mesa Verde National Park.

stratigraphies examined in cross section with reflected light microscopy revealed three layers: a thin bright red wash at the surface (1 mm), a thicker red plaster below (>1 mm), and a gray mortar substrate on the sandstone support. The two red finishes were found by X-ray diffraction (XRD) to contain mostly illite/smectite mixed layers, unusual results considering that kaolinite has been more commonly found in Mesa Verde finishes (Dix 1996; Ferron 2007; Hartzler 1996; Matero, Cancino, and Fourie 2002; Slater 1999). Review of previous research reveals that Mesa Verde plasters contain an average sand:silt/clay ratio of 54:46 percent and an average wash ratio of 16:84 percent (Dix 1996; Ferron 2007; Hartzler 1996; Matero, Cancino, and Fourie 2002; Slater 1999). Findings for Kiva F plaster particle size distribution are in line with these averages. The washes were not analyzed because of the limited sample size.

Investigation of possible treatments for testing was performed in two phases: first, a general assessment of ethyl silicate consolidants on earthen finishes; and second, a closer investigation into the hygric (relating to water vapor) and hydric (relating to liquid water) behavior of consolidated earthen finishes. The methodology for each phase included on-site observation of conditions, characterization of existing materials, review of literature on previous consolidation research, and development of a physical testing program involving the preparation of facsimile samples. Currently, a third phase of testing continues the research at the Getty Conservation Institute with investigation into the use of ethyl silicates on other clay types, including those found at Mesa Verde.

Phase I

Based on a literature review of consolidants used or tested on earthen materials, the commercial alkoxy silanes (or ethyl silicates) Silbond® 40 and Conservare® OH 100 were chosen as the primary treatments to investigate. A dilute form of the aqueous gelatin solution currently used at Mesa Verde for plaster reattachment was also included in the testing program for comparison. After a second literature review, which compiled methodologies for evaluating consolidation treatments, a select set of desired characteristics for assessing consolidated samples was developed. It included good depth of penetration, increased surface cohesion, resistance to wet-dry cycling, and minimal effect on color. Test results are as follows (table 1):

- Depth of penetration was found to be the greatest with Conservare® OH 100 and Silbond® 40 but was inconsistent with the dilute gelatin solution.
- Surface cohesion was significantly improved for all consolidated samples as compared to the untreated control samples.
- During wet-dry cycling, Conservare® OH 100-treated samples developed a tight network of cracks and Silbond® 40-treated samples exhibited no cracking (fig. 2). The results for Silbond® 40 may be explained by its hydrophobic nature, a quality that diminishes over time (Wheeler 2005). Since the curing period was limited to three weeks, the Silbond® 40-treated

Table 1 Results for Phase I testing. Cell shading indicates result assessment, with white cells containing the most desirable results and dark gray containing the least desirable with respect to overall treatment goals.

	Color Change	Depth of Penetration	Surface Cohesion	Wet-Dry Resistance
Control	—	—	—	—
Conservare® OH 100	Darkened by 1.0 Munsell value unit	Full depth	104% improvement	Similar to control
Silbond® 40	Darkened by 1.5 Munsell value units	Full depth (assumed)	95% improvement	No response— inconclusive
Gelatin	No change	Complete but concentrated in pores and on surface	108% improvement	Cracks and blisters produced

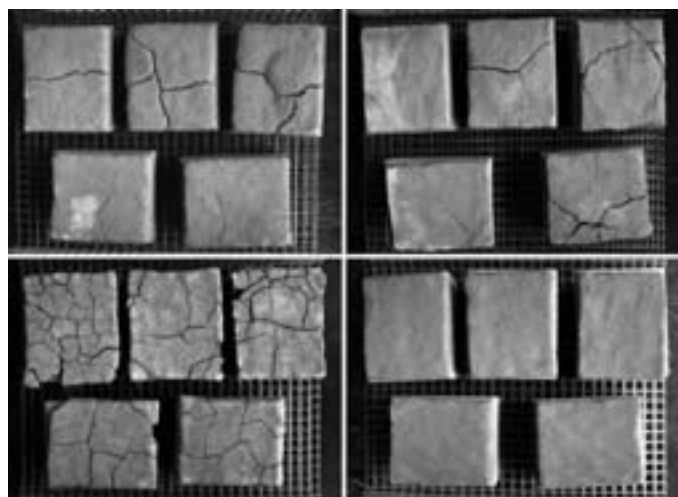


FIGURE 2 Condition of control and treated samples after 20 wet-dry cycles. Clockwise, from upper left, the samples were untreated; and treated with gelatin, Silbond® 40, and Conservare® OH 100. No cracking was visible in the samples before testing.

samples may not have been able to be sufficiently wet during testing.

- Color change was minimal for the gelatin solution but significant for both commercial ethyl silicates, especially Silbond® 40.

This concluded Phase I and marked the beginning of Phase II, in which the focus moved to hygric and hydric responses and included treatment materials not previously reported in the literature. These materials, such as Remmers® elasticized consolidants and surfactants, were designed specifically to address moisture issues with clay.

Phase II

As in Phase I, a literature review was performed, this time focusing on methods of producing a facsimile wash and testing its dimensional change with varying relative humidity. The most appropriate test found involved the use of a displacement transducer in a relative humidity chamber (Bourgès and Simon 2003), which was made available through collaboration with the Getty Conservation Institute. Following the literature review the testing methodology was developed to assess the consolidants' performance capabilities. Properties chosen for evaluation were hygric dimensional change, hydric response, resistance to wet-dry cycling, surface cohesion, color, microdrop absorption, and surface effects.

After establishing the experimental protocols, test samples were designed and produced. There were three types of samples: facsimile washes alone, facsimile washes on facsimile plasters, and original finishes from Kiva F. The facsimile test samples were prepared in small squares (5 × 5 cm) and very small circles (6 mm diameter and 1.5 mm thick) as per test requirements. To ensure uniform sample thickness, acrylic sheets were cut with a laser to exact dimensions and used as molds. Before the molds were filled the sample material was carefully formulated to match the original washes and plasters. The facsimile wash was prepared from two local soils mixed in proportions matching the 16% sand:84% silt and clay composition typical of analyzed Mesa Verde washes. Particle size analysis of the facsimile soil mixture revealed a 23% clay-size fraction. This mixture was found by XRD to contain smectite and small amounts of kaolinite and illite. Chemical spot testing revealed the presence of carbonates and calcium but no nitrates, sulfates, or chlorides.

After preparation the samples were divided into six sets: one was left untreated as a control; four sets were treated with

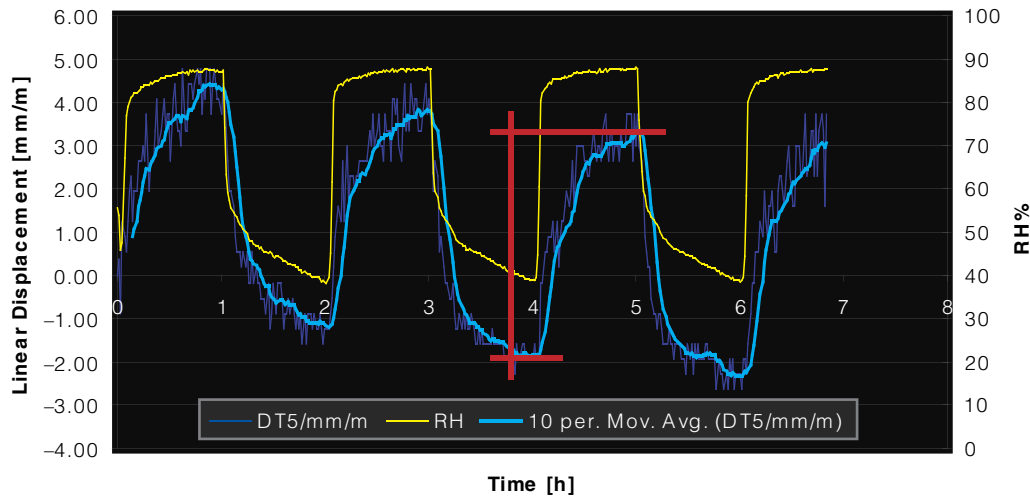


FIGURE 3 LVDT results for an untreated sample (number WD-1-1). Relative humidity fluctuations are seen in yellow, dimensional change in dark blue, and the calculated running average in light blue. Dimensional change for one period is indicated by the red markings.

chemical consolidants (Conservare® OH 100, Silbond® 40, Funcosil® SAE 300E—an elasticized consolidant—used alone and with Funcosil® Antihygro® pretreatment—a material that reportedly diminishes clay swelling by 50 percent (Remmers 2007); the sixth and final set was treated with water as a control and possible consolidant since it has been suggested that the effects of rehydration improve mechanical properties (Silver, Snodgrass, and Wolbers 1993).

Evaluation of hygric dimensional change was performed by subjecting twelve samples—two of each treatment type—to varying relative humidity (RH) and measuring corresponding dimensional fluctuations. The testing chamber produced RH variations in a stepped pattern between approximately 38% and 97%. All twelve samples were tested concurrently, and their expansion and contraction were measured and recorded by the displacement transducer (fig. 3). Noise in these data was minimized by calculating a running average with a period of ten, after which the total dimensional change for each period was measured and averaged for each sample. Since two samples were tested for each treatment type, their average was taken as an indicator of the expansion and contraction for that treatment (fig. 4). Samples treated with water showed the greatest increase in dimensional stability; however, all treated samples gained stability as well. Of the chemically treated samples, Funcosil® Antihygro® maintained the most stability, and Silbond® produced the least significant gains.

The effects of wet-dry cycling were assessed visually by comparing the cracking that developed during testing. Before treatment the samples showed some shrinkage cracking due to the production process and sample composition. Additional fractures formed when they were transferred to the metal sheet

for wet-dry cycling. This initial cracking was more widespread in the control and water-treated samples and less so with the chemically treated samples, where the consolidant appeared to maintain and improve their bulk cohesion. Cycling was performed by spraying the samples, allowing the water to absorb and evaporate for 30 minutes, and then placing the samples in an oven at 60°C for 1 to 2 hours. Forty cycles were performed over a two-week period. After this cycling, it became clear that the untreated control and water-treated samples exhibited a much greater hygric response than the chemically consolidated samples, as illustrated by the significant planar deformation (fig. 5). Of the chemically consolidated samples, Silbond® 40

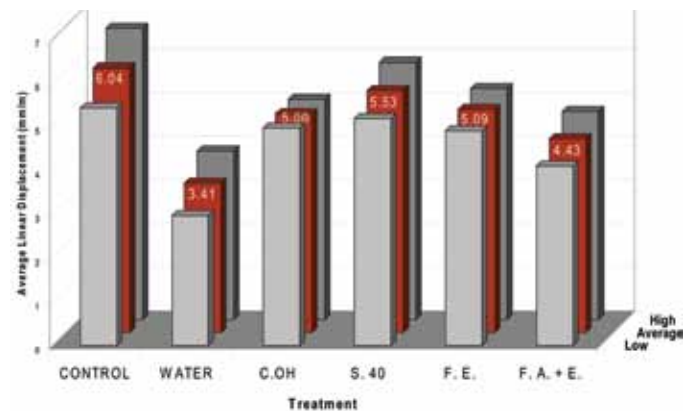


FIGURE 4 LVDT results for all samples (in gray) and the average for each treatment type (in red): control (untreated), water, C. OH (Conservare® OH 100), S. 40 (Silbond® 40), F. E. (Funcosil® SAE 300E), F. A. + E. (Funcosil® Antihygro® pretreatment with Funcosil® SAE 300E).

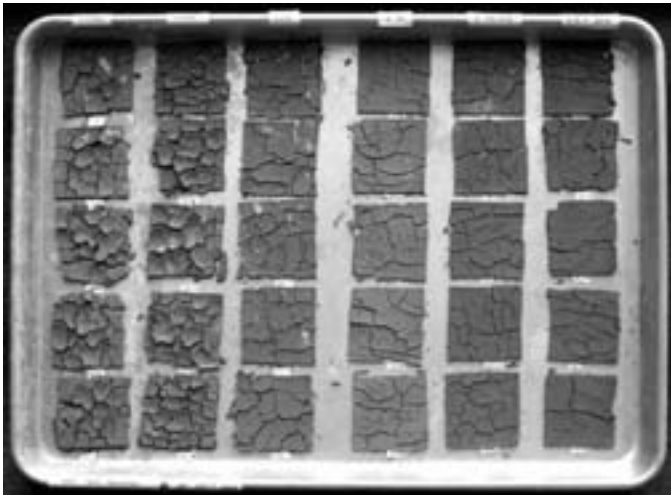


FIGURE 5 Facsimile samples after wet-dry cycling. From left to right the columns of samples represent different treatment types: control (untreated), water, Conservare[®] OH 100 (C. OH), Silbond[®] 40 (S. 40), Funcosil[®] SAE 300E (F. E.), Funcosil[®] Antihydro[®] pretreatment with Funcosil[®] SAE 300E (F.A. + E.).

and Antihydro[®] displayed the least response to cycling, and Conservare[®] OH 100 showed the greatest response by cracking. The color of the treated samples darkened slightly after consolidation, which became less apparent with the wet-dry cycling (fig. 5).

Surface cohesion was evaluated through the adoption of ASTM D4214, a test designed to measure chalking of exterior paints (American Society for Testing Materials 2001). In this test disaggregated surface material is removed from the samples with tape and compared to published standards. In order to improve and quantify the results, the tape pulls were photographed and digitally processed in GIS (ArcView[®]) to analyze the relative density of removed material for each treatment. Surface cohesion was measured both before and after wet-dry cycling; the results relative to the control are displayed in figure 6. Although all samples decreased in surface cohesion after wet-dry cycling, the results are shown here only in relation to that of the control in order to compare their relative performance. Results before wet-dry cycling showed minimal variation from the control, though the Conservare[®] and Funcosil[®] consolidant slightly increased surface cohesion. Water, Silbond[®] 40, and Antihydro[®] treatments unexpectedly decreased surface cohesion. In the case of Silbond[®] 40, this decrease in cohesion may be attributed to its slow curing time. Since the samples were given only eleven

weeks to cure, it is possible that the Silbond treatment had not fully cured before testing. The reduction in surface cohesion for Antihydro[®]-treated samples may be due to an observed change in surface texture immediately after treatment, which left a rough surface and may have allowed more material to adhere to the tape. After wet-dry cycling the variation in results was much more pronounced, with the Silbond[®] 40 and both Funcosil[®]-treated samples showing great improvement in surface cohesion from the control. Since Silbond 40 is hydrophobic for an unknown length of time after application, it again may not have allowed the samples to absorb as much water during wet-dry cycling as samples treated with other consolidants. This may explain the improvement relative to the control for surface cohesion after wet-dry cycling. The Conservare[®] OH 100-treated samples, however, greatly decreased in surface cohesion from the control. When this result is paired with the wet-dry cycling results for Phase I, where the Conservare[®] OH 100-treated sample cracked, it becomes apparent that earthen surface finishes treated with this consolidant are especially sensitive to liquid water.

Water drop absorption, performed before and after wet-dry cycling, revealed the chemically treated samples to be significantly less absorbent than the untreated or water-treated samples (fig. 7). Before cycling the Antihydro[®]-pretreated samples were more absorbent than the other consolidated samples. After wet-dry cycling all the chemically treated samples displayed increases in absorption, Conservare[®] OH 100 exhibiting the greatest increase and Silbond[®] 40 and Antihydro[®] the least.

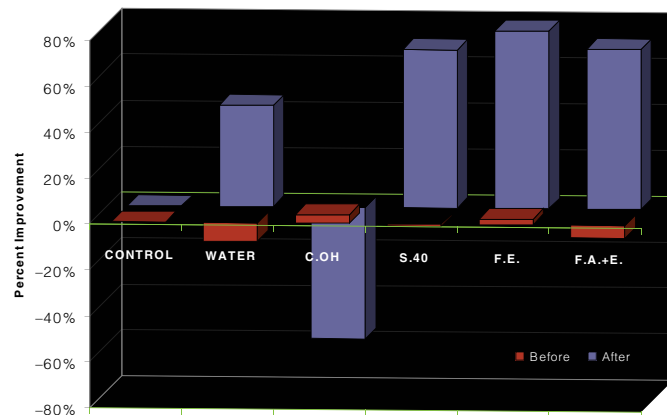


FIGURE 6 Results for surface cohesion before and after wet-dry cycling. Change in surface cohesion is indicated with percent improvement from the control. Only the Conservare[®] OH 100 resulted in a reduction of surface cohesive strength.

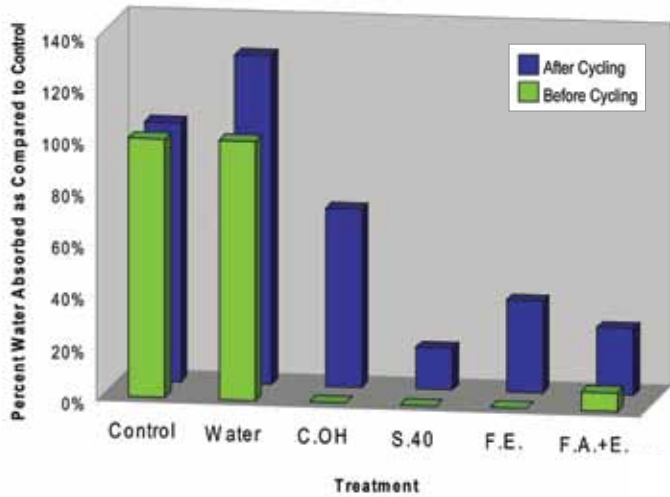


FIGURE 7 Results for microdrop absorption before and after wet-dry cycling.

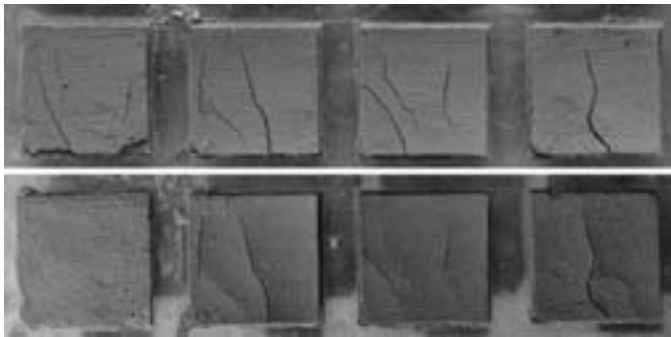


FIGURE 8 Before (above) and after (below) treatment with chemical consolidants. From left to right, the consolidants used were Funcosil® SAE 300E with Funcosil® Antihygro®, Funcosil® SAE 300E, Conservare® OH, and Silbond® 40.

The visual effect of consolidation on the samples' surfaces was recorded for each of the four chemical consolidants. All the samples remained relatively unchanged, with the exception of the Antihygro®-treated samples, where the surface appeared to have expanded, closing some of the cracks and leaving a mottled texture (fig. 8).

Conclusion

The results of the test program show significant differences in the behavior of the untreated and consolidated samples,

as well as across the consolidated samples. These responses must be explored further to better understand and explain the physical and chemical interaction of the various consolidants with these earthen finishes (table 2). Silbond® 40, Funcosil® SAE, and Funcosil® SAE with Antihygro® were found to increase surface cohesion within a similar range, which is a desirable result, but the loss of surface cohesion seen with the Conservare® OH 100 is not acceptable and requires further research and explanation.

The improvement of cohesive strength is a critical property in evaluating the performance of consolidants; however, it is not the only performance characteristic to be considered. Continued plasticity after consolidation, which allows future reattachment and treatment in the case of earthen finishes, is also of great importance. Since plasticity has been shown to be related to hygric expansion, the differential transducer assessments of hygric dimensional change may provide an indication of plasticity. Silbond® had the least effect on dimensional change as compared to the control and should allow treated areas to be plasticized for immediate reattachment or replasticized at a later date for retreatment.

Dimensional stability is another critical performance characteristic often discussed in the conservation of earthen materials. When the tests for hygric change are interpreted with this in mind, water-treated samples exhibited the best results with the least dimensional change; however, field use of this technique clearly shows renewed susceptibility to detachment within a year or more. Dimensional stability was also measured on bulk samples by wet-dry cycling, in which the most stabilizing treatments were the Silbond® 40 and Funcosil® Antihygro® with SAE.

As measured by microdrop absorption, a loss in liquid water permeability was evident in all the chemically treated samples. While water repellency can be a protective quality, it could also inhibit performance of the gelatin-based reattachment treatment since the finishes need to be wet to activate their plasticity and absorption capacity; therefore, in this case, some absorption is a desired quality. When comparing the performance of the ethyl silicates, the Conservare® OH 100 demonstrated the least change in water absorption due to its moderate water repellency.

Last, it is critical that consolidation produce no adverse change in the color or texture of the finishes. In this respect, water treatment had the least effect on the samples. Of the chemically treated samples, Silbond® 40 produced the least color change. In most cases, the texture remained relatively unchanged as a result of consolidation, with the exception of

Table 2 Summary of results for Phase II testing. Results may be interpreted for each treatment type by reading horizontally to assess overall performance. White cells represent optimal results as interpreted for Long House.

	Hygric Dimensional Change	Resistance to Wet-Dry Cycling	Microdrop Absorption (after cycling)	Surface Cohesion (after cycling)	Color Change (after cycling)	Surface Effects (after treatment)
Control	—	—	—	—	—	—
Water	▼ 44%	= Unstable	▲ 27%	▲ 44%	= None	▼ Very little change
Conservare® OH 100	▼ 17%	▲ More stability	▼ 31%	▼ 57%	▼ Minimal	▼ Very little change
Silbond® 40	▼ 8%	▲ Most stability	▼ 84%	▲ 69%	▼ Minimal	▼ Very little change
Funcosil® SAE 300E	▼ 16%	▲ More stability	▼ 65%	▲ 77%	▼ Minimal	▼ Very little change
Funcosil® Antihygro® and SAE 300E	▼ 27%	▲ Most stability	▼ 74%	▲ 70%	▼ Minimal	▼ Texture lost

the Antihygro® treatment, in which an unacceptable level of surface alteration was observed.

After findings are reviewed, consolidant selection becomes a matter of prioritizing selected performance criteria. The water treatment resulted in very unstable samples during wet-dry cycling; Conservare® OH 100 decreased the surface cohesion after wet-dry cycling; Silbond® 40 performed very well for all categories except microdrop absorption; and Antihygro®-treated samples performed fairly well, but the change in texture was not acceptable. The Funcosil® SAE 300E without pretreatment appears at this point to be the best option at Long House because of its moderate hygric dimensional change, increased stability under wet-dry cycling, moderate water repellency, greatly increased surface cohesion, minimal color change, and minimal surface effects after treatment.

Recommendations

The findings outlined here are only preliminary. Further tests and causal explanations of the observed results are necessary to better understand the possibilities and limitations of these consolidants for use on earthen finishes at Mesa Verde and elsewhere. For example, it is uncertain whether the increase in repellency observed with Silbond® 40 will interfere with the gelatin reattachment treatments to be performed. Further testing and eventual on-site trials may yield a more in-depth and relevant interpretation of these results. At the time of publication, a testing program at the Getty Conservation Institute is

continuing this line of research, specifically, to investigate the curing process of a similar set of consolidants and the effect of clay type. As with all sites, any intervention performed should fit within a comprehensive conservation plan that follows a values-led planning model including environmental and cultural impacts and consultation with professional managers and traditional stakeholders.

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Material Suppliers

Funcosil® Antihygro®, Funcosil® Stone Strengthener 100,
Funcosil® SAE 300
Company: Remmers (U.K.) Limited
Web site: www.remmers.co.uk

Phone: 01444-244144
 E-mail: sales@remmers.co.uk
 Address: 14, Victoria Way—Burgess Hill,
 West Sussex RH15 9NF

Conservare® OH 100, Conservare® H 100
 Company: Prosoco
 Web site: www.prosoco.com/
 Phone: 1-800-255-4255
 E-mail: customercare@prosoco.com
 Address: 3741 Greenway Circle, Lawrence, KS 66046

Silbond® 40, Silbond® TMB 70 (catalyst)
 Company: Silbond Corporation
 Web site: www.silbond.com
 Phone: 517-436-3171
 E-mail: silbond@silbond.com
 Address: 9901 Sand Creek Highway, P.O. Box 200,
 Weston, MI 49289

Permacel® J-LAR® Super Clear tape (Used to measure surface cohesion)
 Company: Permacel®
 Web site: www.permacel.com/
 Phone: 800-755-8273
 Address: One Tower Center, 14th Floor,
 East Brunswick, NJ 08816
 Distributor: Pearl Art and Craft Supplies, Inc.
 Distributor Phone: 215-238-1900
 Distributor Address: 417 South Street,
 Philadelphia, PA 19147-1532

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La terre, un béton comme les autres ? Quelques mécanismes de stabilisation du matériau terre

Romain Anger, Laetitia Fontaine, Hugo Houben, Patrice Doat, Henri Van Damme, Christian Olagnon et Yves Jorand

Résumé : Ce programme de recherche est centré sur l'amélioration de la cohésion du matériau terre en vue de l'élaboration de nouveaux « bétons d'argile ». Quelques grands principes de stabilisation du matériau terre sont présentés, par ajouts inorganiques, puis organiques. L'objectif est de consolider le matériau terre en deux étapes. Au moment de la mise en œuvre, les argiles sont dispersées au maximum pour éviter la formation d'agrégats et de porosités qui limitent les résistances mécaniques, et pour obtenir une organisation spatiale des argiles qui maximise les surfaces de contacts. La cohésion de la structure obtenue peut ensuite être améliorée selon diverses méthodes.

Abstract: This research program focuses on improving cohesion in earthen materials for the purpose of creating new "earth concretes." A few major principles regarding the stabilization of earth are presented, through inorganic and then organic amendment. The aim is to consolidate the earthen materials in two steps. Before use the clay is dispersed as much as possible to avoid the formation of aggregates and porosity, which would limit mechanical strength, and to obtain a spatial organization of clay that maximizes the contact surfaces. The cohesion of the structure obtained can then be improved by various methods.

Diversité du matériau terre

La terre est une matière plurielle et à l'heure actuelle, le principal obstacle à sa compréhension est sa diversité. Derrière l'expression « matériau terre » au singulier, se cache une infinité de matières aux propriétés physico-chimiques variées qui définissent toute une gamme de matériaux qui vont du sable au béton. Pour faire face à cette diversité, la solution est peut-

être de considérer cette matière terre dans le cadre plus large des bétons, « béton » étant un terme générique qui désigne un matériau de construction composite fabriqué à partir de granulats (sables, graviers, etc.) agglomérés par un liant : la terre est un béton d'argile.

Stabilisation inorganique

Argiles et CSH (Silicates de calcium hydratés)

Comme dans un château de sable, l'eau, grâce à sa tension superficielle, joue un rôle majeur dans la cohésion du matériau terre. La matrice argileuse qui lie les grains entre eux est constituée de microscopiques particules à faciès lamellaire reliées entre elles par de nanométriques ponts capillaires. L'analogie entre le matériau terre et le béton de ciment est également très forte. Des chercheurs (Sereda, Feldman et Ramachandran 1980), au cours d'une expérience célèbre, montrent que si l'on broie une pâte de ciment durcie et que l'on compacte ensuite la poudre obtenue, on reforme un solide cohérent qui, à porosité égale, possède la même résistance que la pâte initiale. La pâte de ciment durcie est donc une matière divisée, un peu à la manière de l'argile ! Sa cohésion est liée à un phénomène d'adhésion entre particules distinctes ! Les CSH (Silicates de Calcium Hydratés), principaux hydrates et véritable « colle » du ciment, sont particulièrement proches des smectites (argiles gonflantes). Dans les deux cas, il s'agit de lamelles d'épaisseur nanométrique séparées par un espace interfoliaire également nanométrique contenant de l'eau. Dans les deux cas, les surfaces des feuillettes sont chargées négativement. Dans les deux cas, ces charges négatives attirent dans l'espace interfoliaire des cations. Dans les deux cas, il se produit des interactions électrostatiques entre

les charges positives des cations et les charges négatives des feuillettes. Dans un cas, les interactions électrostatiques sont répulsives et provoquent le gonflement des smectites. Dans l'autre, elles sont attractives et provoquent la prise du ciment. La différence est double :

- La charge négative de surface est beaucoup plus importante pour les CSH.
- La nature des cations interfoliaires : exclusivement des ions Ca^{2+} dans le cas des CSH, tandis qu'entre les feuillettes des smectites peuvent se trouver, outre des ions Ca^{2+} , une grande diversité d'ions monovalents et divalents, voire trivalents.
- Les cations dissous dans l'eau de gâchage interagissent avec les charges négatives de surfaces des argiles. Ils contrôlent leur état de dispersion au moment de la mise en œuvre, ce qui influence les propriétés rhéologiques et mécaniques du matériau. Il est possible d'échanger les cations contenus entre les argiles par d'autres cations. Cela se produit chaque fois que l'on ajoute des sels ou des additifs minéraux à la terre. Sans le savoir, le maçon agit au niveau de l'atome.

La réaction pouzzolanique

Ces CSH, qui ressemblent tant aux argiles et qui sont la colle du ciment Portland, sont très importants puisqu'ils sont responsables de la cohésion de nombreux ciments. Le béton romain, par exemple, était réalisé à partir d'un mélange de sable, chaux, brique cuite pilée et eau. Le mélange de chaux, d'argile cuite et d'eau provoque une réaction chimique, appelée réaction pouzzolanique, qui produit des CSH. Cette réaction, bien que beaucoup plus lente, se produit également dans la terre crue stabilisée à la chaux. En somme, le ciment Portland, le béton romain et la terre crue stabilisée à la chaux sont trois recettes différentes qui permettent, à partir des mêmes ingrédients (l'argile et le calcaire), d'obtenir le même produit : les CSH. Cette réaction pouzzolanique se produit chaque fois que de la matière finement divisée contenant de la silice est mise en présence de chaux et est d'autant plus efficace que les particules siliceuses sont de petites tailles et mal cristallisées. Les matières qui répondent à ces deux critères sont des pouzzolanes que l'on trouve fréquemment dans des terres spéciales telles que les terres volcaniques ou les terres à diatomées. Certains déchets produits par l'industrie sont des pouzzolanes artificielles. C'est le cas de la fumée de silice, constituée de grains de différentes tailles de diamètres inférieurs à un micromètre. Ces grains microscopiques

permettent non seulement de remplir les porosités les plus fines mais aussi de réagir avec la chaux libérée par le ciment au cours de la réaction d'hydratation. De nombreuses recherches sont actuellement menées sur la métakaolinite, argile cuite des briques pilées romaines, afin de limiter l'utilisation de ciment Portland et de produire de « nouveaux bétons plus écologiques ». Certaines plantes sont particulièrement riches en silice, sous forme de phytolithes. L'enveloppe du riz est brûlée pour former des cendres contenant 90 % de silice amorphe. Ces cendres sont ensuite recyclées pour réaliser des ciments, en particulier en Inde et en Asie. Au sein de cette vaste famille de ciments silico-calcaires, du béton romain au ciment Portland, en passant par la terre crue stabilisée à la chaux et tout une gamme de pouzzolanes naturelles ou artificielles associées à la chaux, l'objectif est toujours le même : produire des CSH, silicates de calcium hydratés, associant la silice de composés naturellement présents dans les sols, ou produits par différentes industries, au calcium contenu dans les roches calcaires.

Les bétons géopolymères

Produire des CSH n'est certainement pas la seule option pour obtenir un ciment hydraulique. Les trois dernières décennies ont d'ailleurs vu l'apparition d'une nouvelle classe de bétons connus sous le nom de géopolymères qui ne font pas partie de la grande famille des ciments silico-calcaires. La chaux est remplacée par des bases plus puissantes comme la soude ou la potasse qui réagissent avec les argiles pour former une matrice vitreuse qui lie les grains entre eux.

Les ciments naturels

La nature présente des solutions originales : elle possède ses propres ciments. Certains horizons de sols peuvent durcir naturellement. On les appelle en anglais *silcrete*, *ferricrete* ou *calcrete*, contraction de *silicic concrete*, *ferric concrete*, *calcic concrete*. Les plinthites sont par exemple des horizons de sols riches en oxydes de fer capables de rapidement durcir lorsqu'elles sont exposées à l'air. Les habitants, sur place, utilisent ces terres pour confectionner des briques. Les blocs sont découpés dans ces plinthites, peu indurées *in situ*, puis sont stockées à l'air pour, petit à petit, se transformer en pierres. Cette induration est liée à des processus d'oxydo-réductions. Les oxydes de fer II sont plus solubles que les oxydes de fer III. Si, par oxydation, des éléments de fer II sont réduits en fer III, la cristallisation des éléments solubles cimentent les différentes particules du sol. A ces processus d'oxydo-réduction correspondent ainsi des processus de

dissolution-reprécipitation qui sont à la base de tout phénomène de cimentation et d'induration.

Stabilisation organique

Le terme « stabilisants organiques » fait référence aux nombreux ajouts issus de la matière vivante, qu'ils soient d'origine végétale ou animale. Cette grande diversité de matériaux disponibles localement constitue aujourd'hui un obstacle à la compréhension des mécanismes de stabilisation organique du matériau terre. La problématique de cette stabilisation peut être décomposée en trois parties :

- libérer et disperser la matière organique,
- disperser les argiles,
- organiser et lier les argiles et la matière organique.

Libérer et disperser la matière organique

Les molécules organiques et les argiles sont des colloïdes et leurs tailles sont du même ordre de grandeur, c'est-à-dire entre le nanomètre et la dizaine de micromètres. Elles interagissent donc entre elles. Or, la matière organique est extrêmement structurée et hiérarchisée et malgré quelques exceptions, les molécules organiques ne sont pas toujours disponibles sans préparation pour interagir avec les argiles. La déstructuration et la dégradation de la matière organique est possible grâce aux étapes de préparation, c'est-à-dire grâce aux recettes qui préconisent le trempage, la décoction, l'infusion, la macération, la fermentation, le pourrissement ou encore la distillation. Il s'agit de transformations chimiques, comme l'hydrolyse, l'oxydation, la réduction, ou encore les réactions enzymatiques, qui peuvent être liées à l'application de température et/ou de pression et qui se produisent lors des mécanismes de la biodégradation de la matière organique dans les sols, grâce aux processus d'humification qui conduisent à la formation de l'humus. Notons également que l'utilisation des excréments, bouses, urines et fumiers comme stabilisants organiques peut s'expliquer par le fait que le corps de l'animal accomplit lui-même une importante dégradation de la matière organique ingérée.

Disperser les argiles

Les argiles sont des « grains plats », sous forme de feuillets ou de plaquettes, chargés électriquement en surface, avec des faces négatives et des bords le plus souvent positifs. Les ions présents dans l'eau de mélange ainsi que son pH ont une influence primordiale sur ces charges de surfaces et sur celles

des molécules organiques. Étant donné leurs charges électriques, ainsi que la présence de forces attractives comme les forces de Van der Waals, les argiles ont tendance à former des agrégats dans le matériau terre. Disperser les argiles consiste donc à casser ces agrégats de manière à obtenir des feuillets ou plaquettes individuels. Cette dispersion permet d'une part de diminuer la quantité d'eau nécessaire à la mise en œuvre du matériau, donc de diminuer la porosité finale du matériau après séchage et d'améliorer la résistance mécanique. La dispersion des argiles permet également d'augmenter la surface de contact entre les argiles et les autres grains, entre les argiles elles-mêmes, et entre les argiles et les autres molécules organiques, augmentant ainsi la cohésion du matériau.

Ou, certaines molécules organiques sont des dispersants des argiles. Par exemple, les argiles peuvent être agrégées selon des contacts bord-face en empilement en château de cartes, grâce aux liaisons entre leurs bords positifs et leurs faces négatives. En ajoutant certaines molécules organiques chargées négativement, celles-ci se fixent par adsorption sur les bords positifs et rendent les particules argileuses complètement négatives. Ainsi, les particules se repoussent par « répulsion électrostatique » ou « neutralisation de charges électriques ». Les meilleurs dispersants organiques sont généralement des molécules de petite taille et de forte densité de charge de surface. À titre d'exemple, on peut citer certains dérivés de la cellulose, de la lignine, de l'amidon, ou encore les acides organiques, les tanins, les acides humiques et autres.

Lier les argiles par pontage organique

Les mécanismes de pontage organique entre des particules d'argiles permettent d'augmenter la cohésion du matériau : certaines molécules organiques peuvent s'adsorber sur plusieurs particules argileuses et les relier entre elles. Les molécules de grande taille, macromolécules ou encore biopolymères, et qui possèdent une faible charge de surface, sont les plus efficaces. La grande famille des polysaccharides comme la cellulose, l'amidon, les pectines, les mucilages, les gommes, ou les algues, ainsi que la grande famille des protéines comme la caséine, le collagène ou gélatine, qui ont la capacité de former des gels dans l'eau, et que l'on appelle aussi des agents épaississants et/ou gélifiants, sont particulièrement adaptés pour augmenter la cohésion du matériau terre.

Le pontage organique constitue un exemple de formation de composite organo-minéral. Les mélanges de matière organique et de terre sont généralement des matériaux macro-composites constitués de terre armée avec des fibres végétales, l'objectif étant de limiter la fissuration et d'augmenter

la résistance à la traction du matériau. Les mélanges qui nous intéressent sont différents : ce sont des nano- ou micro-composites, dispersions colloïdales de biopolymères dans une matrice argileuse. L'échelle d'interaction entre les matières minérales et organiques est différente.

L'exemple de la nacre : Organiser et lier

La nacre est constituée d'un assemblage de briques minérales plates et polygonales qui sont des cristaux d'aragonite (CaCO_3), entourées d'un mortier de matière organique (une protéine appelée conchyoline, donc un biopolymère). Le complexe organo-minéral formé est très structuré et à l'origine de l'exceptionnelle résistance de la nacre qui possède une résistance à la rupture 3 000 fois supérieure à l'aragonite seule ! L'objectif de la stabilisation organique du matériau terre est de faciliter une meilleure organisation, et donc une plus grande cohésion des particules argileuses, à l'image de ce que fait la nature avec la nacre. Il est évident que le matériau terre n'est pas uniquement constitué d'argiles et que les autres grains ont un rôle primordial à jouer dans cette organisation structurelle. Le matériau modèle qu'est la nacre a été reproduit par des chercheurs (Tang et Magonov 2003) qui sont parvenus à synthétiser une « nacre artificielle », en utilisant des particules argileuses comme briques et un polymère comme mortier. Les propriétés mécaniques de ce nanocomposite organo-minéral sont proches de celles de la nacre ! Il est illusoire de chercher à organiser le matériau terre à l'échelle nanoscopique mais cet exemple peut servir de modèle à suivre et montre surtout l'extraordinaire cohésion des composites argiles-polymères.

Un autre mécanisme : Les molécules hydrophobantes

Par ailleurs, certaines molécules organiques sont hydrophobantes et permettent de protéger le matériau terre de l'eau : ce sont des molécules amphiphiles, c'est-à-dire qu'elles possèdent une partie hydrophile et une partie hydrophobe. Les parties hydrophiles s'adsorbent sur les particules argileuses, au contact avec l'eau, tandis que les parties hydrophobes restent en surface du matériau, au contact avec l'air, et forment une pellicule de surface qui empêche l'eau de pénétrer dans la

terre. De très nombreuses molécules organiques sont amphiphiles et l'on peut citer comme exemple l'albumine, une glycoprotéine présente dans le sang, le blanc d'œuf, le lait, etc.

Conclusion

La « stabilisation » optimale du matériau terre s'effectue en deux temps.

Dans un premier temps, au moment de la mise en œuvre, il s'agit de disperser au mieux les particules les plus fines, en d'autres termes de les « décoller ». Ceci permet d'utiliser moins d'eau au moment de la mise en œuvre, donc de réduire la porosité finale du matériau, et d'obtenir une meilleure structure afin de maximiser la proportion de surfaces de contact entre les argiles. Diverses stratégies peuvent être mises en œuvre : induire des forces électrostatiques répulsives en séquestrant les cations divalents et trivalents de la solution, ou encore rendre les bords positifs des argiles négatifs, soit par ajout d'une base, soit à l'aide de petites molécules organiques négatives qui s'adsorbent sur les bords.

Après avoir correctement organisé et structuré le matériau lors de la mise en œuvre, la deuxième étape est de « figer » cette structure. Encore une fois, diverses stratégies existent : faire apparaître des interactions électrostatiques attractives entre les argiles de nature similaire à celles présentes entre les CSH, lier les argiles à l'aide de biopolymères par pontage organique, ou encore indurer le matériau par cimentation (réaction pouzzolanique, géopolymérisation, oxydation des oxydes de fer II, etc.). Les différentes stratégies doivent être élaborées en tenant compte de la grande diversité des sols.

Références

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Étude expérimentale et modélisation des mouvements d'eau dans la muraille en terre extérieure de Khiva (Ouzbékistan) en relation avec les faciès de dégradation observés

Olivier Grossein, Jean-Paul Laurent, Laurent Oxarango, Thierry Joffroy, Mahmoud Bendakir et Hugo Houben

Résumé : *Deshan Kala, muraille extérieure en terre crue de Khiva (Ouzbékistan), présente un sillon de dégradation à sa base. Dans cette étude, les transferts hydriques dans le sol et la muraille sont quantifiés pour évaluer leur rôle dans le processus de dégradation. En se basant sur un suivi en continu des conditions hydroclimatiques sur le terrain, un modèle de transferts d'eau en phases liquide et vapeur est utilisé pour décrire le mouvement de l'eau entre la nappe proche et la surface. Les premières simulations numériques montrent une bonne cohérence entre la zone d'évaporation et la localisation de la dégradation.*

Abstract: *Deshan Kala, the external earth wall of Khiva (Uzbekistan), has a band of degradation running along its base. In this study, water transfers in the soil and the wall are quantified to assess their role in the degradation process. Based on continuous monitoring of hydroclimatic conditions on the ground, a water transfer model in liquid and vapor phase was used to describe the movement of water between the water table and the surface. The first digital simulations show consistency between the evaporation zone and the area of degradation.*

Khiva est une ville d'Ouzbékistan située à 250 km environ au sud-est de la mer d'Aral, non loin du fleuve Amou Daria (fig. 1) dans une large zone alluviale fortement irriguée pour permettre l'agriculture intensive du coton dans cette région malgré les très faibles précipitations (150 mm par an en moyenne). Conséquence de cette irrigation intensive, la nappe phréatique à Khiva est en permanence très proche de la surface du sol, entre 2 et 3 m de profondeur.

La ville de Khiva est placée sur l'ancienne route de la soie. Sa ville intérieure, Ishan-Kala, présente un inté-

rêt architectural majeur qui lui a valu d'être classée au patrimoine mondial de l'humanité par l'UNESCO. Elle est construite essentiellement en briques cuites alors que la muraille extérieure protégeant la ville – Deshan Kala, objet de notre étude –, a été construite au XIX^e siècle en terre crue. Elle fait actuellement l'objet d'un projet de restauration élaboré conjointement par les autorités ouzbèques compétentes, le bureau de l'UNESCO à Tachkent et le laboratoire CRATerre.

Elle s'étendait à l'origine sur 16 km, dont seulement environ 4 km subsistent actuellement en tronçons discontinus. Sa structure est composée d'un mur en « bauge » et d'un chemin de ronde en briques crues accolé au côté interne du mur. Sa hauteur totale est d'approximativement 7 m et sa largeur varie entre 3,5 m à la base et 0,5 m au sommet. La base de la muraille est presque partout dégradée des deux côtés et l'on observe quasi systématiquement un « sillon de dégradation » (fig. 2). Celui-ci se forme par effritement et chute de matériau sur une zone qui peut aller jusqu'à 2 m de hauteur et 1 m d'épaisseur manquante. Il met clairement en danger la pérennité de l'ouvrage à moyen terme (Joffroy, Valtchanova, et Moriset 2004).

La localisation du sillon à la base du mur, la faible profondeur de la nappe et le climat local désertique favorisant l'évaporation laissent supposer que les transferts d'eau et de sels de la nappe vers la surface jouent un rôle important dans les processus de dégradation en entraînant une perte de cohésion du matériau dans cette zone. Pour tester la validité de cette hypothèse, l'objectif de cette étude est de modéliser les transferts d'eau, de chaleur et de sels dans ce système nappe/sol/mur/atmosphère.



FIGURE 1 Carte de l'Ouzbékistan.
Réf. : Uzbekistan no. 3777 Rev. 6
January 2004. © UN Cartographic
Service



FIGURE 2 Vue du côté externe de la
muraille de Deshan Kala. Le sillon
de dégradation est bien visible à la
base du mur. © LTHE

Le dispositif expérimental

Dans un premier temps, une mission financée par l'UNESCO a permis l'installation en novembre 2006 d'un dispositif expérimental pour le suivi en continu des sollicitations hydroclimatiques auxquelles est soumise Deshan-Kala, d'une part, et de l'état hygrothermique du mur en terre lui-même, d'autre part. Pour des conditions de sécurité et de maintenance, le site que nous avons retenu pour installer ce dispositif de « monitoring » se situe dans la cour privée d'une ferme au nord-ouest de Khiva, le long de la muraille. C'est essentiellement la face externe du mur, exposée au nord, qui a été équipée. Des échantillons ont été également prélevés lors de cette mission à des fins d'analyse et de caractérisation des matériaux en présence.

Description

Le dispositif expérimental que nous avons conçu (fig. 3) remplit trois fonctions principales :

- i. Une station météorologique (WXT510 de *Vaisala*, Helsinki, Finlande), placée en haut du mur, mesure simultanément toutes les variables climatiques : pression atmosphérique, vitesse et direction du vent, température et humidité relative de l'air, rayonnement solaire incident et pluie ;
- ii. Un tube piézométrique a été installé dans un forage de 6 m de profondeur, creusé à proximité du mur. Un capteur de pression (ATM/N de *STS*, Sirmach, CH) placé dans ce tube permet de suivre le niveau de la nappe dont la salinité est par ailleurs évaluée par l'intermédiaire d'une mesure de conductivité électrique (sonde CS547 de *Campbell Scientific Inc.*, Logan, UT, États-Unis) ;
- iii. Un profil vertical a été instrumenté sur le mur à la fois en teneur en eau (6 points de mesures dans le mur + 3 dans le sol alentour) et en température sur 4 points de mesure regroupant 3, 4 ou 5 profondeurs : 5, 10, 20 et 30 cm. Le capteur de teneur en eau que nous avons retenu est la sonde capacitive CS616 de *Campbell Scientific*. Munie de 2 tiges de 30 cm de long et de seulement 3,2 mm de diamètre pour un entraxe de 32 mm, cette sonde est normalement prévue pour être utilisée dans les sols. Nous avons donc dû la modifier et mettre au point une procédure spécifique pour pouvoir l'introduire



FIGURE 3 Vue du site d'étude. La station météorologique est installée au sommet du mur. Les capteurs d'humidité et de température placés dans le mur sont visibles, alors que ceux placés dans le sol sont enterrés. Au premier plan se trouve le piézomètre contenant les instruments mesurant le niveau et la salinité de la nappe. Tous les capteurs sont reliés à la centrale d'acquisition abritée dans le boîtier blanc qui stocke des données. © LTHE

dans un matériau consolidé comme la terre. Pour mesurer les températures, nous avons utilisé des thermistances bon marché mais performantes (thermistances 100 kOhms à 25 °C de *BC Components* distribuées par *Radiospares* sous la Ref. 538-0812), placées dans des tubes en acier inoxydables de 6 mm de diamètre et de faible épaisseur, pour limiter autant que possible les courts-circuits thermiques. Elles avaient été préalablement étalonnées et la précision absolue de mesure ainsi atteinte était de l'ordre du dixième de degré.

Premières observations

Les conditions atmosphériques à Khiva présentent des amplitudes journalières très importantes et un contraste saisonnier marqué, typique du climat continental qui règne dans cette zone semi-désertique. Par exemple, la température de l'air peut varier à l'échelle de la journée de plus de 20 °C avec des extrêmes annuels de - 25 °C et + 40 °C, environ (fig. 4). Les fluctuations de température qui en résultent dans le mur sont également très importantes : il peut geler à cœur dans le mur très profondément en hiver et les écarts de températures jour/nuit sont clairement susceptibles de créer des contraintes mécaniques d'origine thermique.

Le niveau de la nappe, par contre, reste toujours haut et varie peu au cours de l'année, sauf au printemps à cause de l'irrigation. L'amplitude de la remontée de la nappe est alors d'environ un mètre en une vingtaine de jours. La conductivité électrique de la nappe – plutôt stable et élevée : de l'ordre de 4,5 mS/cm – correspond à une salinité de plusieurs grammes par litre, soit environ cent fois plus que ce que l'on considère comme admissible pour une eau potable. Indépendamment de son usage pour les cultures, cette eau est pourtant localement utilisée à cette fin pour les animaux et les gens...

Cette conductivité électrique élevée que nous n'avions pas complètement anticipée nous a posé un problème par rapport à nos capteurs de teneur en eau. En effet, une sonde capacitive telle que les CS616 que nous utilisons réalise en fait une mesure de permittivité électrique qui comporte une partie réelle effectivement bien liée à la teneur en eau, mais

aussi une partie imaginaire qui, elle, est liée aux pertes par conduction électrique dans le milieu. Dans notre cas, les fortes concentrations en sels à la base du mur ont faussé nos mesures dans cette zone où les sondes correspondantes délivraient des valeurs anormalement élevées. Pour corriger ce problème, nous avons tenté, lors d'une deuxième visite en juillet 2007, de gainer les tiges de ces sondes, ce qui a partiellement ramené leur gamme de fonctionnement dans un domaine plus raisonnable. Néanmoins, il conviendra d'étalonner en laboratoire ces mesures en les répliquant sur un bloc réalisé avec la terre de Khiva et porté à la même conductivité électrique. En attendant, on observe une très grande stabilité dans le temps des mesures réalisées sur les capteurs de teneur en eau, ce qui laisse penser que celles-ci varient très peu tout au long de l'année.

L'ensemble des mesures est centralisé sur une centrale d'acquisition de données (CR1000 de *Campbell Scientific*) qui dispose d'une autonomie électrique (alimentation secteur et batterie) et de stockage de données (carte *CompactFlash*, 128 Mo) importantes. Les données sont relevées par un intervenant sur place environ tous les 3 mois et transmises en France. Globalement, ce dispositif a fonctionné de manière continue depuis son installation.

Modélisation des transferts couplés d'eau et de chaleur

La physique des transferts

L'objectif est de modéliser les transferts d'eau dans le milieu poreux non saturé que constituent le sol et le mur en terre. Le modèle conceptuel de transfert que nous avons retenu est celui de De Vries (Philip et De Vries 1957) classique pour les sols. Il comporte deux équations pour le transfert d'eau : l'une pour le transfert sous forme liquide sous l'effet de la capillarité et de la gravité et l'autre pour le transfert en phase vapeur, et une troisième pour le transfert de chaleur.

Simulation numérique : Outils et premières études de cas

Le modèle nécessite la connaissance de paramètres décrivant les propriétés hydrothermiques du matériau. La méthode de porosimétrie par intrusion de mercure appliquée sur les échantillons ramenés de Khiva a été utilisée pour caractériser la structure porale du matériau et en déduire la courbe de rétention, liant la teneur en eau à la succion capillaire. Elle est ensuite modélisée par la relation de Van Genuchten (Van Genuchten 1980). La conductivité hydraulique dépend également de la teneur en eau du milieu et sa représentation peut être obtenue à partir des paramètres de Van Genuchten

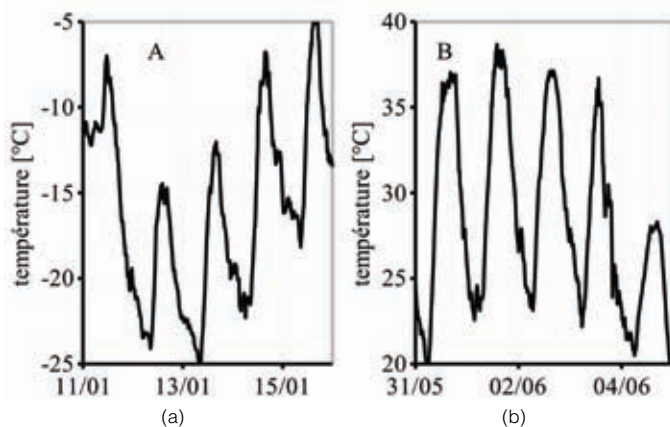


FIGURE 4 Exemples d'évolution mesurée de la température de l'air à Khiva, en janvier 2007 (a) et en juin 2007 (b). On observe de fortes amplitudes journalières et un contraste été/hiver très marqué. © LTHE

que nous venons d'évoquer. La conductivité hydraulique à saturation et les propriétés thermiques sont choisies d'après la classification granulométrique du matériau (Summer 1999).

Les conditions limites du problème sont fournies par le dispositif expérimental : la succion (charge hydraulique) à la base du problème est imposée par la hauteur de la nappe ; le flux convectif de vapeur à l'interface sol/atmosphère est liée à l'humidité relative de l'air. Le transfert de chaleur est, lui, contraint à la base par la température de la nappe tandis que le flux à l'interface sol/atmosphère prend en considération les échanges convectifs, les flux radiatifs et l'évaporation à la surface du sol.

Le modèle hydrothermique a été implémenté dans l'environnement de programmation en éléments finis *COMSOL Multiphysics™* (Comsol Inc., Burlington, MA, États-Unis). Afin d'évaluer l'impact des conditions limites, une première série de simulations a été réalisée sur une géométrie monodimensionnelle. Cette approximation correspond à l'étude des transferts verticaux entre une nappe phréatique et la surface horizontale du sol. Le formalisme du modèle décrit explicitement l'état hydrique du matériau en terme de succion et de taux de saturation en eau S_e ($0 \leq S_e \leq 1$, $S_e = 0$: milieu sec, $S_e = 1$: milieu totalement saturé).

Les conditions atmosphériques classiques (pas de pluie, humidité relative de l'air loin de la saturation . . .) engendrent des flux de type « remontées capillaires » de la nappe vers la surface du sol avec un assèchement progressif du matériau à l'approche de la surface.

La première simulation présentée sur la figure 5 illustre l'impact d'une variation du niveau de la nappe sur l'état hydrique du sol entre la nappe et la surface. Les conditions atmosphériques sont constantes avec la température de l'air fixée à 30 °C et l'humidité relative de l'air fixée à 30%. La température de la nappe est constante à 17 °C. Le niveau de la nappe oscille de façon sinusoïdale d'une amplitude de 1 m et selon une période de 20 jours correspondant aux variations observées au printemps. Le niveau minimum de la nappe est fixée à -3 m. Le tableau 1 présente la variation relative du taux de saturation du matériau à différentes profondeurs au cours de cette simulation. L'oscillation du niveau de la nappe est fortement amortie sur le premier mètre au dessus de la nappe et ne se transmet pas jusqu'à la surface. L'état hydrique du matériau proche de la surface n'est pas influencé par le battement de la nappe à une fréquence élevée. Ce résultat est très cohérent avec les mesures faites par sondes capacitatives.

L'humidité circule dans le système essentiellement en phase liquide. Cependant, proche de la surface, l'eau s'éva-

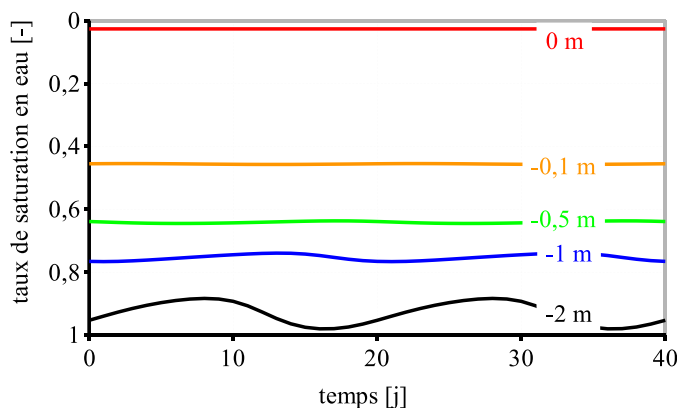


FIGURE 5 Simulation de l'évolution du taux de saturation en eau à différentes profondeurs sous le mur, montrant un impact du battement de la nappe sur l'état hydrique du sol entre la nappe et la surface qui ne se propage pas jusqu'à la surface. © LTHE

Tableau 1 Résultats de simulation de la variation relative du taux de saturation à différentes profondeurs pour un battement de nappe de 1 m. © LTHE

Profondeur	Variation relative de la saturation effective
-2 m	11 %
-1 m	3,7 %
-0,5 m	1,3 %
-0,1 m	0,6 %
0 m	0 %

pore et le flux d'eau en phase vapeur devient prépondérant dans les derniers centimètres. Le modèle utilisé permet de représenter ces phénomènes et donc de localiser l'évaporation. La figure 6 présente le taux d'évaporation en fonction de la profondeur pour différentes humidités relatives de l'air ambiant. Il s'agit de trois simulations en régime stationnaire qui diffèrent uniquement par la valeur de l'humidité relative de l'atmosphère. La température de l'air est fixée à 40 °C. La température et le niveau de la nappe sont constants à 17 °C et -4,5 m respectivement. Pour les trois simulations, l'épaisseur de la zone d'évaporation mesure environ 1 cm. Pour des humidités relatives de l'atmosphère fixées à 50 %, 30 % et 10 %, la zone d'évaporation se situe respectivement à 3,5 cm, 7,5 cm et 11,3 cm de profondeur. Plus l'atmosphère est sèche, plus l'évaporation a lieu profondément dans le matériau. Une diminution de l'humidité relative de l'atmosphère de 50 % à

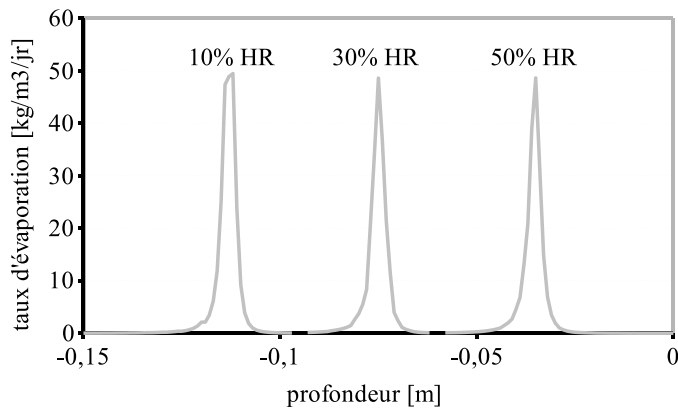


FIGURE 6 Localisation de l'évaporation à l'intérieur du matériau pour différentes humidités relatives (HR) de l'air.
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30 % et 10 % induit une augmentation du flux d'humidité à la surface de 2,5 % et 5 % respectivement.

Le transfert d'humidité dans le système sol/mur caractéristique du site d'étude a été simulé sur une géométrie bidimensionnelle simplifiée. Afin de réduire les temps de calcul, le mur est considéré parallélépipédique et symétrique. La figure 7 représente le taux de saturation en eau et le flux d'eau liquide dans le sol et le mur. Le matériau subit un fort assèchement proche de l'interface avec l'atmosphère. Le flux d'eau dans le sol est dévié vers la base du mur. Le flux de vapeur vers l'atmosphère est d'environ 0,5 mm/jour à la base du mur alors qu'il est inférieur à 0,1 mm/jour dans la partie haute du mur (au dessus de 1,5 m). Ces premières simulations mettent en évidence une corrélation entre la zone préférentielle d'évaporation et le sillon de dégradation.

Conclusion et perspectives

Un dispositif expérimental complet permet de suivre les sollicitations hydroclimatiques du sol et de la muraille de Deshan Kala (Khiva, Ouzbékistan), fortement dégradée à sa base. Les données recueillies *in situ* alimentent des simulations numériques des transferts d'eau dans le système, depuis la nappe vers l'atmosphère. L'intérêt majeur du modèle choisi est de localiser la zone d'évaporation de l'eau à l'intérieur du matériau, alors que la plupart des modèles de transfert d'eau en milieu poreux non saturé considèrent que l'eau s'évapore à la surface. Les premiers résultats montrent que le battement de la nappe n'influence pas l'état hydrique proche de la surface, alors qu'une modification de l'humidité relative de

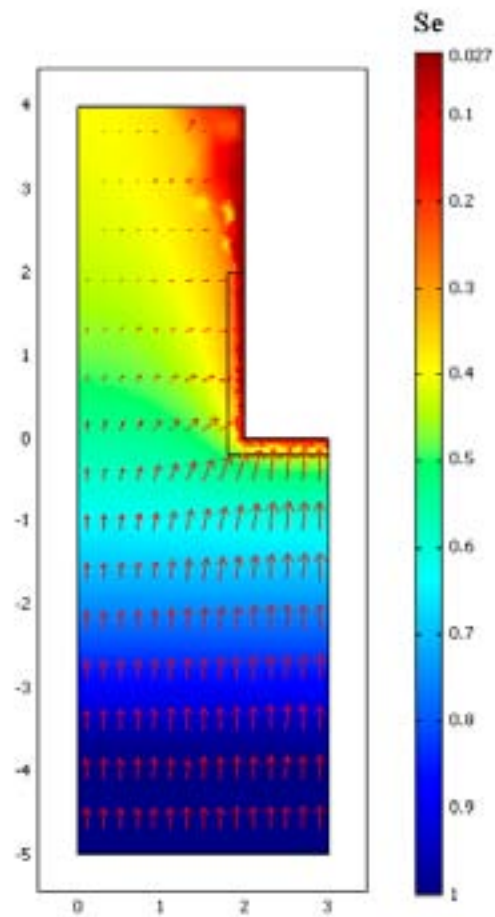


FIGURE 7 Vue en coupe du taux de saturation en eau (couleur) et visualisation des flux d'eau liquide (flèches) dans le sol et le mur. Ce résultat de simulation montre un assèchement important du haut du mur et de la surface proche. Le flux d'eau de la nappe vers l'atmosphère est clairement dévié vers la base du mur, ce qui est conforme aux observations.
© LTHE

l'atmosphère déplace la zone d'évaporation de l'eau. La zone préférentielle d'évaporation de l'eau dans le mur correspond à la position du sillon de dégradation.

Des images et analyses élémentaires faites au microscope électronique à balayage sur des échantillons de terre prélevés dans la zone dégradée du mur montrent la présence de cristaux de sel (fig. 8). Il est probable que ces cristaux de halite (NaCl) contribuent à la perte de cohésion du matériau, et donc à la dégradation du mur. Modéliser le transport du sel est une perspective majeure de ces travaux. L'objectif sera de quantifier les flux de sels vers la surface et par conséquent de localiser les zones de cristallisation du sel.

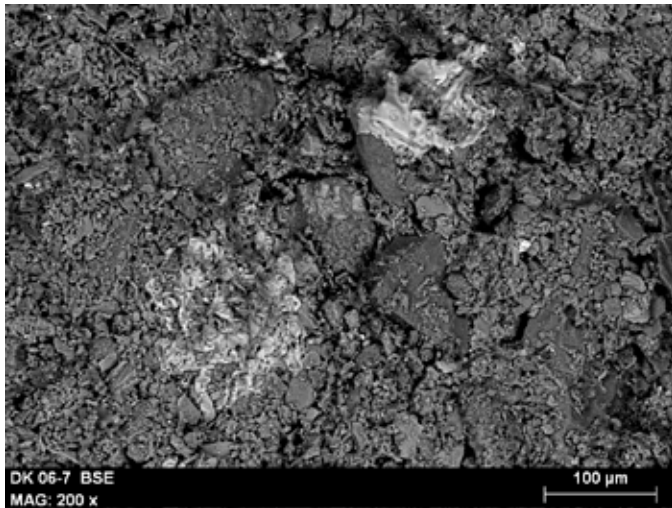


FIGURE 8 Observation au microscope électronique à balayage d'un échantillon prélevé dans le sillon de dégradation. Les analyses élémentaires effectuées par microsonde montrent que les zones qui apparaissent en clair sur cette photo sont riches en sel (chlorure de sodium). © LTHE

Remerciements

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Conserving Earth Structures in a Damp Climate

Tom Morton

Abstract: Decay patterns of earth structures in northern Britain and appropriate methods for their conservation and repair relate to a damp climate, where freeze/thaw cycles and flooding are significant hazards. Another threat is the cultural context, where vernacular earth construction died out about 150 years ago. Recent experience with three monolithic earth-walled buildings highlights two key issues: first, the challenge of understanding the complex weathering patterns that result from microclimatic exposure, varied historic construction techniques, periods of neglect, and inappropriate repairs; and second, the challenge of specifying appropriate lime- and clay-based renders to protect degraded earth walls.

Résumé : Il est traité de la détérioration des structures en terre dans le Nord de la Grande-Bretagne et des méthodes appropriées de conservation et de réparation tenant compte d'un climat humide où les cycles de gel/dégel et les crues constituent des risques importants. Le contexte culturel – avec la disparition de la construction vernaculaire en terre il y a 150 ans environ – constitue une autre menace. L'expérience récente menée sur trois bâtiments monolithiques aux murs en terre permet de dégager deux questions essentielles : premièrement, la difficulté de comprendre les phénomènes complexes de dégradation due aux intempéries par exposition au microclimat, les différentes techniques de construction au cours de l'histoire, et les périodes d'abandon et de réparations inadaptées ; deuxièmement, la difficulté de prescrire des enduits appropriés à base de chaux et de terre pour protéger les murs en terre dégradés.

Northern Britain has a diverse heritage of vernacular earthen buildings that is very scarce but increasingly valued by the conservation community (fig. 1). Efforts to protect this heri-



FIGURE 1 The Schoolhouse, Cottown: An early mud wall conservation project.

tage are faced by challenging climatic conditions and a complete loss of traditional knowledge about earth construction. The northern half of Britain has a complex geology and physical geography. Clays are mainly illites of glacial and marine origin. This geophysical complexity, combined with associated climatic variation, resulted in an unusually rich diversity of distinct regional vernacular earth construction techniques.

These local traditions all developed to use materials that were available at low cost in the immediate area and could create durable structures with little effort. A high construction quality and building performance were only achieved by the development of building skills and materials knowledge that were specific to a local area, its climate, and natural resources.

Having developed over more than 6,000 years, these regional earth building traditions died out as Britain

industrialized between 250 and 100 years ago, a period that saw deep cultural and social changes and wide-scale replacement of the building stock. Old buildings were abandoned or demolished, and new buildings were constructed in new ways. Industrialized construction methods and materials replaced traditional means, while distribution by the expanding railway network gradually erased the historic geographic isolation of construction skills and reduced the cost of moving materials.

While the logical necessity of a local character to vernacular building methods was negated by the introduction of a “modern” construction industry, social changes also devalued the cultural appeal of traditional ways of building. Earth buildings came to be seen as the product of poverty, not the product of progress, the image of modernity to which people aspired. Ways of building that had lasted for millennia were rapidly abandoned and the buildings they had created demolished or concealed behind modern facing materials.

By the late twentieth century there had not been any earth building in northern Britain for many generations, and knowledge of traditional earth building methods had been completely lost. Surviving earth buildings were increasingly scarce and in very poor condition. The cultural significance of earth materials in the history of vernacular construction was not recognized, the physical record was not documented, and there was no understanding of how to conserve what remained.

The tide turned in the late 1980s. Over the past twenty years there has been increasing recognition of the rich heritage of earth construction, a greater understanding of traditional materials and techniques, and the development of appropriate methods of conserving the buildings that have survived. A key aspect of this work has been to understand the local character of the weather, which is temperate maritime, dominated by wet winds from the Atlantic, and its effect on earth buildings. Annual rainfall in Scotland varies between 600 and 4,500 millimeters, with a maximum of 238 millimeters recorded in one day and an average of more than 250 rain days per year. So in some places it is persistently wet and in others relatively dry.

Scotland is the windiest place in Europe, with some places having more than fifty days of storm-force winds per year, so wind-driven rain can be severe, especially on west-facing walls.

The maximum recorded daily temperature is 23.9°C and the lowest, -27.2°C. There are commonly around 150 days of ground frost per year inland. This means that damp materials often vary diurnally in temperature around 0°C, making freeze/thaw cycles a significant hazard. Humidity is

generally high, commonly ranging between 65 and 90% RH, which means that the air is often damp and earth materials slow to dry.

A practical problem is that repairs materials have to be made indoors and take about three months to dry. Mold can affect wet materials. With a huge regional variation, microclimatic analysis of individual sites is very important.

In an effort to develop a better understanding of traditional materials and techniques, Historic Scotland initiated the Earth Structures, Renders & Plasters (ESRP) research program. More than 230 field tests of different materials in different climatic conditions were undertaken and monitored for over seven years, between 1996 and 2004. Materials tested included earth, straw, flax, hay, hair, dung, manure, lime, wood shavings, seaweed, ash, oil, tallow, whey, lanolin, urine, and blood.

A full report is awaiting publication by Historic Scotland; in the meantime, a summary can be downloaded from our Web site.¹ The program reached three key conclusions.

1. Traditional methods were well suited to the climate and local materials; imported materials and techniques did not perform as well.
2. Particle size distribution was the key factor affecting the durability of exposed earth materials. Well-graded materials, for example, earth renders, proved remarkably durable (fig. 2), while a poorly graded material would always decay, no matter what other additives were used.
3. Lime-based finishes demonstrated an underlying incompatibility to earth substrates, commonly suffering failure through loss of bond (fig. 3). The means of preparation and application did not make a significant difference to performance. A variety of traditional additives were tested but had only a minor effect on workability and durability. The one notable exception was the lime/whey render, which performed very well, seeming to be more flexible to differential hygrothermal movements.

While the lime coatings suffered failure, they did not damage the earth substrate, merely giving it sacrificial protection for a period of between two and seven years. This reflects the relatively compatible vapor permeability characteristics of the two materials and was in dramatic contrast to the tests of cement renders (fig. 4). This was a significant finding, as lime renders were a common traditional finish, frequently



FIGURE 2 ESRP earth-rendered wall: showing only washing away of surface fines after seven years of exposure.

used in restoration projects. It was subsequently reinforced by evidence of minor lime render failures from other conservation projects. Similar failures have also been reported in other climatic conditions, such as Italy (Stazi 2003). This finding instigated a more detailed investigation of specifications for suitable finishes on earth buildings.

Alongside the issues commonly encountered in conserving earth structures around the world, such as decay caused by animals, four key aspects characterize the conservation of earth structures in northern Britain.

1. Understanding the building's history: diagnosing decay and predicting performance. Because the earth structures that have survived are typically of low status and value, they rarely have any documented history. A limited understanding of the construction chronology can be gained from historic maps and historic descriptions of traditional construction practices from the area. A good example is a description recorded a few years before the construction of the Logie Schoolhouse, one of the last vernacular earth buildings built in Angus:

In some parts of the county where stones are scarce, cottages and even small farmhouses, are frequently



FIGURE 3 ESRP lime-rendered wall: showing loss of bond but not damage to the earth wall.



FIGURE 4 ESRP cement-rendered wall: showing major damage that subsequently led to collapse of the wall.

built with clay, which is wrought and mixed with straw. . . . [T]he clay is laid in alternate layers, smoothed and allowed to dry in the air. Such buildings, if in a dry situation, are very warm and comfortable, and if white-washed, they may even be rendered elegant . . . and are commonly covered with thatch, fastened to the rafters by cords. The roof is made to project somewhat over the walls in order to throw the water off them, which would wash down the clay. (Headrick 1813: 129–30)

While care has to be taken in directly applying historic descriptions to an individual building, there seems to have been little variation within local traditions, and the types of buildings that survive tend to be typical examples. Surviving earth buildings have commonly been altered several times and a careful examination of the physical fabric and any historic photographs is needed to appreciate the chronology of their construction and decay.

2. *Inappropriate repairs.* Where earth buildings survived because of continued use, the uses were for economically marginal activities, and as a result the buildings were poorly maintained and inappropriately repaired. Typically, hard materials, such as cement and fired brick, were used, encouraging sacrificial decay of the earth and progressive weakening of the structure. By the time a conservation project is instigated, structural integrity is often compromised, and a carefully sequenced program of stabilization and repairs is required to replace the inappropriate materials.

3. *The effects of high moisture content.* High moisture levels are a key factor in most decay mechanisms. While it is easy to construct durable earth buildings suited to this climate if they are well built and maintained to a good standard, the intimate dance that all clay-bound materials conduct with moisture is easily thrown out of balance by the poor maintenance and inappropriate alterations that these old buildings have experienced.

High moisture levels in earth walls are commonly caused by leaking roofs and gutters and rising damp and are exacerbated by the common application of cement renders, which crack, allowing wind-driven rain in, but prevent moisture from evaporating. The results are as follows:

- a) *Rotting of the straw component*, which reduces tensile strength, exacerbating structural movements and cracking. The extent and distribution of rotted straw is a useful indicator in assessing the condition and stability of a wall.
 - b) *Animal-induced decay* is encouraged.
 - c) *Growth of plants*, whose roots pull materials apart and turn earth into soil.
 - d) *Rotting of timber lintels.* At normal moisture levels below about 15 percent, the earth materials will wick moisture away from timber components, assisting their preservation. But at high moisture levels, the timber elements will decay, potentially leading to more serious failures.
 - e) *Salt migration.* This is usually a relatively minor problem, but it can damage internal finishes and lead to significant decay of earth at the base of a wall.
 - f) *Loosening of secondary fixings and finishes*, for example, of internal timber facings or renders.
 - g) *Slump* and ultimately collapse of the wall, if moisture levels reach the plastic and liquid limits.
4. *Resisting ground moisture.* Unsurprisingly, it is a common characteristic of earth buildings that they are built on areas of clay-rich subsoil that does not drain well and is prone to moving as a result of changes in groundwater levels and other factors. Earth buildings commonly have shallow foundations, heavy walls subjected to outward thrust, and low tensile strength and are vulnerable to moisture. This is not a good combination.
- Rising damp in walls was commonly reduced by a masonry plinth. This, however, creates a zone where the base of the earth material is vulnerable to sacrificial decay, especially if there is a strong rising damp or, more commonly, moisture moving down in the wall from other points of ingress.
- The extreme danger presented by ground moisture is flooding. On at least three occasions over two years, the Cottown Schoolhouse was flooded to about 600 millimeters above ground level for periods of a week. This resulted in detachment of the lime render and damage to the earth walls, including significant slump as the outer wall base softened more than the inner; rotting of straw; and shrinkage cracking from wetting/drying cycles and possibly freeze/thaw. We investigated the known flood risk and precipitation patterns without identifying a cause.
- Investigation of the ground conditions showed that there was an unusual, local, shallow deposit of impermeable clay over the well-draining sandy clay, which meant that the ground was very slow to drain excess surface water. Critically, the excavations showed that there had been no movement of the foundations but that all the wall movement had been due to the softening of the earth wall above. Therefore, in this case, complicated and expensive underpinning was unneces-

sary. When repair of the flooded earth wall was undertaken, the particle size grading of the earth blocks was carefully specified, so that higher porosity would make them less vulnerable to the effects of flooding.

5. *Achieving durable external finishes.* Where earth buildings have not been faced with brick, they have often been rendered with a sand/cement mix. The buildup of moisture that results causes many problems, including decay of the earth wall surface layer as the straw rots and the earth is subjected to increasingly severe wetting and drying and freeze/thaw cycles and possibly clay leaching. The material weakens as its internal clay bonds are lost and its surface bond to the stiff cement render fails.

A different problem seems to occur with lime renders. Here strong initial suction allied to later differential hygro-thermal movements appears to result in a weakening of the lime undercoat, causing loss of bond to the earth substrate, though the lime topcoat surface remains in good condition, especially if regularly limewashed (fig. 5). Where an earth wall is just limewashed, rather than rendered, there does not seem to be the same problem, as burnishing in the limewash creates a more flexible composite lime/clay interface layer.

In formulating suitable external finishes for earth walls that have been degraded by cement renders, the earth wall face material can be significantly different. At Moorhouse the large stones and straw banding provided a good mechanical key (fig. 6), while at Cottown the silty material of the cob (or mud



FIGURE 5 Cottown Schoolhouse: the lime base coat has lost coherence, while the topcoat and limewash remain sound.



FIGURE 6 Moorhouse Washhouse: removal of cement render revealed a coarse mud wall with lines of straw layers.



FIGURE 7 Cottown Schoolhouse: the surface was highly degraded, silty, very friable, and lacking in stones or straw.

wall) was highly degraded and first had to be stabilized with limewater (fig. 7). This was followed by a 40-millimeter-thick lime-stabilized clay undercoat, then by a traditional two-coat lime harl, about 10 millimeters thick in total, and seven coats of limewash (fig. 8). We were unable to source suitable whey as an additive.

This render coat is not attempting to replicate the original but rather is our best attempt at a durable long-term sacrificial coating to the original fabric of the earth wall, whose



FIGURE 8 Cottown Schoolhouse: application of the final limewash.

preservation was our priority, while maintaining the original appearance. For new work, or where there is no clear evidence of a lime finish as at Logie, I would prefer to avoid the problems of differential movement created by lime renders and rely on closely specified and well-detailed earth renders, possibly with limewash. The main preservation problem is consistently the compatibility of different materials rather than surface erosion.

We have three objectives in our work on the historic earth buildings in northern Britain: to increase our technical

knowledge, to stimulate public appreciation, and to conserve key examples of regional types. In conserving and understanding the cultural significance of these vernacular earth buildings, we recognize that the design holism, environmental sustainability, and cultural distinctiveness they embody have a growing relevance to contemporary nontraditional earth building.

These earth buildings are not architectural masterpieces; they are humble buildings that express a people's closeness to their environment. In an international context, I hope that our efforts to value a lost earth building heritage and its fostering of contemporary earth buildings sends signals of support to our colleagues in other countries who are working to protect their own, often more significant living traditions, all too often from forces of cultural change very similar to those that we experienced in previous centuries.

Notes

- 1 www.arc-architects.com/research/The-ESRP-Project.htm.

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Justification for the Combination of Organic and Inorganic Stabilizers to Stabilize Traditional Earth Materials (Mud) for Quality and Capacity Utilization in Africa

N. A. Nwankwor

Abstract: *Earth building is an ancient tradition in several African countries. Through years of practice and experience, several changes and additions have been made to traditional earth building techniques and materials to improve their quality. Two types of additives—organic and inorganic—are commonly used. This research, which tested and analyzed the earth material stabilized with various combinations of cement, rice husk ash, and straw, revealed significant improvements in the quality of the earth material for higher-capacity utilization in earth building.*

Résumé : *La construction en terre est une tradition ancienne dans plusieurs pays africains. Des années de pratique et d'expérience ont amené à modifier et compléter les techniques traditionnelles de construction en terre et les matériaux afin d'en améliorer la qualité. Deux types d'additifs – organiques et inorganiques – sont communément utilisés. Cette recherche, qui a testé et analysé le matériau terre stabilisé avec différentes combinaisons de ciment, cendre de balle de riz, et paille, a révélé des améliorations significatives de la qualité du matériau terre permettant de mieux utiliser ses capacités dans la construction en terre.*

Traditionally in Africa, earth building materials have been stabilized to improve their strength, water resistance, and durability. Early conventional methods of improvement, which included choosing different soil types and adding straw, cow dung, and other locally available additives, were developed over many years of practice and experience. Between the 1950s and the 1960s mechanized earth block molding machines were used to produce more stable blocks with uniform sizes, shapes,

and surface texture, as well as to increase manufacturing efficiency (Maini 2002). This gave birth to compressed stabilized earth blocks (CSEBs), the use of which is gradually gaining ground in several African countries. Compressed stabilized earth blocks take advantage of new technologies in the construction industry and traditional construction practices, and in doing so improve the quality, economy, and flexibility of earth buildings.

In Africa a wide range of additives have been used to stabilize earth for building purposes, including straw, a postharvest waste product that is cheap and readily available in many communities. Cement and lime are frequently used as stabilizers and are available at predetermined market prices. Rice husk ash, a new biofiber by-product of paddy rice (cultivated in many African countries), is being studied for use as a stabilizer (Ou, Xi, and Corotis 2007). When the rice husk is burned under controlled temperatures, it produces a high-silica amorphous compound that can be added to the earth material to improve its performance. When this high-silica amorphous compound combines with calcium hydroxide, its reaction is similar to that of other common pozzolans. Commonly, heaps of rice husks are left to waste away in many rice production communities, so their use as additives incurs only negligible additional cost to the end users.

Material Selection and Preparation

This paper presents the results of a laboratory test program on the combination of organic and inorganic stabilizers to improve the performance of compressed stabilized earth blocks and increase their capacity utilization for earth building

works at negligible extra cost. Throughout this study a well-graded clayey, red soil was used. It was collected from an existing soil pit from the university neighborhood, which is still in use by local earth builders. A particle size analysis of the soil yielded results of 10.2% lateritic gravel, 53.8% sand, 28.4% clay, and 7.6% silt with other impurities.

The inorganic stabilizers, cement and lime, were purchased from local vendors. The organic stabilizers, rice husk ash and straw, were acquired locally and prepared by the researcher. The rice husk from which the ash was produced was purchased from a public rice mill near the campus. The rice husk was burned in a locally fabricated “drum-kiln” at temperatures between 480°C and 530°C for each drum load. The burning and cooling conditions were controlled throughout the production process. It took an average of four and a half hours for each drum to burn completely, producing an average of 8.60 kg of rice husk ash. The rice husk ash was ground to a fine powder with a blender to approximately 25 μ .

The straw was collected from open farm fields near campus. The collected bundles were screened to remove unwanted particles such as nonstraw, broad-leafed grasses and mud. The screened straw was cut down to lengths of approximately 3 to 6 cm.

Specimen Production

A laboratory-based experimental approach was adopted for this study to ensure that the results are easily replicable and useful for practical community housing projects in Africa. All the materials for this experiment were dry-batched by weight at the various mix points. Three laboratory tests—compressive strength, water erosion resistance, and acid (sulfate) attack resistance—were conducted on the specimen, on separate days to ensure proper labeling and accuracy of the measurements.

Water was added to the straw-earth mix and left overnight to allow for adequate fiber impregnation of the mix. The straw-earth matrix was properly mixed after the fiber impregnation and molded into blocks using a manually operated block-molding machine. For the lime-earth mixtures, quick lime purchased from the market was slaked for at least twenty-four hours before use. Clean drinking water was added to all the mixes until the desired workability was achieved.

Eighty-one CSEBs were produced for this study. The locally fabricated block-molding machine, delivering an average of 38 N/mm² compression impact, was used. The weight and dimensions of each block were taken immediately after

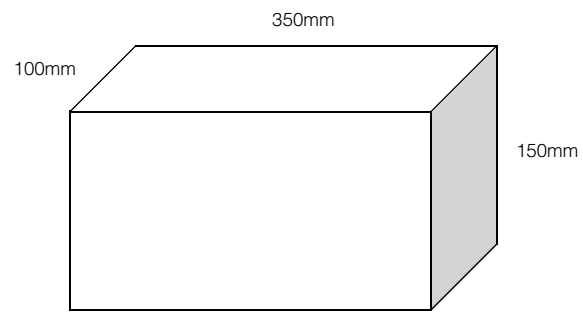


FIGURE 1 Specimen earth block.

removal from the mold, and then at seven and twenty-eight days. All the blocks were wet cured for seven days and dried on an open platform for twenty-one days. A simple drop test (the process of dropping each of the specimen blocks from an average height of 1 m above the ground) was used to select twenty-seven sample blocks for the experiment. One block from each of the different mixes was selected. The specimen blocks measured 100 × 150 × 350 mm, which is the normal earth block size within the locality (fig. 1).

Testing Instrument and Materials

Compressive strength test. A medium-strength cube-crushing machine was used for measuring each sample's compressive strength. Results were calculated following standard formulas.¹

Water erosion test. The sprayer used for this test was custom-made, incorporating some of the features used by Crytryn (1957), Wolfskill, Dunlop, and Callaway (1970), and Heathcote (1997). This modified instrument consists of a 15° angled lance with a 100-mm-diameter nozzle on a rotating coupler. A 12.5-mm-diameter water hose is attached to the lance and to a hydraulic water pump with water pressure between 50 and 120 kPa. This modified sprayer can be set to deliver water at any angle. For the water erosion test, the sprayer was adjusted to a height of 200 mm on the vertical axis and 450 mm horizontal relative to the surface of the samples. The spray velocity was approximately 12.0 m/sec. discharging about 51 droplets per second. The droplet size was estimated to be approximately 2.5 mm due to the size of the nozzle holes at 2 to 3 mm diameter. The rotating sprayer nozzle, based on Heathcote (1997), was incorporated to create a turbulence resembling natural rainfall.

Acid resistance test. A large plastic container and 10% diluted sulfuric acid were the basic items for the acid resistance test.

Experimental Procedure

Three sample cubes from each of the twenty-seven mixes were subjected to the compressive strength, water erosion resistance, and sulfuric acid resistance tests. Each of the twenty-seven block samples was cut into three equal-sized cubes measuring $100 \times 110 \times 150$ mm each.

Compressive strength test. One cube from each of the twenty-seven samples was subjected to a standard cube-crushing test using a medium-strength cube-crushing machine. The cubes were sandwiched between two smooth hardwood surfaces to avoid direct contact with the metal surface of the machine, which could cause unwanted surface breakdown (unwanted or avoidable wearing out of the block surfaces as a result of direct contact with the metal surfaces) of the samples. Crushing weights were applied at 15 kg until each of the cubes crumbled or disintegrated under load. The readings were recorded and calculated accordingly.

Erosion resistance ratio. Another set out of the twenty-seven sample cubes was placed in turns on a clean platform. One face of the sample cube was placed under the vertically inclined spray at 70 kPa for 120 minutes. This delivered a total of 7,500 mm spray on the surface of the sample cube, which is equivalent to the strongest driving rain in Nigeria (over a six-year period). The sample was removed, dried, and measured to ascertain the depth of wear. The dried sample was also weighed to measure the difference in precipitation (mass loss). The second face of the sample was subjected to a horizontal spray test for another 120 minutes. The block sample was again dried and measured similarly. (See calculated mean values² as presented in table 2.) These results are presented in ratios indicating the percentage of precipitation/mass loss over time as a result of the water spray as compared to the original block size/weight.

Acid resistance test. One cube from each of the twenty-seven samples was soaked in a 10% sulfuric acid solution for six hours. The cubes were then removed from the solution and allowed to drip-dry. The weight of each cube was taken before and after soaking. The percentage of disintegration was calculated accordingly as the loss of mass.³ Following this, the same sample cubes were soaked a second time for twelve hours and measured. The group means for the six-hour and twelve-hour test readings are presented in table 2.

Analysis of the Results

The results of the experiments revealed that different stabilizer combinations can improve the quality of the earth blocks in different ways and that changes in the proportion of the constituent materials affect the characteristics of the end product. A combination of rice husk ash (organic stabilizer) with cement or lime (inorganic stabilizers) produced stabilized earth blocks of compressive strengths above the minimum standard (2.07 Mpa or 300 psi; NMSBBC 2003) and erosion resistance qualities higher than the acceptable minimum ratio of 10 (Crytryn 1957). It also produced blocks within acceptable range of sulfuric acid resistance of 25% (Mbata 1993) (see experiments 1, 3, 5, 6, and 7). The results also indicate that the acid resistance of the blocks is reduced as the proportion of the straw (a highly cellulose- $[C_5H_{10}O_5]$ and hemicellulose-based compound with a good percentage of alcohol-benzene solubility and polymer phenol $[C_7H_{10}O_3]$) (Charoenvai et al. 2005) content is increased in each matrix, except in experiments 7 and 9, where the addition of lime and rice husk ash (a pozzolan) appears to have achieved some measure of success in reducing the alkaline attack of the cement environment on the cellulose fibers of the straw material. A major advantage of combining straw with other stabilizers is the increase in mechanical strength. In experiments 7 and 9, the addition of rice husk ash reduced the alkaline effect of the straw as calcium hydroxide (formed during hydration) reacts with the silica present in the rice husk ash, making a strong, more durable earth block. This development occurs as a result of the chemical reaction between the reactive silica in the rice husk ash and the calcium hydrate compounds to form calcium silicate hydrates, which also lowered the alkalinity in the composite material of the straw-rice husk ash matrix (Shafiq 1988). Through this interaction the dangers of alkaline composite pore water effect in the fiber (straw) stabilized earth blocks was reduced.

A summary of the results (expressed as mean values) for compressive strength, erosion, and acid resistance is presented in table 2 and further illustrated in figure 2.

Discussion of the Test Results

Through quality selection of organic and inorganic stabilizers at certain proportions there can be a major improvement in the functional and structural qualities of the compressed stabilized earth block in terms of compressive strength, erosion resistance, and acid attack resistance. As demonstrated in tables 1 and 2, experiment 7-iii shows relatively high erosion

Table 1 Details of experimental results

EXPERIMENTS	MIX PROPORTIONS	MEAN VALUES OF VARIABLES INVESTIGATED			REMARKS
		Compressive Strength	Erosion Resistance Ratio	Acid Resistance	
Group 1 [Cement:Rice Husk Ash:Earth]	i. Mix Proportion [%] – 5:20:75	3.34	7.7	18.0%	Experiments 1 and 2 investigated a combination of each of the organic and inorganic stabilizers to stabilize the earth blocks. The results demonstrate an improvement in the compressive strength, erosion resistance, and acid resistance of the cement–rice husk ash–stabilized blocks as the percentage of the rice husk ash increased.
	ii. Mix Proportion [%] – 5:25:70	4.07	6.4	27.0%	
	iii. Mix Proportion [%] – 5:30:65	4.69	5.3	32.3%	
Group 2 [Cement:Straw:Earth]	i. Mix Proportion [%] – 5:20:75	4.49	6.5	28.1%	The cement–straw–stabilized blocks show a complete reverse in the behavior pattern, compared to the cement–rice husk ash–stabilized blocks with a proportionate decrease in the compressive strength, the erosion resistance quality, and the acid resistance capacity of the cement–straw–stabilized blocks as the straw content increased.
	ii. Mix Proportion [%] – 5:25:70	3.83	7.3	21.8%	
	iii. Mix Proportion [%] – 5:30:65	3.24	7.9	18.6%	
Group 3 [Lime:Rice Husk Ash:Earth]	i. Mix Proportion [%] – 5:20:75	2.67	8.3	17.8%	In the second set of experiments testing a combination of lime with rice husk ash and lime with straw in experiments 3 and 4, behavior characteristics similar to those in experiments 1 and 2 were recorded.
	ii. Mix Proportion [%] – 5:25:70	3.82	7.3	22.1%	
	iii. Mix Proportion [%] – 5:30:65	4.24	7.0	26.5%	
Group 4 [Lime:Straw:Earth]	i. Mix Proportion [%] – 5:20:75	3.28	9.1	23.5%	The three variables of the lime–rice husk ash–stabilized blocks improved at reduced levels. The effect of increases in the straw content was further amplified in the lime–straw–stabilized blocks of experiment 4 for all three variables investigated. The erosion resistance ratio of experiment 4–iii was outside the acceptable ratio of 10.
	ii. Mix Proportion [%] – 5:25:70	2.91	9.9	18.4%	
	iii. Mix Proportion [%] – 5:30:65	2.62	11.0	15.8%	

Table 1 (continued)

EXPERIMENTS	MIX PROPORTIONS	MEAN VALUES OF VARIABLES INVESTIGATED			REMARKS
		Compressive Strength	Erosion Resistance Ratio	Acid Resistance	
Group 5 [Cement:Rice Husk Ash: Straw:Earth]	i. Mix Proportion [%] – 5:10:10:75	3.62	7.0	30.8%	The interactive effect of the combination of the cement and the other two organic stabilizers showed up in improvement in the compressive strength and erosion resistance qualities with a corresponding reduction in the acid resistance capacity of the earth blocks stabilized with cement–rice husk ash–straw as against those stabilized with single organic and inorganic stabilizers, above.
	ii. Mix Proportion [%] – 5:12.5:12.5:70	4.77	6.7	25.0%	
	iii. Mix Proportion [%] – 5:15:15:65	5.88	6.2	18.6%	
Group 6 [Lime:Rice Husk Ash: Straw:Earth]	i. Mix Proportion [%] – 5:10:10:75	2.86	6.2	25.4%	The behavior patterns of the three variables in experiment 6 show a closer association with those of cement–rice husk ash–stabilized earth blocks. The values of the three variables improved as the proportions of the rice husk ash and straw increased in the matrix.
	ii. Mix Proportion [%] – 5:12.5:12.5:70	3.58	6.8	21.3%	
	iii. Mix Proportion [%] – 5:15:15:65	4.70	8.2	16.5%	
Group 7 [Cement:Lime:Rice Husk Ash:Earth]	i. Mix Proportion [%] – 2.5:2.5:20:75	4.05	5.9	26.2%	In experiment 7 the combination of the two inorganic stabilizers—cement and lime—demonstrates a remarkable improvement in compressive strength, erosion resistance quality, and acid resistance capacity of the stabilized earth blocks as the rice husk ash content increased in the mix.
	ii. Mix Proportion [%] – 2.5:2.5:25:70	5.53	5.1	31.8%	
	iii. Mix Proportion [%] – 2.5:2.5:30:65	6.38	4.8	36.3%	
Group 8 [Cement:Lime:Straw:Earth]	i. Mix Proportion [%] – 2.5:2.5:20:75	4.67	6.8	28.7%	The result of the test also shows an improvement in the values of the three variables but at lower degrees compared to the earth blocks stabilized with cement–lime–rice husk ash as the straw proportion increased.
	ii. Mix Proportion [%] – 2.5:2.5:25:70	4.12	7.2	23.8%	
	iii. Mix Proportion [%] – 2.5:2.5:30:65	3.29	7.6	19.8%	
Group 9 [Cement:Lime:Rice Husk Ash:Straw:Earth]	i. Mix Proportion [%] – 2.5:2.5:10:10:75	3.94	6.0	38.7%	The result of experiment 9 demonstrates that there is no significant improvement in the values of the three variables to warrant a combination of the four stabilizers in any given mix for stabilized earth block production.
	ii. Mix Proportion [%] – 2.5:2.5:12.5:12.5:70	4.86	7.6	32.0%	
	iii. Mix Proportion [%] – 2.5:2.5:15:15:65	5.56	7.9	29.6%	

Table 2 Summary of results from the experiments

EXPERIMENTS	MEAN VALUES OF VARIABLES INVESTIGATED		
Experimental Groups	Compressive Strength	Erosion Resistance Ratio	Acid Resistance
Group 1 [Cement:Rice Husk Ash:Earth]	3.34	7.7	18.0%
	4.07	6.4	27.0%
	4.69	5.3	32.3%
Group 2 [Cement:Straw:Earth]	4.49	6.5	28.1%
	3.83	7.3	21.8%
	3.24	7.9	18.6%
Group 3 [Lime:Rice Husk Ash:Earth]	2.67	8.3	17.8%
	3.82	7.3	22.1%
	4.24	7.0	26.5%
Group 4 [Lime:Straw:Earth]	3.28	9.1	23.5%
	2.91	9.9	18.4%
	2.62	11.0	15.8%
Group 5 [Cement:Rice Husk Ash:Straw:Earth]	3.62	7.0	30.8%
	4.77	6.7	25.0%
	5.88	6.2	18.6%
Group 6 [Lime:Rice Husk Ash:Straw:Earth]	2.86	6.2	25.4%
	3.58	6.8	21.3%
	4.70	8.2	16.5%
Group 7 [Cement:Lime:Rice Husk Ash:Earth]	4.05	5.9	26.2%
	5.53	5.1	31.8%
	6.38	4.8	36.3%
Group 8 [Cement:Lime:Straw:Earth]	4.67	6.8	28.7%
	4.12	7.2	23.8%
	3.29	7.6	19.8%
Group 9 [Cement:Lime:Rice Husk Ash:Straw:Earth]	3.94	6.0	38.7%
	4.86	7.6	32.0%
	5.56	7.9	29.6%

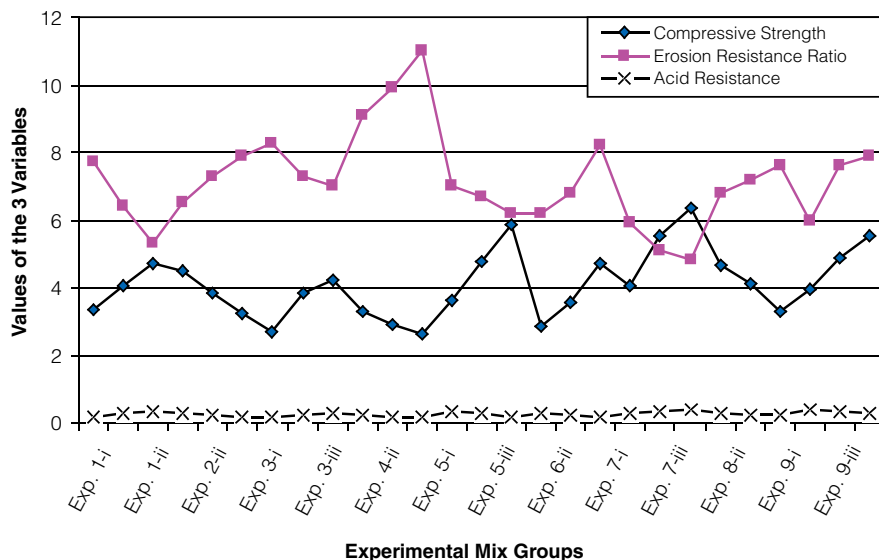


FIGURE 2 Graphic representation of the behavior pattern of the three variables: compressive strength, erosion resistance ratio, and acid resistance of the compressed stabilized earth blocks based on stabilizer combinations/proportions.

resistance at 4.80 (better than the acceptable minimum ratio of 10, with a significant measure of compressive strength at 6.38 Mpa (almost thrice the minimum standard of 2.07 Mpa or 300 psi; NMSBBC 2003) and an acid attack resistance at 36.30% (better than the minimum acceptable; Mbata 1993). On the other hand, the results in experiment 4-iii (tables 1 and 2) give an earth block with a comfortable compressive strength of 2.62 Mpa (above minimum standard, 2.07 Mpa), an acid attack resistance at 15.8%, and a weak erosion resistance ratio of 11.00. These two mixes are very different. While the mix in experiment 7-iii will produce quality earth blocks, that in experiment 4-iii is not recommended for quality earth buildings, especially on soils with the possible presence of sulfuric acid. Experiment 6-iii is also not recommended for any quality earth building works as a result of its not-too-good erosion resistance and weakness against sulfuric acid attacks.

Recommendations

The results of our tests provide evidence that the structural and functional qualities of compressed stabilized earth blocks can be improved by combining locally produced, inexpensive organic stabilizers with market-supplied inorganic stabilizers. Based on the results, this researcher recommends the following:

1. A combination of cement, lime, and rice husk ash, at a proportion of 2.5:2.5:30 percent [1:1:12], to produce high-strength and erosion- and sulfuric-acid resistant compressed stabilized earth blocks.

2. In areas where rice husk ash is not available, a combination of cement, lime, and straw at a mix proportion of 2.5:2.5:20 percent [1:1:8] is recommended to produce compressed stabilized earth blocks for normal-strength single-story earth buildings.
3. In areas where both rice husk ash and straw are readily available, a combination of all four stabilizers does not demonstrate any significant improvement of the block qualities to encourage such combinations (see experiment 9, table 1).
4. There is need for caution in the selection and combination of the stabilizers as well as choosing appropriate mix proportions to obtain quality stabilized earth blocks.
5. A field test of the findings based on the recommended stabilizer combinations, at the prescribed mix proportions, from this experiment, is necessary to confirm and validate these laboratory results and for real-world application.

The outcome of this experiment is encouraging for the improvement and growth of the use of earth materials to build high-quality, low-cost housing in Africa.

Notes

1. *Compressive Strength* (α) is expressed as total load at crushing moment/square area of contact, or N/mm².

Formula: $(\alpha) = \text{Mpa} \frac{\text{Crushing Load (N)}}{\text{Effective Surface Area (mm}^2\text{)}}$

[where Crushing Load = load at which the block crumbles/crashes; Effective Surface Area = the surface area of the block in direct contact with the hardwood surface on the crushing machine].

- 2 *Erosion Resistance Ratio (ERR)* represents a ratio of the rate at which the earth blocks precipitate (mass loss) under the water spray (simulated rainfall) over time.

$$\text{Formula: ERR } (\chi) = \frac{E_d}{T}$$

[where: E_d (Depth of Erosion) = $V_b - V_c$; V_b = volume of block before the water spray; V_c = volume of block after the water spray; T = total time of water spray (simulated rain)].

- 3 *Acid Resistance Capacity*, expressed in percentages, represents the degree to which the earth blocks can withstand the disintegrating effect of the simulated acid attack over time. It indicates the amount of mass loss as the block disintegrates under acid attack.

$$\text{Formula: Acid (Sulfuric) Resistance } (\beta) = \frac{M_b - M_c}{M_b} \times 100$$

[where: M_b = mass of block before soaking in the acid trough and drip-drying; M_c = mass of block after soaking in the acid trough for the specified time and drip-drying it; 100 = constant for percentages].

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Saliva de cupim: Recent Experiments with Termite Mound Soil and Termite Saliva as Stabilizers for Earthen Structures

Honório Nicholls Pereira

Abstract: *Since ancient times termite mound soil has been used as a soil amendment, with applications in agriculture, architecture, and engineering. Most recently the termites' expertise as "ecosystem engineers" has been the starting point for the development of industrial products used to stabilize roads, dams, and slopes. Some of these products are now available for commercial use in Brazil. This paper presents recent analysis and experiments with termite mound soil and various industrial products for the conservation of earthen architecture. These products are discussed in terms of their composition, suggested uses, ideal concentrations, additives, and application methods.*

Résumé : *Depuis les temps anciens, la terre de termitière est utilisée pour amender le sol, avec des applications en agriculture, architecture et ingénierie. Récemment, le savoir des termites, véritables « ingénieurs de l'écosystème » a servi de point de départ au développement de produits industriels utilisés pour stabiliser les routes, barrages et pentes. Certains de ces produits sont commercialisés au Brésil. Cette communication présente une analyse et des expériences récentes concernant la terre de termitière et différents produits industriels pour la conservation de l'architecture en terre. Ces produits sont abordés sous divers angles : composition, utilisations possibles, concentrations idéales, additifs et méthodes d'application.*

Termite Mound Soil

Termites are considered "ecosystem engineers" because they modify the environment, creating biogenic structures (galleries, sheetings, nests, mounds, and fungus-comb chambers) that change the physical and chemical properties of soils (Lavelle 1996). When building their mounds, termites aim to create

optimum environmental conditions for the growth of their colonies, providing good shelter and avoiding enemies, sunlight, and fluctuations in temperature and moisture content. Termites also aim to create adequate combs for the symbionts that live in their nests (fig. 1).

To reach these aims, termites alter the soil. The nature of these alterations varies from species to species and depends



FIGURE 1 An abandoned Macrotermitidae mound near Ségou, Mali. Photo: © Honório Nicholls Pereira

on the termite's feeding habits, the soil's physical and chemical properties, and other local factors such as groundwater level, rainfall regime, and drainage conditions. Termite workers are responsible for the mound building process (Grassé 1986). They generally use subsoil particles (Hesse 1955; Miedem and Van Vuure 1977), incorporating great amounts of clay, which improves soil aggregation (Lee and Wood 1971). They masticate the soil pellets individually with their buccal appendices and mandibles. During this process, workers cement soil particles with variable quantities of salivary secretions and fecal excrements. Salivary secretions are made of enzymes,¹ hydrocarbonates, and nondigested lignocellulose. Some termites also incorporate proteins into the rehandled soil. Termite feces are rich in organic matter (OM), organic carbon (C), and nutrients calcium (Ca), phosphorus (P), potassium (K), magnesium (Mg), and nitrogen (N). The addition of organic matter has an effect similar to that with the addition of clay: a higher micro-aggregation of the soil.

The introduction of fine particles, organic matter, and exchangeable cations results in the improvement of the cation exchange capacity (CEC), hence the improvement of aggregation and related properties. Termites may also introduce antibacterial and antifungal properties to the soil (Mahaney et al. 1999; Mobaek et al. 2005; Matsuura et al. 2007).

The physical and chemical properties of termite mound soil (TMS) have been researched. Termite mound soil has different, generally higher concentrations of calcium carbonate, organic matter, organic carbon, extractable cations, and nutrients when compared to the reference soil (RS).²

My own research with *Cornitermes cumulans* mounds in a clay-silt oxysoil showed different concentrations of the mentioned parameters on the top, base, and interior of the mounds compared to reference soil. Granulometric analysis showed that TMSs (top and interior) have a different granulometric curve, with more silt and less fine sand, while clay and coarse sand fractions remained unaltered (fig. 2).

Termite Mound Soil Applications

TMS has been used in agriculture since ancient times. The traditional chitemene agriculture in Tanzania is influenced by termite mound location (Mielke and Mielke 1982). Some termite species improve the pH and increase the amounts of organic matter and nutrients in the soil, thus improving crop production (Watson 1977; Fageria and Baligar 2004). Several experiments with TMS in engineering and architecture have been reported. Termite mound clay proved better than ordi-



FIGURE 2 A *Cornitermes cumulans* mound near Coromandel, Brazil. *C. cumulans* is considered a keystone species in Cerrado (Brazilian savanna). To build this mound, *C. cumulans* added silt and removed sand from the soil. In the mound top, K, N, and OM increased. In the interior, Al, CEC, and OM increased. Photo: © Honório Nicholls Pereira

nary clay for brick molding (Odumodu 1991) and to have better performance in dam construction (Yohanna et al. 2003).

TMS has higher plasticity when compared to ordinary clay. Bricks made with heat-treated termite mound clay were reported to be more resistant to weather, abrasion, and penetration of liquids. Termite mound clay has been used to fabricate heat-treated bricks for silo construction. Early results show the silos have good interior environmental conditions, with low temperature fluctuations and low moisture condensation (Adegunloye 2007; Mijinyawa et al. 2007).

C. cumulans mounds were examined in Rio Grande do Sul, Brazil, to determine if they meet Brazilian construction standards for external earthen floors. Dry resistance proved high due to the great concentration of fine clays. The soil from

the mounds' external surface met the regulations' requirements. It was not reported if the soil from the interior of the mound also met the regulations' requirements. The external surface of the mounds proved to have different granulometric composition than the reference soil, resulting in low humidity, good flocculation, and high resistance to erosion (Dávila et al. 2001).

To sum up, termite mound soil seems to be a good amendment for engineering and architecture applications if it has, when compared to the reference soil,

- higher proportion of fine particles;
- higher concentration of organic matter and/or organic carbon;
- higher concentration of nutrients and/or exchangeable cations.

These properties are usually found in soils modified by soil-feeding termites, but termites with other feeding habits may also modify the soil in the same manner.

***Saliva de cupim*: Industrialized Stabilizers and Their Characteristics**

Since the 1970s several studies have been carried out in Brazil to understand TMS properties. It has been used traditionally for earthen road construction due to its known gains in cohesion and impermeabilization. Some products emerged from these studies and are available for commercial use. Their formulations have organo-mineral compounds that improve soil cation exchange capacity, acting as natural cements and generating a stable cohesion between the soil particles (Ferreira and Freire 2001).

Due to space constraints, this paper discusses only experiments made with Brazilian products that resemble the termites' building process. This technology is popularly known as *saliva de cupim* (termite saliva). According to Brazetti (1998), the products that use this technology are DS-328® (Dynasolo), Dynacal® (Dynacal), Ecolopavi® (Idesa Amazônia), Homy Solo GB® (Homy Química), Moldezol 43® (Gienex), and VIXIL I® (Melbar). Other products made worldwide claim to use the same technology.³

These products have the following basic characteristics. They are ecologically sustainable, hydrophobic, water soluble, resistant to oxidation, resistant to microorganisms, applicable as a low-viscosity liquid and cost-efficient (Silva 2007). They are sold as liquids in barrels of 200 or 212 kilograms

and currently cost approximately R\$1,500/U.S.\$880 (in 2008). Recommended dosages are 1:1,000 to 1:2,000 (mass of product per mass of dry soil). Depending on the soil composition and the desired result, the producers also recommend the addition of aluminum sulfate, hydrated lime, or portland cement.

The proprietary formulations of these products are not publicized. It was suggested that their main components are sugarcane molasses (*Saccharum officinarum* L.), sulfonate oils, lignin, vegetal resins, silicates, and aluminates and calcium-iron-aluminates (Silva 2007). My personal research points to the presence of potassium silicates and organic compounds derived from carnauba (*Copernicia cerifera*), babaçu (*Orrbignya speciosa* (Mart.) Barb. Rodr.), mamona (*Ricinus communis* L.), and coconut (*Cocos nucifera* L.).⁴

Saliva de cupim technology has been extensively tested and used to enhance the performance of materials used in dams, roads, and airports. Good overall results were reported for cohesion, stability, impermeability, compaction, and erosion control (Sosa 1997; Vaillant et al. 1997; Brazetti 1998; Gregori and Sosa 2000). Tests were also conducted to determine if soils amended with saliva de cupim meet Brazilian standards for architecture. The results are promising for some soil-product mixtures, with enhancement in shear strength, cohesion, impermeabilization, and stabilization (Freire 1983, 1984; Ferreira and Freire 2001; Silva 2007).

Case Studies: Recent Experiments with Saliva de cupim

Saliva de cupim has recently been applied in architectural conservation. This paper summarizes two case studies: the restorations of Fazenda Jardim (Jardim Farm) and Igreja do Rosário (Rosário Church).

Fazenda Jardim

Fazenda Jardim is located in Jacareí, Brazil. The main building dates from 1693. Rammed earth and adobes were used as construction materials. The farm also has rammed earth ruins in the surroundings. Oikos Arquitetura restored the farm in 2004 under the responsibility of architect Raymundo Rodrigues.⁵ Saliva de cupim was used in the impermeabilization and stabilization of the ruins.

Saliva de cupim (in a 1:40 mass of product per mass of water ratio) and aluminum sulfate⁶ were combined and used as additives in the impermeabilization of the ruins. The mixture was sprinkled over the rammed earth walls. Also, a new mortar made with saliva de cupim was applied with

a bricklayer's trowel on the top of the walls to prevent water infiltration; the proportion of the mixture was not publicized. The results, both of the water repellent and of the capping, were reported by Rodrigues to be excellent, in terms of cohesion and stability.

Igreja do Rosário

Rosário Church is located in Pirenópolis, Brazil. It was built from 1728 to 1761 and was listed as a national monument in 1941. The construction technique is rammed earth, except for the towers, which are timber frame with adobe walls (fig. 3). Construtora Biapó restored the church in 1996–99.⁷ In 2002 a great fire almost destroyed the building. Another restoration took place in 2002–4, at which time the church was largely rebuilt (fig. 4).⁸

Saliva de cupim was used in the second restoration as a mortar additive to stabilize and impermeabilize the top of the restored rammed earth walls (the mortar proportion was not publicized) (fig. 5). Architect Paulo Sérgio Galeão, IPHAN's manager in Pirenópolis,⁹ reported that the mortar had good results for impermeabilization and cohesion. The appearance of the new mortars has slightly changed since



FIGURE 4 Igreja do Rosário's interior after the second restoration. Photo: © Honório Nicholls Pereira



FIGURE 3 Igreja do Rosário (Rosário Church) in Pirenópolis, Brazil, built in the eighteenth century with rammed earth and adobes. Photo: © Honório Nicholls Pereira



FIGURE 5 Detail of the top of a rammed earth wall after treatment with saliva de cupim. Photo: © Honório Nicholls Pereira



FIGURE 6 Adobe samples amended with hydrated lime and saliva de cupim. Photo: © Honório Nicholls Pereira

their application; they are brighter, and there are white stains, probably caused by salts or hydrated lime, which was used as an additive.

Saliva de cupim was also tested for the construction of new rammed earth walls. Samples were made to determine ideal concentrations of the product. The samples exhibited high cohesion, compaction, and resistance to erosion. Saliva de cupim did not change the visual properties of the samples (fig. 6). Although the test results were positive, saliva de cupim was not used in the new walls but instead 20 percent hydrated lime was added.

Conclusion

The properties of termite mound soil vary considerably according to termites' feeding habits and other local characteristics. Termite mound soil may be used as an amendment in architectural conservation if it has better qualities than the reference soil.

The saliva de cupim technology resembles termites' procedure in mound building. The principle of this action is natural cementation and cation exchange. Tests and research on its use are promising, but case studies show conflicting results. Major problems seem to be alteration of visual properties and migration of soluble salts. Further research on both termite mound soil and saliva de cupim using sound scientific methodology is needed.

Notes

- 1 Enzymes in termites' digestive tracts are produced by symbionts and are related to lignocellulose digestion (Nakashima and Azuma 2000; Purwadaria et al. 2003). Reports suggest that some termites produce cellulase and break down cellulose to generate their food (Watanabe et al. 1998).
- 2 RS is soil that has had no termite activity. It was reported that termites change the soil in an extensive area, up to 12 meters underground and 10 meters laterally (Miedem and Van Vuure 1977).
- 3 A tentative list of international products and respective producers: EMC2[®] (SSPco); Terrazyme[®] (Natureplus); Permazyme[®] (International Enzymes); RBI Grade 81[®] (Anyway Solid); Enzymatic[®] (Enzymatic); Conaid[®] (Conaid Plus); Biocat[®] and Soil Seal[®] (Soil Stabilization); Clay Pack[®] (Soil Bond); and PSCS-320[®] (Alpha Omega).
- 4 ECOLOPAVI[®] samples went through X-ray fluorescence and infrared spectrometry. First results show peaks of S, K, and Al; and a band (3,377 cm⁻¹) attributed to an N-H chain, compatible with cocoamide (diethanolamine). Engineer Hélio Rubens, responsible for DS-328[®]'s formulation, reported the presence of K and compounds derived from babaçu, mamona, and carnaúba.
- 5 For Fazenda Jardim and Oikos Arquitetura, see www.oikos.arq.br.
- 6 Aluminum sulfate (Al₂(SO₄)₃•nH₂O) is a metallic salt with a 16 percent minimum of alumina, soluble in water, and sold as a white powder. It acts as a catalyzer and is recommended as an additive for sand-clay or clay-sand soils. Ratios vary from 1:5,000 to 3:100 (mass of product per mass of dry soil).
- 7 For information on Construtora Biapó, see www.biapo.com.br.
- 8 Information on the restoration of Rosário Church may be found at www.matrizdepirenopolis.com.br.
- 9 IPHAN is the National Institute for the Historic and Artistic Heritage.

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Experimental Analysis for Compressive Strength Evaluation of Earthen Materials

Silvia Briccoli Bati, Luisa Rovero, and Ugo Tonietti

Abstract: *Earthen buildings are highly vulnerable to damage, especially when compressive strength is a decisive factor. For this reason, the compressive strength of the adobe bricks must be determined as part of a diagnostic analysis or in the evaluation of the material properties of new construction. This paper presents the results of an experimental analysis comparing different methods to evaluate compressive strength, including the three-point bending test, uniaxial compression test, and sclerometer tests on adobe samples.*

Résumé : *Les bâtiments en terre sont particulièrement vulnérables à l'endommagement, particulièrement lorsque la résistance à la compression est un facteur décisif. Ainsi, la résistance à la compression des briques en adobe doit être déterminée dans le cadre d'une analyse diagnostique, ou en effectuant une évaluation des propriétés matérielles d'une nouvelle construction. Cette communication présente les résultats d'une analyse expérimentale visant à comparer différentes méthodes d'évaluation de la résistance à la compression y compris, l'essai de flexion à trois points, l'essai de compression uniaxiale et les essais au scléromètre sur des échantillons d'adobe.*

Preservation and enhancement of traditional earthen buildings, as well as the practice of constructing new buildings with earth, require a deep knowledge of construction techniques and of the physical and mechanical properties of the material. The mechanical behavior of earth construction can be qualitatively compared to that of other masonry construction types; however, some characteristics, specifically, strength and stiffness, do not compare well because the mechanical values of earth are considerably lower than those of other traditional masonry construction materials.

These circumstances make earthen buildings very vulnerable to the typical pathologies in which compression strength is a decisive factor. Therefore, it is essential that diagnostic analysis of earthen structural elements include evaluation of their compressive strength. Moreover, quality control testing of compressive strength is recommended for all new construction to guarantee a high safety standard.

In New Mexico and Arizona construction codes require that compressive strength be determined with the tensile strength through a three-point bending test. This test is often used as a quality control test for adobe bricks since it can be carried out easily in the construction yard. Other standard tests for compressive strength are not practical outside of the laboratory. The uniaxial compression test, for example, requires a hydraulic press and samples that are perfectly square with smooth surfaces. Since it is not always possible to extract masonry samples (as always happens for pisé), compressive strength can be determined through indirect methods based on the sclerometer, which can also be used in situ. This paper presents the results of an experimental analysis comparing different compressive strength evaluation methods. Particular attention was given to investigating the link between compressive and tensile strength as measured by the three-point bending test. Analysis was carried out on both ad hoc and cut adobe samples prepared in the laboratory of the Dipartimento di Costruzioni of the University of Florence. The following mechanical tests were performed on each adobe sample: sclerometer, three-point bending, and uniaxial compression. These were carried out on the two pieces obtained from samples broken in the three-point bending test (fig. 1).

Outline of the Different Procedures for Compressive Strength Evaluation

The uniaxial compression test is the standard method for compressive strength evaluation. It requires a hydraulic press and well-squared, cubic, or parallelepiped-shaped samples with smooth surfaces. The samples must be produced ad hoc or cut from larger adobe blocks; however, cutting is often not viable because the earth is not cohesive and easily crumbles. Also, loads that must be applied to yield collapse through a compression test are high (obviously the peak load is proportional to the cross-section area). For all these reasons, the uniaxial compression test is extremely difficult to execute in the construction yard.

In some cases, compressive strength measurements can be obtained using the indirect three-point bending test. For brittle materials, there is a ratio between compressive and tensile strength (i.e., for bricks and stones, compressive strength is about ten times tensile strength). Such constitutive behavior, typical of brittle materials, has been highlighted in many experiments and depends on the specific mineralogical structure. Compressive strength, therefore, may be determined as a multiple of tensile strength. For this reason, it is important to determine tensile strength correctly; however, direct tensile tests are not easy to perform for brittle materials, especially for earth, because it is difficult to grip and pull the sample without damaging it. For all these reasons, construction codes in New Mexico and Arizona, for example, determine compressive strength σ_c with tensile strength σ_t through the three-point bending test

$$\sigma_c = A \sigma_t \quad (1)$$

with $A = 8$. With reference to figure 1, the three-point bending test allows a determination of tensile strength by applying the following equation (Navier's formula):

$$\sigma_t = (1.5 \times P \times B)/(L \times H^2) \quad (2)$$

where the force P is measured at failure.

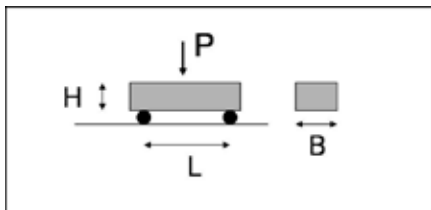


FIGURE 1 Three-point bending test.

Unlike the uniaxial compression test, the bending test can be carried out in the construction yard with simple equipment directly applied to adobe bricks. In fact, the adobe samples can be used without preparation (i.e., cutting or leveling) since the collapse force is several times lower than that needed to measure compressive strength on half of the same adobe brick. It is important to observe, however, that some hypotheses on which equation (2) is based are not respected in earth blocks, such as (1) linear elastic behavior until collapse and (2) aspect ratio L/H of a beam.

If it is not possible to extract masonry samples, compressive strength may be determined in situ through non-destructive tests such as with flat jacks or through indirect methods using a sclerometer or a penetrometer. The test with flat jacks is very reliable but requires complex instrumentation. The penetrometer is generally used for ground that exhibits low compaction compared to pressed earth (adobe or pisé). The sclerometer test is easy to achieve; nevertheless, it is necessary to carry out experimental tests to verify how instruments available on the market (which are calibrated for stones, bricks, and concrete) can be applied to the earthen materials.

Experimental Analysis

In order to compare different compressive strength evaluation methods, the following mechanical tests were performed on each adobe sample (figs. 2–4): first the sclerometer; then the three-point bending; and finally uniaxial compression tests on the remaining pieces obtained from samples broken in the three-point bending tests. Experimental analysis was carried out on six samples ($14 \times 10 \times 26$ cm—base \times height \times length) taken from a restored building in Lamezia Terme and on twenty-four samples produced in the laboratory using earth from the same site.

Four different sample mixtures were prepared in the laboratory. They differed in water percentage and mixing method as follows:

1. 5% water by weight of the earth, with manual mixing;
2. 10% water by weight of the earth, with manual mixing;
3. 25% water by weight of the earth, with mechanical mixing;
4. 30% water by weight of the earth, with mechanical mixing.



FIGURE 2 Sclerometric test.

With each mixture, three samples with the dimensions $8 \times 8 \times 32$ cm and three samples at $8 \times 8 \times 16$ cm were made.

Before using the samples for mechanical tests, the earth was characterized. The following analyses were performed:

- principal mineralogical and clay mineral composition through X-ray diffraction (XRD);
- grain-size distribution through sieving (ASTM D 2217) and sedimentation (AASHTO T 88-72);
- liquid (Wl%) and plastic (Wp%) limits (Atterberg limits), which make it possible to compute the plasticity index (Ip%) (CNR-UNI 100014 guideline) and to classify the earth material according to the Casagrande Chart.

The results of these tests, shown in tables 1 and 2 and in figures 5 and 6, lead us to some conclusions about the analyzed earth.

Table 2 Clay mineral composition

kaolinite	illite	chlorite	smectite	vermiculite	chlorite-vermiculite
20	50	10	—	—	20

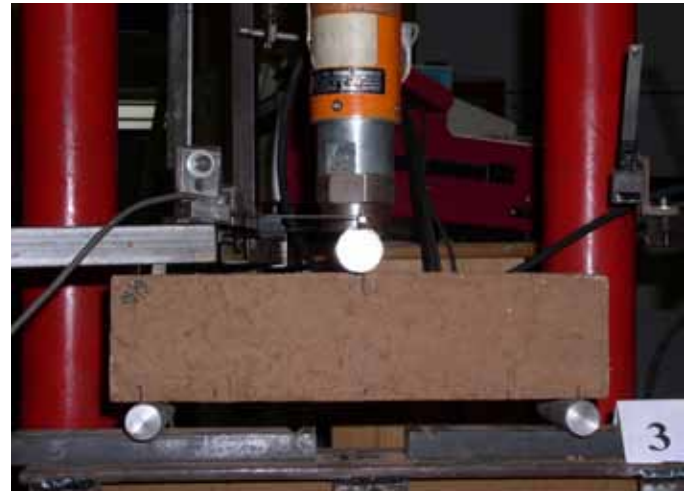


FIGURE 3 Three-point bending test.



FIGURE 4 Compression test.

Table 1 Principal mineralogical composition

quartz	feldspar	calcite	dolomite	clay
34	3	—	—	63

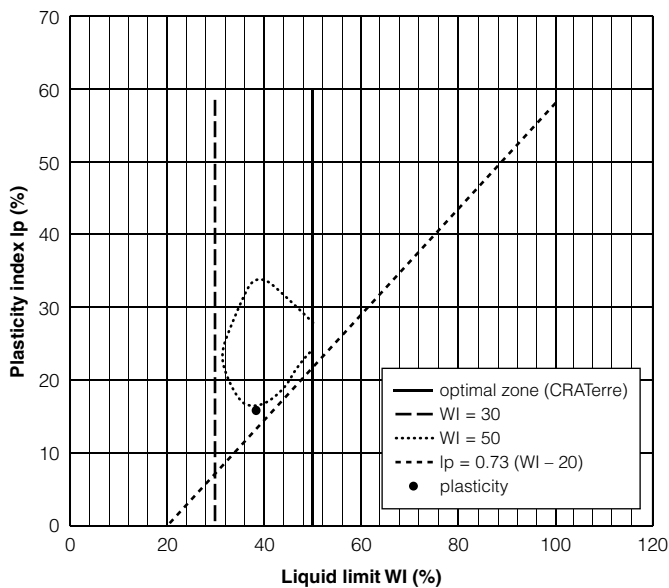


FIGURE 5 Casagrande's diagram.

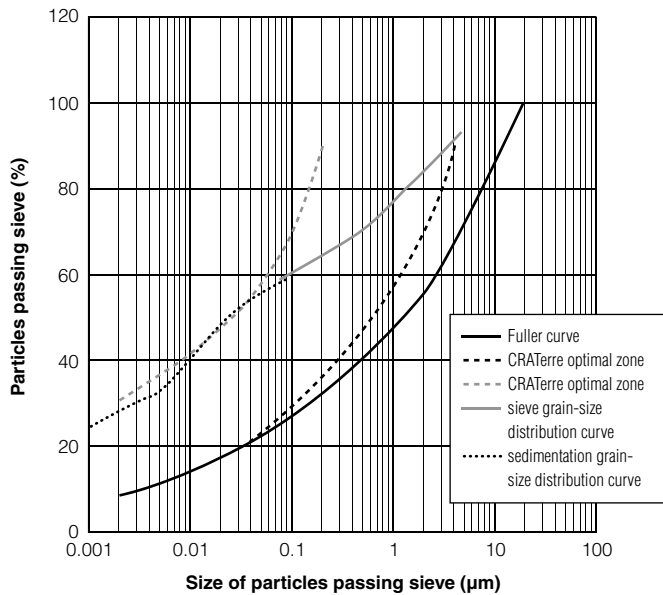


FIGURE 6 Grain-size distribution.

The mineralogical composition (tables 1, 2) shows that the earth contains a high quantity of clay, the minerals of which, however, do not exhibit highly plastic characteristics. In fact, analysis reveals that of the 63% fraction of clay, 50% are illites, 20% kaolinites (minerals that are relatively coarse-grained and not expandable), and 20 percent are chlorite-vermiculite (fine-grained minerals that are normally expandable and increase plasticity). This behavior is confirmed by the plasticity parameters ($WI = 38\%$, $Ip = 15.6\%$), which permit classification on Casagrande's diagram (fig. 5), yet are outside the optimal area recommended by CRATerre (low plasticity). The grain-size distribution is within the optimal area suggested by CRATerre and indicates a well-graded earth (fig. 6). Based on the plastic parameters and grain-size distribution values, the geotechnical classification USCS SYSTEM describes this material as a "low plasticity clay (CL)." The index of activity at $A = 0.56$ indicates that the earth is inactive.

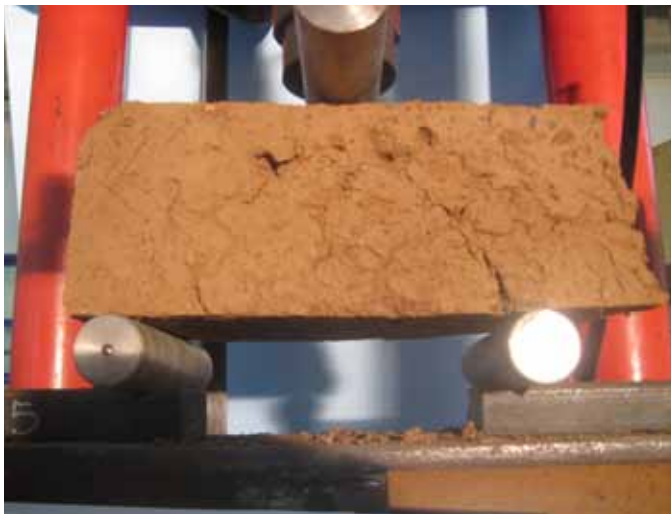
Experimental Results

Table 3 compares the experimental results. In particular, the average compressive strength and the average tensile strength determined on samples with different dimensions (with different H/L ratio, fig. 1) are reported. The C/T_1 ratio (A in equation (1)) is the coefficient needed to derive compressive strength by tensile strength. The correlation between the three-point bending tests and the compression tests highlights that the shape of the sample influences the results. In fact, when the samples are characterized by the maximum span ($L = 30$ cm, $L/H = 3.73$), the coefficient necessary to obtain the correct value of compressive strength from the tension value is 9.09, whereas when the samples are characterized by the minimum span ($L = 12$ cm, $L/H = 1.5$), the coefficient is 4.87. This suggests that sample shape has a substantial influence on the results of the bending test. In particular, the influence of the ratio between the height and the span of each sample is clear (the sample's base dimension exhibits only a simple linear influence that can be neglected). With the minimum ratio (i.e., $L/H = 1.5$), the sample behaves not as a beam but as a different structure. Indeed, the peculiar shape modifies the mechanical behavior. In the case of a unilateral (brittle) material, the fractures show that the seeming beam acts as a kind of arch with a compressive thrust line that is clearly demonstrated in the fracture pattern of the sample reproduced in figure 7.

In this case, the strength evaluated through equation (2) is overstated, almost doubled. Structural mechanics theory

Table 3 Experimental results of mechanical tests

	Compressive Strength by Sclerometer Test (24 new samples, 12 old samples) (MPa)	C Compressive Strength by Monoaxial Test (24 new samples, 12 old samples) (MPa)	T ₁ Tensile Strength by 3-Point Bending Test (12 samples) H = 8 cm L = 12 cm (MPa)	C/T ₁ Ratio	T ₂ Tensile Strength by 3-Point Bending Test (12 samples) H = 8 cm L = 30 cm (MPa)	C/T ₂ Ratio	T ₃ Tensile Strength by 3-Point Bending Test (6 samples) H = 10 cm L = 18 cm (MPa)	C/T ₃ Ratio
New samples	mean value 2.2	mean value 2	mean value 0.41	4.87	mean value 0.22	9.09		
	std. deviation 0.51	std. deviation 0.39	std. deviation 0.12		std. deviation 0.05			
	vari. coeff. 0.23	vari. coeff. 0.19	vari. coeff. 0.3		vari. coeff. 0.21			
Old samples	mean value 0.92	mean value 0.86					mean value 0.17	5.06
	std. deviation 0.27	std. deviation 0.21					std. deviation 0.05	
	vari. coeff. 0.29	vari. coeff. 0.25					vari. coeff. 0.28	

**FIGURE 7** Arch behavior in adobe subjected to three-point bending test.

does not indicate exactly when a solid can be considered a beam. We can reasonably deduce from the De Saint Venant principle that a minimum ratio equal to 3 or, deriving it from the strength test codes employed for mortar samples, a ratio equal to 4. This fact indicates that the bending test can be applied only to samples that exhibit that geometrical ratio.

Conclusion

The main conclusion is that the three-point bending test is not reliable for every kind of adobe.

In Italy earthen construction is characterized by a large variability in building techniques, and there are many types of adobe whose H/L ratio is not always acceptable for using the three-point bending test. For shaped adobes, there are more suitable indirect tests for determining tensile strength. A reliable test is the “indirect tensile test” (Brazilian or splitting test) in which the results are not affected by geometrical dimensions (fig. 8). Furthermore, this test is easily applied in



FIGURE 8 Indirect tensile test (Brazilian or splitting test).

the construction yard. However, it is useful to remember that when using the Brazilian test, traction strength is about 1.5 times the direct tensile strength (in the three-point bending test, strength is about 2 times).

To complete the assessment of different compressive strength evaluation methods, the comparison between the sclerometer tests and the other compression tests allows us to validate the use of this indirect test (as confirmed in table 3). In this case, the average values recorded by the sclerometer correspond to the average values deduced from the compression tests. Nevertheless, it is relevant to observe that the sclerometer values are scattered.

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Comparative Testing of Earthen Grouts for the Conservation of Historic Earthen Architectural Surfaces

Stefan Simon and Daniela Geyer

Abstract: *This paper presents the results of a collaborative study performed in 2005–7 with the PUCP (Pontifical Catholic University of Peru–Lima), the Rathgen Research Laboratory (Berlin), and the University of Applied Sciences (Potsdam) on the development of appropriate grout formulations to conserve earthen architectural surfaces. Mineral composition, consistency limits, flow behavior and viscosity, fissure shrinkage, and sedimentation behavior of the grouts were recorded in preliminary tests. Biaxial flexural strength, Young modulus, pull-off strength, water vapor diffusion resistance, fissure penetration capability, and performance in cavities were studied on the set grouts. Additives used to modify the grouts were methylcellulose glue, Tylose MH 300, Klucel E, rabbit skin glue, glass microballoons, and quartz powder. A procedure for investigating the material composition and current condition of earthen architecture and the formulation of suitable soil-based grouts is proposed.*

Résumé: *Cette communication présente les résultats d'une étude réalisée en collaboration avec la PUCP (Pontificia Universidad Católica del Perú–Lima), le Laboratoire de recherche Rathgen (Berlin) et l'Université des Sciences appliquées (Potsdam) sur des formulations de coulis adaptés à la conservation de surfaces architecturales en terre. La composition minérale, les limites de consistance, le comportement de l'écoulement et la viscosité, le retrait des fissures et la sédimentation des coulis ont été enregistrés aux cours d'essais préliminaires. La résistance biaxiale à la tension par flexion, le module de Young, la capacité d'adhésion, la perméabilité à la vapeur d'eau et la capacité de pénétration dans les fissures, ainsi que les performances dans les cavités ont été étudiés avec les différents coulis. De la colle à base de méthylcellulose, du Tylose MH 300, du Klucel E, de la colle de peau de lapin, des billes de verre et*

de la poudre de quartz ont servi d'adjuvants pour les coulis d'injection. Il est proposé une procédure pour étudier la composition matérielle et l'état de l'architecture de terre, ainsi que la formulation de coulis appropriés à base de terre.

Detachment of plaster and loss of adhesion between the technological strata are among the most common problems an architectural conservator faces. Being aware of the duality of historic and aesthetic values, the conservator acts to protect the existing substance by preventing further deterioration. For the past twenty years grouts have become a favorable agent for reattaching delaminated layers of architectural surfaces. During this time, grout technology has been modified with regard to the types of binder, fillers, and additives.

The main purpose of an injection grout is to reattach detached layers by filling voids, cavities, and cracks in the plaster and to consolidate the architectural surface. To meet this aim, the grout should be stable, injectable, and both mechanically and chemically compatible with the original substrate. Other criteria to be taken into account include sufficient cohesion and tensile strength, minimal shrinkage, adequate water transport characteristics, low weight and low salt content, and an appropriate working time (Zajadacz and Simon 2006). In recent decades the importance of “retreatability” as a conservation concept has surpassed the concept of reversibility in conservation ethics (Petzet 1991).

A collaborative study performed in 2005–7 by the PUCP, the Rathgen Research Laboratory (Berlin), and the University of Applied Sciences (Potsdam) conducted comparative testing of earthen grouts for the conservation of historic earthen architectural surfaces. The history of scientific research on grouts for earthen substrates started in the 1980s with the

development of the ICCROM grout based on liquid hydraulic lime mortar. In this study scientific testing of additives to improve performance was introduced to the field (Ferragni et al. 1984, 1985). In 1986 a low-alkali hydraulic lime, liquid lime, or PVAC grout was used to reattach murals on earthen plaster by Schwartzbaum, Na Songkhla, and Massari (1986). The injection of modified earth for filling cracks in adobe was proposed for the first time by Roselund (1990). The importance of physico-mechanical testing was stressed during a study on grouts for lime plasters on earthen architecture by Matero (1995) and Bass (1998). Earthen grouts on wall paintings have been studied by Shekede (2000).

While research conducted through Frank Matero at the University of Pennsylvania focused on hydraulic lime grouts with sand and microspheres and with/without the addition of acrylic emulsion (Matero and Cancino 2003), the suitability of earthen grouts and the development of appropriate testing procedures are at the center of this study. The cause of grout failure in both structural and nonstructural repairs (e.g., post-seismic) is often attributed to zones of discordancies due to the dissimilarity of materials and subsequent peaks of stress load during hygric or thermal fluctuations at the boundary between grout and substrate (Simon 2007). Earthen grouts are expected to perform well in this respect.

The logical approach for developing a suitable grout is to use dispensable original earthen substrate material from the object or, alternatively, soil with a similar clay composition. This provides for simple, cheap, and widely available raw materials. This base material may be modified to produce an injectable grout that is compatible with the physico-mechanical properties of the substrate after drying.

The main requirement for successful grouts is low viscosity combined with low water content that allows for good injectability and minimal shrinkage. In addition, the grout must have homogeneous distribution in the voids, good adhesion to the cavity surfaces, and compatible strength and water transport characteristics with the substrate. The challenge is to obtain adhesion in a material with very low tensile strength. Furthermore, it is important to move away from case-dependent analysis to a more reproducible testing program (Houben, Alva Balderrama, and Simon 2004).

Quantitative and reproducible testing is one of the main research aims in conservation science (Tabasso and Simon 2006). Although multiple standards for mortars or building materials have been developed by agencies such as CEN, ASTM, NORMAL, RILEM, DIN, AFNOR, GOST, and BS, most of them cannot be applied to earthen grouts without

major modifications due to their special characteristics and requirements. A compilation of test methods and normative references for injection grouts is given by Knöfel et al. (1993), Snethlage (1997), and Zajadacz and Simon (2006).

Materials and Methods

Basic Composition of Test Grouts

Three different soil types were investigated: an adobe that came from a local adobe house (next to the case study site) and two typical German building soils from Glindow and Westerwald. The different soils were sieved and the particle fractions from 0 to 0.063 mm \varnothing with clay and silt content and 0.063 to 0.125 mm \varnothing as fine-grained sand were obtained. Carboxy methylcellulose, Tylose MH 300, Klucel E, rabbit skin glue, glass microballoons, and quartz powder were selected as additives. An overview of the composition of selected test mixes is presented in table 1. Analysis of the raw materials included wet sieve granulometry, X-ray diffractometry, methylene blue tests, Atterberg (consistency) limits, and ion chromatography.

To determine the particle-size distribution, a conventional granulometry with a wet sieve procedure was carried out. Analysis of the clay minerals was accomplished by X-ray diffractometry. This allows us to distinguish between specific swelling and nonswelling clay minerals, recognized by a shift in the diffraction pattern at reflexes with low 2-theta values after glycol intercalation.

The methylene blue test (based on the amount of methylene blue dye absorbed by the sample) was carried out to reveal clay types and content and thus the total surface area of the grout. The correlation between the methylene blue value and the hygroscopic dilatation of earthen materials, an important damage process, has been shown by Bourgès, Simon, and Müller (2003).

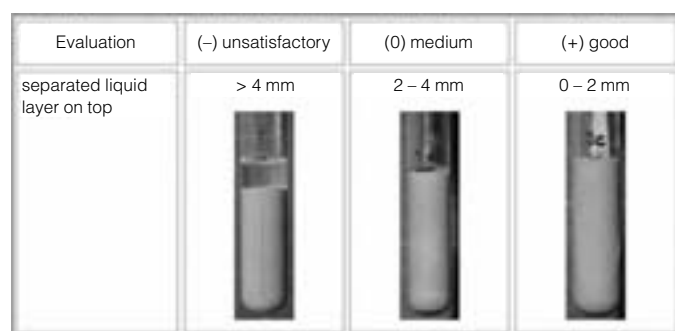
Atterberg limits were determined to describe the interaction between the original substance and the water content of the grout (DIN 18122 Parts 1 and 2). Furthermore, the soluble salt content was determined by ion chromatography, as well as the amount of organic and calcareous components.

Tests on Liquid Grouts

To study sedimentation behavior, approximately 8 milliliters of grout were placed into test tubes, covered, and photographed after twenty-four hours. Phase separation (the amount of the liquid that formed at the surface) was measured and evaluated (fig. 1).

Table 1 Composition of test grouts

Grout Mix	Base Material	Grain Size <63 μm (M%)	Grain Size 63–125 μm (M%)	Glass Microballoons (M%)	Quartz Powder (M%)	Additional Water (ml)	Additional Amount of Additive (ml)	Type of Additive (2% solution in H_2O)
LA9c	Original adobe	38	42	20	—	30	30	Klucel E
LA14	Original adobe	18	62	—	20	40	20	Tylose MH 300
LA15	Original adobe	18	62	10	10	40	20	Klucel E
LG9c	Glindow soil	38	42	20	—	30	30	Klucel E
LG14	Glindow soil	18	62	—	20	40	20	Tylose MH 300
LG15	Glindow soil	18	62	10	10	40	20	Klucel E
LW14	Westerwald soil	18	62	—	20	40	20	Klucel E
LW15	Westerwald soil	18	62	10	10	40	20	Klucel E

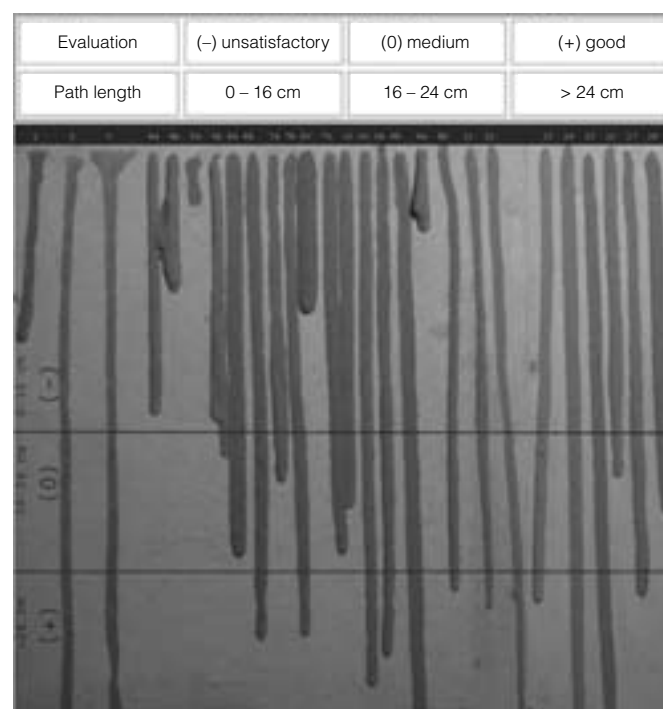
**FIGURE 1** Sedimentation behavior.

Determination of flow behavior was carried out with approximately 2 ml of each grout formulation mixed in a beaker. The grout was poured on a vertical plaster test panel. Afterward the flow distance was measured. The flow was classified as good, medium, or unsatisfactory (fig. 2).

In this method of testing flow behavior, shear stress is not modified. These results may be misleading with regard to injectability. As a result, a more elaborate viscosity (Brookfield) test was carried out using a Viskomat NT (Scheiblinger). Here, a special shear body, which is also the measuring paddle, is immersed in the rotating sample, assuring consistent mixing under variable shear rate.

To estimate the crack width into which the grout will flow, grouts were injected behind glass plates attached to a porous stone panel. The angle of each plate was defined and the crack width was calculated from the flow depth.

Finally, shrinkage and cracking behavior were investigated. Plastic rings (\varnothing 5 cm, h 0.5 cm) were filled with the grout and air-dried at ambient conditions. The grouts were

**FIGURE 2** Flow test.

then classified according to the number of cracks formed. A preferred testing method would have been to dry the samples under controlled hygrothermal conditions and to record shrinkage by low voltage displacement transducers (LVDT) or micrometer. To determine drying kinetics, it is crucial to monitor temperature and relative humidity of the environment, as well as air speed, which also plays a major and often underestimated role and should be controlled.

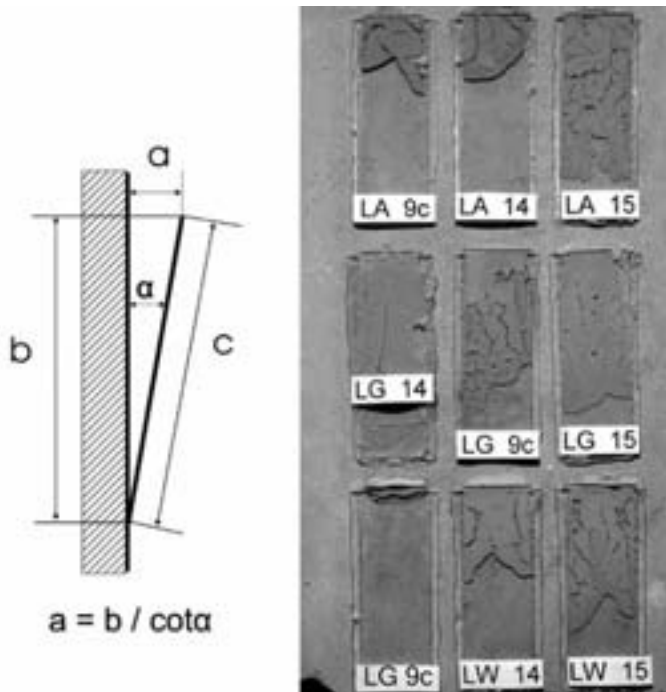


FIGURE 3 Test for the determination of penetrated crack width.

Tests after Setting

The biaxial flexural strength of dry soils depends on various parameters, such as clay type and content, density, and grain size distribution. It was measured on preconditioned (20°C / 65% RH) drill core slices with a 50 mm diameter and 5 mm height under double ring load. The strength and Young moduli were calculated following the equation established by Wittmann and Prim (1983). The test slices were cut by dry sawing. Due to the fragility of the material, the samples were temporarily consolidated with cyclododecane in white spirit and subjected to the mechanical test after sublimation of the agent.

A test was conducted to evaluate the pull-off strength of the grout/substrate sandwiches. The absolute values of tensile strength quantified in this test are much lower than other strength parameters. The location of the fracture, which is ideally cohesion failure in the grout, is of special importance.

A final test was conducted to determine the coefficient of water vapor diffusion resistance μ on grout specimens using the dry-cup method. Due to a lower contribution of capillary transport mechanisms, the μ -value determined by the dry-cup method was generally lower than the μ -value determined by the more commonly used wet-cup method.



FIGURE 4 Preparation of the mock-up.

Behavior in the Cavity

To evaluate the behavior of the grouts in the cavity, mock-ups were prepared. The mock-up represents the plaster and underlying earth structure in two layers and contains a void. The void was first marked and later filled with sand (fig. 4). The mock-ups were dried and the sand removed before the grouts were injected through a little outlet at the upper edge of the mock-up. After drying, the mock-ups were cut perpendicular to their surface, and the degree of filling and shrinkage cracks was evaluated.

Results

The content of swellable and nonswellable clays in the Glindow and Westerwald soils is high (26% and 50%, respectively) and comparable to the cob/chineh construction of the Būdnerhaus with 20%. Sedimentation, flow, and cracking tests allowed screening of suitable grout mixtures. With an increasing shear rate, the viscosity of the grouts dropped, showing typical thixotropic behavior, a desired property for injection purposes. In the earthen grouts prepared without additives, a slow increase of viscosity during mixing time was observed.

In the samples modified with additives, viscosity continues to drop with increased mixing time and needs almost three days to reach equilibrium. After three days it remains constant at higher shear rates. But at lower shear rates, viscosity starts to increase, a phenomenon that may deserve further investigation (fig. 5).

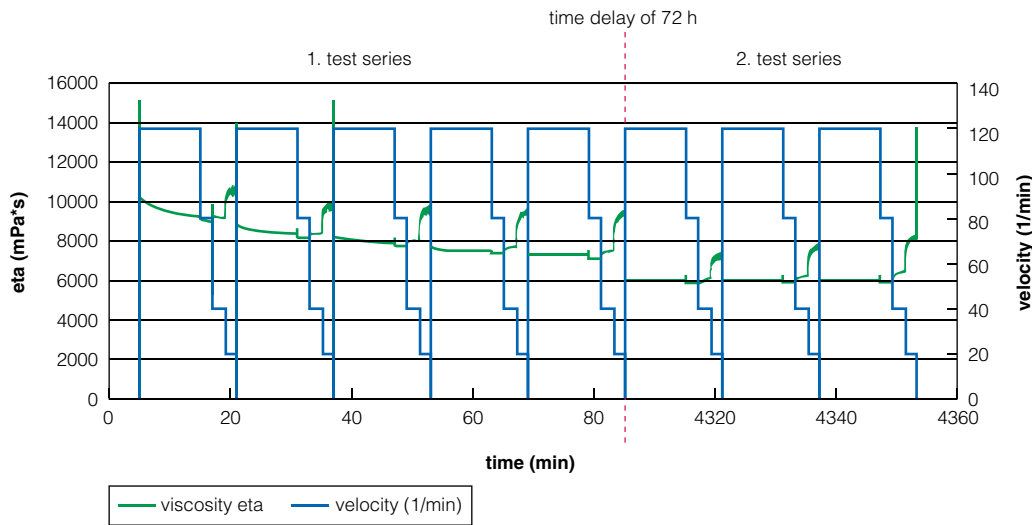


FIGURE 5 Viscosity behavior of injection grout (green); shear rate in blue.

It can be derived that the grouts do not necessarily need to be agitated. Soaking the grout materials for several days may decrease the viscosity, but agitating the grout accelerates the production process. Stable suspensions can be made only with grain sizes up to 125 μm . Extended mixing has a positive impact on flow and viscosity of the modified grouts. Grouts diluted with water show the opposite tendency.

An addition of 1% methylcellulose to the water improved grout viscosity and flow, while too-high concentrations often showed a negative impact. Partial replacement of the finest sand fractions with quartz powder and glass microspheres enhanced those properties. The tendency toward cracking, however, increased with clay content. Most grout formulations have strength values similar to that of the substrate, which

are in the low range of 0.5 N/mm^2 . Methylcellulose additives slightly increased grout strength.

The Young moduli for most tested grouts are comparable to the value of the original substrate, though, due to the high silt content, are slightly higher. The pull-off strength varied between 0.1 and 0.7 N/mm^2 , which is at the low margin of acceptable values according to Knöfel et al. (1993). Water vapor diffusion coefficients μ were comparable to those of the original substrate. A summary of the grouts' physico-mechanical properties is given in table 2.

Cross sections of the mock-ups show (in most cases) good filling capacity and a good connection to the surface of the cavities (fig. 6).

Table 2 Physico-mechanical properties of grouts (μ -value, σ_{BZ} and Young moduli) and results of preliminary tests

Grout	σ_{BZ} [N/mm^2]	E [kN/mm^2]	μ [—]	Pull-Off Strength (N/mm^2)	Crack Width (mm)	Flow	Cracking	Sedimentation Behavior	Behavior in the Cavity
LA9c	0.46	0.64	13.4	0.14	1.3	+	+	+	0
LA14	0.67	0.75	14.2	0.12	1.4	+	+	+	+
LA15	0.59	0.9	16.3	0.12	0.4	+	+	+	—
LG9c	1.17	0.82	17.2	—	0.2	+	+	+	—
LG14	0.4	1.04	13.5	0.17	0.1	+	0	—	+
LG15	0.58	0.65	14.1	0.09	0.5	+	+	+	+
LW14	0.69	1.38	15.4	0.15	1.1	+	+	0	0
LW15	0.62	1.22	15.4	0.1	0.6	+	+	+	+
Substrate 1	0.49	0.54	14.7						



FIGURE 6 Grout behavior in the cavities.

Field Application

The grout selected to repair the Būdnerhaus (Berlin, Germany), a characteristic nineteenth-century vernacular building in northern Germany built of cob/chineh construction, contained soil (maximum particle size 150 μm), quartz powder, and Tylose MH 300. The house has well-preserved historic earthen plaster in large parts of the interior. The field test area covers approximately 2 m^2 . Infrared thermography, a non-destructive imaging method that provides exact information about discontinuities of thermal conductivity at the surface and possibly within the building structure, was carried out by Christine Mayerhofer at the Federal Institute for Materials Research and Testing, Berlin.

Bright areas in the thermographic images indicate detached zones between the paint layer and the earthen plaster, as well as between the plaster and the cob substrate. Figure 7 shows the treatment area before (left) and after (right) intervention. Grouted areas are marked in red.

Comparison of the thermography before and after the grouting indicates that the treatment was effective. The grout was injected neatly; the grouted surface has no visible deformations, and only partial dampening of the plaster was observed. The treatment has had no visible impact on the historic paint layer.

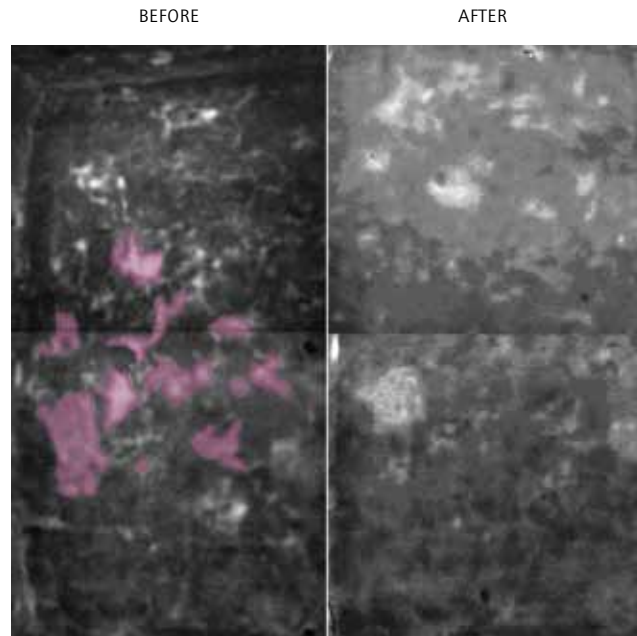


FIGURE 7 Infrared thermography of test wall.

Conclusion

Grout formulations made from local adobe soil as a base material, with quartz powder and Tylose as additives, performed well. Grains sizes above 0.125 mm cannot form stable suspensions. A suitable ratio of clay/silt content and sand is of key importance. The tendency of the grout to crack increases with clay content.

The additives used in this testing program tend to enhance flow behavior. Tylose increased the pull-off strength, while glass microballoons decreased the biaxial flexural strength slightly but increased viscosity. Extended mixing has a positive influence on flow, at least for the modified grouts; grouts made with water only showed the opposite tendency. High concentrations of methylcellulose or glue can also have a negative impact on these properties. Replacement of water with ethanol is not advised because it can lead to increased cracking as a consequence of fast drying.

With these tested materials, it is possible to make grouts with good injectability, low water content, and negligible shrinkage. The grouts show high compatibility in their water vapor transport characteristics, match the mechanical properties of the substrate, and achieve good adhesion to surfaces within the cavities. These results were confirmed through in situ application at the Būdnerhaus.

The testing methodology described here is promising but needs further development to increase reproducibility. It is especially important to focus additional research on the rheological behavior of grouts.

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Le rôle de l'eau dans la cohésion et l'adhésion du matériau terre : Une question d'équilibre

David Gelard, Laetitia Fontaine, Romain Anger, Yehdih O. M. Abdelhaye,
Jean-Paul Laurent, Christian Olagnon, Hugo Houben et Henri Van Damme

Résumé : L'objectif de notre travail est de comprendre l'origine de deux propriétés remarquables de la terre crue : d'une part, sa forte cohésion à l'état sec et, d'autre part, son remarquable pouvoir collant à l'état de boue. Nous montrons que la cohésion de la terre à l'état (apparemment) sec est essentiellement due aux forces capillaires générées par les quantités minimales d'eau de condensation en équilibre avec l'humidité atmosphérique. D'autre part, nous montrons que son pouvoir collant à l'état humide est lié à un phénomène de cavitation dans la solution aqueuse entre les grains solides. L'eau est impliquée dans les deux cas.

Abstract: The aim of our work is to understand the origin of two remarkable properties of unfired earth: its strong cohesion when dry and its remarkable adhesive strength when in the form of mud. We show that the cohesion of earth in an (apparently) dry state is essentially due to capillary forces generated by minimal quantities of condensation water in balance with atmospheric moisture. Furthermore, we show that its adhesive capacity when it is moist is linked to cavitation in the aqueous solution between the solid grains. Water is involved in both cases.

La terre est un matériau de construction remarquable sous au moins deux aspects. À l'état sec, sous forme de brique de boue séchée (adobe), de bloc compacté ou de massif damé, elle peut présenter une cohésion et une résistance en compression étonnante, malgré l'absence de liants chimiques. À l'état humide, sous forme de boue ou de glaise, elle peut présenter un pouvoir collant remarquable, meilleur que celui de la plupart des mortiers cimentaires. L'objectif de notre travail est de comprendre l'origine de ces deux propriétés et, plus particulièrement, de comprendre le rôle de l'eau même lors-

que, comme dans les adobes, le matériau en est, en apparence, totalement dépourvu¹.

Friction et cohésion

Comme tous les matériaux granulaires, la terre doit ses caractéristiques mécaniques à la conjonction de deux types de forces internes : d'une part, les forces de frottement entre grains, qui empêchent les grains de glisser facilement les uns sur les autres et, d'autre part, les forces de cohésion qui attirent les grains les uns contre les autres. Ces deux types de forces agissent de concert. Plus les forces de cohésion sont fortes entre grains en contact, plus la force à exercer pour les faire glisser est grande. Cette influence très forte de la force de cohésion sur la force de frottement est une des lois de base de la mécanique des milieux granulaires (Nederman 1992).

Une autre caractéristique importante de la terre est qu'il s'agit d'un matériau granulaire dont la distribution granulométrique peut être particulièrement large. Entre les argiles les plus fines et les granulats les plus grossiers, il peut y avoir une différence de taille de plus de 10^5 . Construire en utilisant uniquement les grains les plus grossiers est impossible sans coffrage. En revanche, les grains de taille intermédiaire, comme le sable, autorisent déjà quelques audaces, pour autant qu'ils ne soient pas totalement secs. L'eau introduit une certaine cohésion due à ce qu'on appelle des ponts capillaires, c'est-à-dire des petites gouttes d'eau qui lient deux grains l'un à l'autre. Par rapport aux gouttes d'eau habituelles, comme les gouttes de pluie par exemple, les ponts capillaires présentent une particularité. Au lieu d'être courbés de manière convexe comme ces dernières, ils sont courbés de manière concave, du moins dans les plans qui passent par le centre des grains de

sable. Au lieu de se refermer sur elle-même, l'eau, qui mouille les grains de sable, s'étale sur leur surface, ce qui inverse sa courbure. La goutte s'étire, mais les liaisons entre les molécules d'eau résistent. L'eau dans la goutte est donc en tension (fig. 1). Le calcul de la tension dans la goutte, qu'on peut exprimer sous la forme d'une différence de pression entre l'air et l'eau, a été fait il y a deux siècles, par des grands noms de la science comme Young et Laplace. Le calcul montre que la tension est d'autant plus forte que le ménisque (la surface de la goutte) est courbé de manière concave (Hunter 1993). Une autre loi physique, due à Lord Kelvin, permet de relier la courbure du ménisque à la pression de vapeur d'eau (Hunter 1993). Plus la courbure est forte, plus la pression de la vapeur, c'est-à-dire l'humidité atmosphérique qui est en équilibre avec le ménisque, est faible. Cette relation est très importante, car elle nous dit que la tension dans un pont capillaire ne dépend pas de la manière dont on a apporté l'eau. On peut ajouter de l'eau au sable sous forme liquide ou humidifier l'atmosphère, on obtiendra le même résultat, pour autant que la courbure du pont capillaire soit la même.

Pour calculer la force qui attire les grains l'un vers l'autre, connaître la pression ne suffit pas. Il faut aussi connaître la surface sur laquelle s'exerce la pression, c'est-à-dire la section du ménisque. Et là il se produit une chose très étonnante, c'est que, d'après les théories classiques (Fischer et Israelachvili 1981), il y a une compensation quasi-parfaite

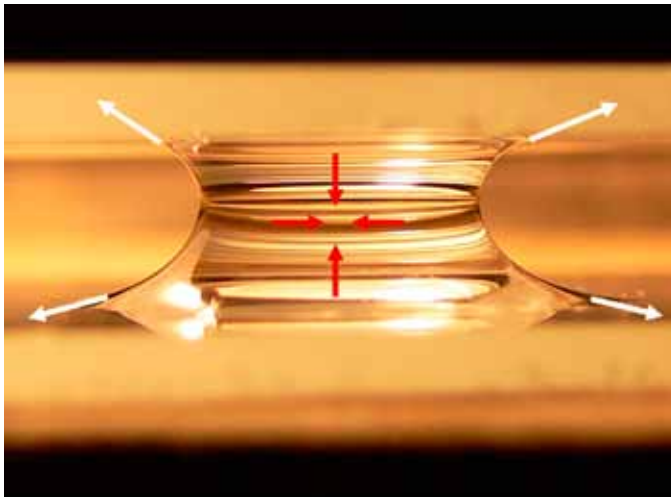


FIGURE 1 Dans un pont capillaire entre deux grains, le mouillage des grains met l'eau en tension. Ceci courbe le ménisque et provoque une dépression d'autant plus forte que le ménisque est fortement courbé. © CRATerre-ENSAG

qui se produit. Si on diminue la quantité d'eau, la courbure devient de plus en plus forte et la pression attractive aussi, mais cette pression s'exerce sur une section de plus en plus petite. Les deux effets agissent en sens contraire. Le résultat est que la force devrait rester à peu près constante. Donc, on aboutit à la conclusion que la cohésion du sable humide ne devrait pratiquement pas dépendre de la quantité d'eau, tant que le sable n'est pas complètement noyé, ce qui est contraire à l'expérience de chacun !

Il a fallu attendre près de deux siècles pour trouver la solution du problème (Hornbaker et al. 1997 ; Halsey et Levine 1998). Le problème vient de ce que les grains de sable ne sont pas lisses à l'échelle microscopique. Ils sont, comme toutes les surfaces, garnis d'aspérités microscopiques. Lorsqu'on ajoute de l'eau, soit sous forme liquide, soit en augmentant l'humidité de l'air, le pont capillaire commence par se former entre les plus petites aspérités. Puis le pont capillaire s'élargit à plusieurs pointes, mais il n'est pas encore suffisamment large pour sentir la courbure du grain de sable. Ce n'est qu'au-delà d'une certaine largeur qu'il commence à sentir la courbure du grain. À ce stade là, on peut considérer que le pont capillaire n'est plus sensible à la rugosité, et la théorie classique devient correcte.

Si on examine la manière dont la cohésion évolue avec la quantité d'eau, on a donc plusieurs régimes. À l'état totalement sec, il n'y a aucune cohésion capillaire. Ensuite, lorsque le pont capillaire commence à se former entre une ou plusieurs aspérités, la force augmente progressivement à mesure que le pont capillaire s'élargit. Lorsqu'il devient suffisamment large, la rugosité ne joue plus et la cohésion devient constante. Enfin, si on rajoute trop d'eau, les deux grains sont noyés et toute la cohésion disparaît. On a donc une région de cohésion optimale, entourée de chaque côté par des zones dangereuses (fig. 2). L'humidité relative à laquelle on entre dans la zone dangereuse du côté sec, dépend de la courbure, et donc de la taille des grains. Avec de gros grains, on perd très vite de la cohésion, dès que l'atmosphère s'assèche. Avec des grains fins, on peut sécher beaucoup plus fort avant que la cohésion ne commence à décroître, mais tôt ou tard, on finit par la perdre. Le même comportement est obtenu si l'on considère non plus deux grains seulement mais une population de grains (Scheel et al. 2008).

D'autres forces peuvent contribuer à la cohésion. Les premières sont celles que l'on regroupe sous le nom de forces de van der Waals (Van Damme 2002). Ce sont celles qui sont à l'œuvre dans le collage, et dont se servent les animaux qui, comme les insectes ou les lézards, grimpent avec une facilité déconcertante sur des surfaces verticales. Ce sont des forces

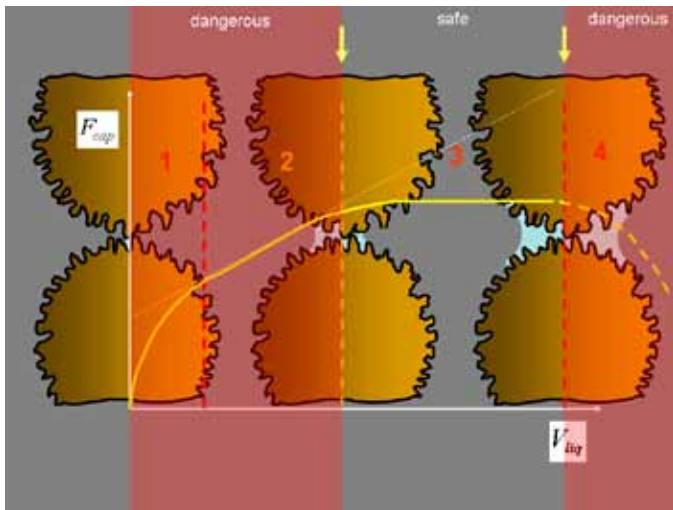


FIGURE 2 La force de cohésion capillaire entre deux grains n'est maximale et indépendante de la teneur en eau que dans un domaine limité. En dessous d'une humidité minimale et au dessus d'une valeur maximale (flèches jaunes), la cohésion décroît. Le même phénomène se produit pour une population de grains. Sur ce graphe, F_{cap} est la force de cohésion capillaire et V_{liq} est la quantité d'eau. © CRATerre-ENSAG

quasi-universelles. Elles sont dues aux champs électriques générés par le mouvement des électrons dans les atomes. Elles peuvent être intenses, mais à condition que les objets soient en contact étroit.

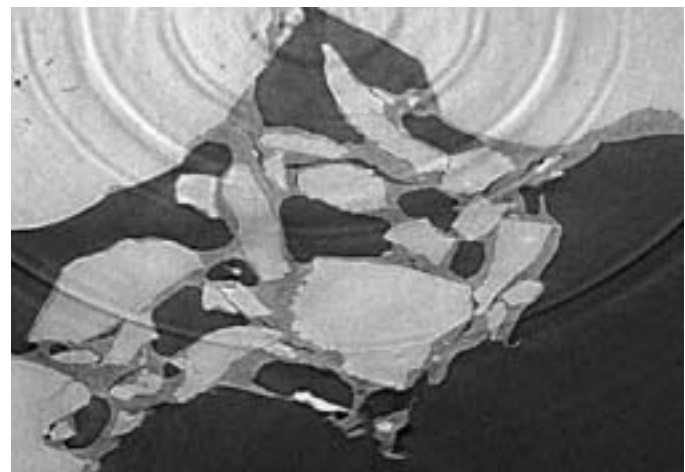
Il y a une troisième catégorie de forces attractives qui est due à des charges électriques (Van Damme 2002). Ce sont elles qui agissent au sein des paillettes de mica par exemple, ou encore dans le ciment ordinaire lorsqu'il « prend », ou encore lorsque notre ADN se replie pour former des chromosomes. Elles interviennent lorsque la charge électrique sur la surface des objets est très forte et que les ions qui séparent les grains sont eux aussi fortement chargés (mais avec une charge de signe opposé à celle des grains, pour garder l'ensemble électriquement neutre). Certaines argiles, formées de particules en forme de feuillets négatifs séparés par des ions calcium positifs, sont sensibles à ces forces.

La cohésion de la terre : Un cas modèle

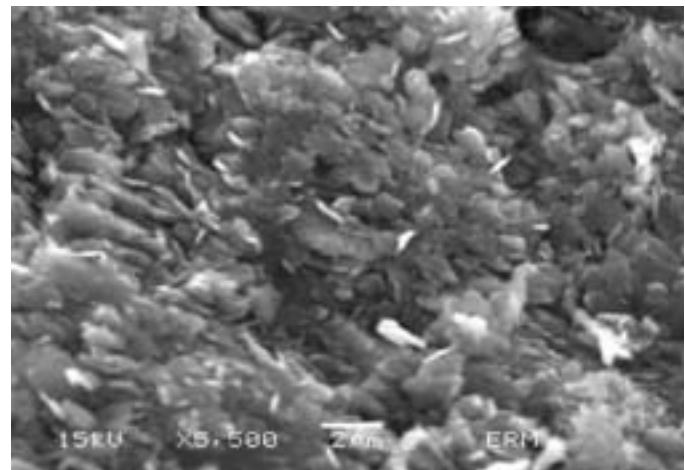
Quelles sont les forces responsables de la cohésion du matériau terre ? Nous avons effectué des mesures expérimentales et fait des calculs. Nous avons fabriqué une terre artificielle en mélangeant un sable propre avec une boue préparée à partir

d'une argile bien connue, la kaolinite, puis en laissant sécher le matériau. La kaolinite est une argile qui ne porte pratiquement pas de charges électriques. Les seules forces appréciables sont donc les forces capillaires et les forces de van der Waals. L'examen au microscope ou en microtomographie montre que les particules d'argile tapissent les grains de sable et forment des ponts entre eux (fig. 3).

Nous avons mesuré la cohésion de ce matériau par les techniques habituelles de mécanique des sols (Nederman 1992). En parallèle, nous avons calculé la contribution des forces capillaires et des forces de van der Waals à la cohésion



(a)



(b)

FIGURE 3 L'image au scanner (a) de la terre que nous avons étudiée montre que l'argile (gris moyen) enrobe les grains de sable (gris clair) et forme des ponts entre ces derniers. L'examen au microscope électronique (b) révèle les plaquettes d'argile à la surface des grains de sable. © CRATerre-ENSAG

théorique du matériau en représentant celui-ci, afin de pouvoir faire les calculs, par un assemblage simplifié de sphères (le sable) et de plaquettes (l'argile) (fig. 4). Pour calculer la cohésion, la tension dans les ponts capillaires a été déterminée à partir de l'humidité atmosphérique, la section des ménisques d'eau a été prise égale à leur rayon (ce qui semble raisonnable, compte tenu du désordre d'orientation des plaquettes d'argile) et, enfin, la section des ponts de boue séchée entre grains de sable a été déterminée sur les clichés de microscopie. La comparaison de la cohésion mesurée (140 KPa) avec la contribution capillaire (de 60 à 600 KPa) et la contribution de van der Waals (de 5 à 30 KPa) montre que ce sont bien les forces capillaires – donc la très faible quantité d'eau conservée par l'humidité atmosphérique – qui sont principalement responsables de la cohésion du matériau.

La terre comme colle

Comment se fait-il qu'un mélange de terre et d'eau, à l'état de boue, soit une colle suffisamment forte pour coller plusieurs briques l'une sur l'autre dans une position qui défie la pesanteur, le temps de fermer une voûte par exemple (fig. 5). D'après le contenu des paragraphes précédents, la cohésion devrait

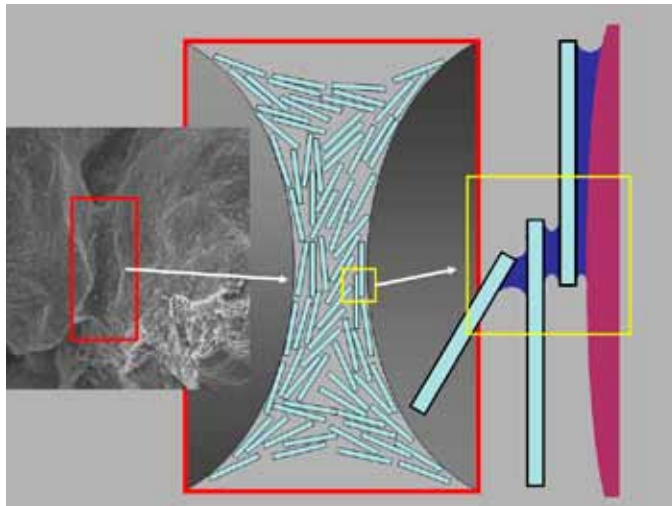


FIGURE 4 Ce schéma décrit le modèle simplifié utilisé pour calculer la cohésion. On considère deux grains de sable sphériques, séparés par un pont de boue séchée dans lequel les plaquettes d'argile ne sont en contact que sur une surface limitée. C'est dans ces zones de contact que se forment les ménisques. © CRATerre-ENSAG

être quasi-nulle. Et pourtant, retirer sa chaussure de la boue est parfois très difficile !

La propriété qui est en jeu dans ce cas n'est plus la cohésion mais l'adhérence ou le « collant » (« *tackiness* » en anglais). Une manière simple de mesurer le pouvoir collant est de mettre une couche de boue entre deux surfaces, puis de séparer ces deux surfaces, en mesurant la force qu'il faut exercer. En augmentant progressivement la quantité de terre dans le mélange, on observe des changements très révélateurs. Lorsque la boue est très fluide, on observe la même chose que lorsque l'on place une goutte d'huile entre deux doigts. En écartant les doigts, on force l'huile à couler vers le centre, et en même temps, on crée une dépression dans la couche d'huile (Abdelhay, Chaouche, Chapis, et al. 2008). Très rapidement, elle forme un mince filet, qui finit par se casser.

Avec des boues plus épaisses, les phénomènes sont différents. On commence par observer, non plus un seul, mais plusieurs filets de boue. Comme la viscosité de la boue est plus forte, la force à exercer est plus grande, elle aussi. Lorsque la boue est vraiment très épaisse, il n'y a plus vraiment d'écoulement vers le centre. La couche de boue se déforme et s'ouvre un peu partout, et la force à exercer est encore plus grande. On observe la même chose avec les vraies colles, ou avec les mortiers de ciment. Ce qui se passe, c'est que la dépression



FIGURE 5 La boue est une colle remarquable qui permet de réaliser temporairement, tant qu'elle contient assez d'eau, des assemblages étonnants comme ici, pour la démonstration, neuf briques collées à l'horizontale sur un mur vertical.

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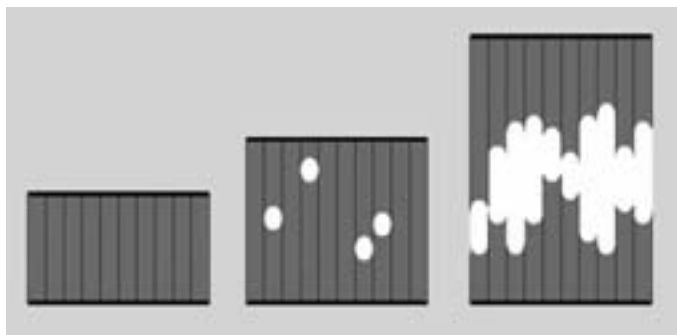


FIGURE 6 La raison du pouvoir collant de la boue se trouve dans la dépression et les microbulles qui sont créées par cavitation lorsque les surfaces collées tendent à se séparer.
© CRAterre-ENSAG

dans la couche de boue est tellement forte que l'on forme des « bulles » dans la boue (fig. 6). C'est ce que l'on appelle de la « cavitation ». C'est dans cet état que la boue est la plus collante. Le calcul montre que les premières bulles qui se forment ont la taille de l'espace entre les grains de la boue (Abdelhaye, Chaouche, et Van Damme 2008). Une boue fine sera donc plus collante qu'une boue grossière car elle formera des bulles plus fines, avec une dépression plus grande. Il y a cependant une limite à ce jeu. Si la boue est trop concentrée, c'est-à-dire s'il n'y a plus assez d'eau, par exemple en séchant, la boue ne peut même plus se déformer et former de bulles. À ce stade, elle perd son pouvoir collant.

Conclusion

Le message que nous avons voulu faire passer est que l'eau peut intervenir de manières très différentes, mais toujours déterminantes, dans les propriétés du matériau terre. Certes, elle peut être néfaste pour la durabilité, mais dosée correctement, elle est essentielle pour la cohésion et pour l'adhésion.

Note

- 1 La recherche sur la cohésion a fait l'objet d'une collaboration fructueuse avec le Getty Conservation Institute (GCI) dans le cadre du projet Terra. Le GCI est chaleureusement remercié.

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Modern Innovations in Unfired Clay Masonry in the United Kingdom

Pete Walker, Andrew Heath, and Mike Lawrence

Abstract: *This paper reviews traditional architectural practice using earthen materials and discusses its influence on developments in the modern use of unfired clay building materials in the United Kingdom. Unfired extruded clay bricks offer new opportunities for modern earthen construction, including much thinner walls better suited to current construction requirements. However, this development is contingent on achieving adequate flexural bond strength between the bricks and mortar. Experimental results from ongoing research on unfired clay masonry at the University of Bath are summarized, as are test results for bond strength between mortar and bricks. The significance of experimental findings is presented, including recommendations for construction and design.*

Résumé : *Cette communication évoque la pratique traditionnelle architecturale utilisant des matériaux en terre et son influence sur l'utilisation actuelle des matériaux de construction en terre crue au Royaume-Uni. Les briques de terre crue extrudées offrent de nouvelles possibilités pour la construction moderne en terre, y compris des murs moins épais et plus adaptés aux besoins actuels en matière de construction. Cependant, cette évolution dépend de la réalisation d'une adhérence adéquate entre briques et mortier. Les résultats expérimentaux de la recherche sur la maçonnerie en terre crue en cours à l'Université de Bath sont présentés, ainsi que les résultats des essais sur l'adhérence entre le mortier et les briques. L'importance des résultats expérimentaux est soulignée et des recommandations sont proposées pour la construction et la conception.*

Unfired clay materials provide a sustainable and healthy alternative as a replacement to conventional masonry materials, such as fired clay and concrete block, in both non-load-bearing

and low-rise load-bearing applications. Environmental benefits include significantly reduced embodied energy, thermal mass, and regulation of humidity. Materials may be taken from sustainable resources (low-grade clay and overburden) and are readily reused, recycled, or harmlessly disposed of on end use. Though the use of traditional vernacular techniques, such as cob, has raised the profile of earthen architecture, wider impact on modern construction is likely from innovations such as extruded masonry units.

Traditional U.K. Earth Construction

Traditional earth construction techniques, including cob, mud-block, wattle and daub, and rammed earth, have a long and largely successful history in the United Kingdom (Pearson 1992). There are an estimated 500,000 occupied earthen buildings in the United Kingdom, most dating to before the twentieth century (Little and Morton 2001). Earth is primarily used for wall and, occasionally, floor construction. Walls are of thick solid construction, in contrast to modern masonry walls, which are generally composed of two thin leaves with an insulated cavity between. The thermal insulating qualities of traditional earth walls in general do not meet the requirements of modern building regulations in the United Kingdom, although the poor insulating qualities are to some extent offset by the high thermal mass and hygrothermal properties.

Cob

Traditional cob walls are typically built in situ in a series of lifts about 600 mm high. Lifts are allowed to dry for a few days before construction is continued. Walls are typically 450 to 600 mm thick. As construction proceeds, walls are cut back

using a shovel head to trim and smooth the line and batter. Straw is added to limit cracking following drying shrinkage and to improve tensile strength. For protection, walls are plastered or rendered with a lime-based mix.

Though perhaps fewer than some other forms of new earth building, some recent cob building projects have been undertaken in the United Kingdom, including housing, education centers, and transportation infrastructure. The wet nature of cob allows scope for sculptural expression of form, as exhibited in some recent projects by Abey Smallcombe (fig. 1).

Rammed Earth

Throughout the nineteenth century, a large number of rammed earth chalk houses were built in southern England (Pearson 1992) as spoil material from local railway works became available, but by the beginning of the twentieth century, rammed earth was no longer practiced to any extent. After World War I a government experiment built a small number of earthen houses at Amesbury



FIGURE 1 Modern cob building, Eden project, Cornwall.
Photo: P. Walker

in an attempt to reestablish earth building during a period of general building material shortage (Williams-Ellis 1919).

In the past ten to twelve years there have been over twenty new rammed earth projects of varying size in the United Kingdom, including housing, a nursery, visitor centers, sports centers, storerooms, stables, and business accommodations. Where in situ or locally sourced materials have been used, the embodied carbon content is very low. Natural earth is also readily recycled or disposed of when the building reaches the end of its life. The high-quality architectural appeal is another factor in its selection. In common with other earth building techniques, rammed earth provides considerable thermal mass to buildings. Recently completed rammed earth projects in the United Kingdom include Rivergreen Centre (fig. 2).

Mud-Block

Mud-block has been used historically in some regions of the United Kingdom, most notably East Anglia during the nineteenth century. Prefabrication of mud-blocks has advantages in comparison with in situ techniques such as cob and rammed earth. The quality of blocks can be readily checked after manufacture but before construction. Traditionally blocks are laid in a mud mortar and bonded as with other forms of masonry construction. The comparatively high thickness of walls, 225 to 300 mm, generally means that the low strength of mud mortar is not a concern as the weight of the wall is sufficient to ensure stability under lateral loading.



FIGURE 2 Rammed earth wall, Rivergreen Centre, Durham.
Photo: P. Walker

Manual block presses, similar to the CINVA Ram, have been used in a small number of projects in the United Kingdom, though high labor costs in block production have prohibited wider usage. Mechanically pressed blocks (e.g., the SUMATEC block produced by Lime Technology Ltd.) are now increasingly available. Compressed earth blocks are a familiar form of construction, similar to solid concrete blocks, allowing easier adoption by skeptical industry and public. Blocks are more readily incorporated into conventional building forms, such as cavity wall and timber frame construction.

Modern Development of Unfired Clay Masonry

The demand to reduce climate change impact of modern building has offered new opportunities for earth construction. The low embodied carbon, combined with hygrothermal performance and high aesthetic value, has encouraged consideration and modern use of unfired clay techniques. For wider, mainstream uptake, unfired clay building materials must fit in with modern methods of construction, deliver high-level and consistent performance, and be available at a competitive economic cost.

Unfired clay masonry can replace fired brick and concrete block masonry in many applications, with significant reductions in the consumption of natural resources and in waste sent to landfill as the raw materials. These benefits are inherent in the manufacture process but continue through the whole life cycle as the bricks are easy to recycle. There are numerous examples of modern and historical unfired clay masonry, but modern uses in developed countries have generally been limited to specialist conservation and green construction niche markets (Morton 2006). In order to realize the full potential of unfired clay masonry in the United Kingdom, this technology needs to move to mainstream markets. As the U.K. brick manufacturing industry uses approximately 5.4 TWh of power each year (BDA 2002), for every 1% of the fired brick market that is replaced with unfired bricks, the energy saving could be sufficient to power about twenty thousand U.K. homes for a year (assuming 85 percent of the energy from processing goes into firing) (BGS 2005).

The technical approaches that have been adopted with existing modern unfired masonry products are to use very thick walls or to use a timber frame infilled with unfired clay bricks. In both these approaches, mortar strength is not critical to the design. Neither of these approaches is considered appropriate for the U.K. market, where very thick walls will increase material usage and decrease usable floor space and



FIGURE 3 Modern timber frame and unfired clay brick building, Dalguise, Scotland. Photo: P. Walker

where a timber frame infilled with bricks will slow construction and require different trades working in the same location on-site. To move unfired clay masonry into mainstream markets where thin, freestanding walls are used will require increased bond strength to give the required structural performance. Successful recent projects include a domestic house in Dalguise, Scotland, by Arc Architects (fig. 3).

The bond strength of masonry is required to create a stable wall that will not collapse if it experiences lateral loading. Wall thickness has a large effect on required bond strength. A 2.4 m high vertically spanning wall at 300 mm thick, even with very low bond strength (0.001 N/mm^2), can carry a load of approximately 600 N/m length at mid-height. In order to reduce the thickness of the wall to 100 mm while providing the same flexural resistance, the bond strength must be increased to approximately 0.2 N/mm^2 . There are many examples of single-story 300 mm thick earthen walls where the bond strength approaches zero (e.g., adobe blocks with clay mortars). The bond strength of 0.2 N/mm^2 for a 100 mm thick wall is considered a reasonable characteristic strength for unfired earth masonry.

Experimental Study

Outline

To investigate the bond strength of unfired clay masonry units, a number of tests were performed on masonry prisms built using the Errol Brick Company's Eco-brick (Burt 2006). Bond

Table 1 Mortar mix proportions

Mortar Mix	Mix Details (by volume)
1	2 parts brick clay:3 parts building sand
2	1 part brick clay:3 parts building sand
3	1 part cement:3 parts building sand
4	1 part brick clay:3 parts building sand: lignosulphonate solution
5	Errol brick proprietary clay:sand:lignosulphonate mortar
6	Proprietary sodium silicate mortar

strengths were investigated using differing mortar mixes, including cement:sand, clay:sand, and a proprietary sulfate-resistant sodium silicate-based mix used for chimney flue linings. To investigate the effect of surface integrity on bond, a bonding agent (commercial PVA-based solution) was painted onto the bedding surface of the bricks and allowed to become tacky before the mortar was applied, as per the supplier’s instructions for normal use. The bonding agent is conventionally used for plastering applications and not for mortared masonry joints. The five experimental mortar mixes are summarized in table 1.

All mortar mixes, except for mix 6, were mixed with sufficient water to provide a mortar flow value between 150 and

170 mm. The particle-size distributions of the brick clay and sand are illustrated in figure 4, along with the Atterberg limits for the clay. The proprietary sodium silicate mortar was ready-mixed for use.

Mixes 4 and 5 had a 5% sodium lignosulphonate, at 55% concentration, added to the clay, sand, and water. Lignosulphonate (or lignosulfonate) is a lignin-based by-product of the paper production industry and is commonly used as a binder in a variety of applications. It is also used in the construction industry as a concrete plasticizer. It has previously been used as a mortar additive for a limited number of construction projects in the United Kingdom. The Eco-brick was extruded in a commercial brick plant and the bedding faces wire cut. The properties of the bricks are summarized in table 2. The unfired brick is slightly larger than a standard fired brick unit (215 × 102.5 × 65 mm), but it would shrink slightly if it was fired to have nominal dimensions similar to those of the fired brick. The initial rate of absorption (IRA) for the unfired bricks was tested with and without a PVA bonding agent coating according to ASTM C67 (ASTM 1987).

Results of Bond Tests

The average compressive strength of the different mortars was determined after twenty-eight days in accordance with BS EN 1052-5:2005 (BSI 1999b); the values are summarized in table 3.

FIGURE 4 Particle-size distribution for clay and sand used in mortar.

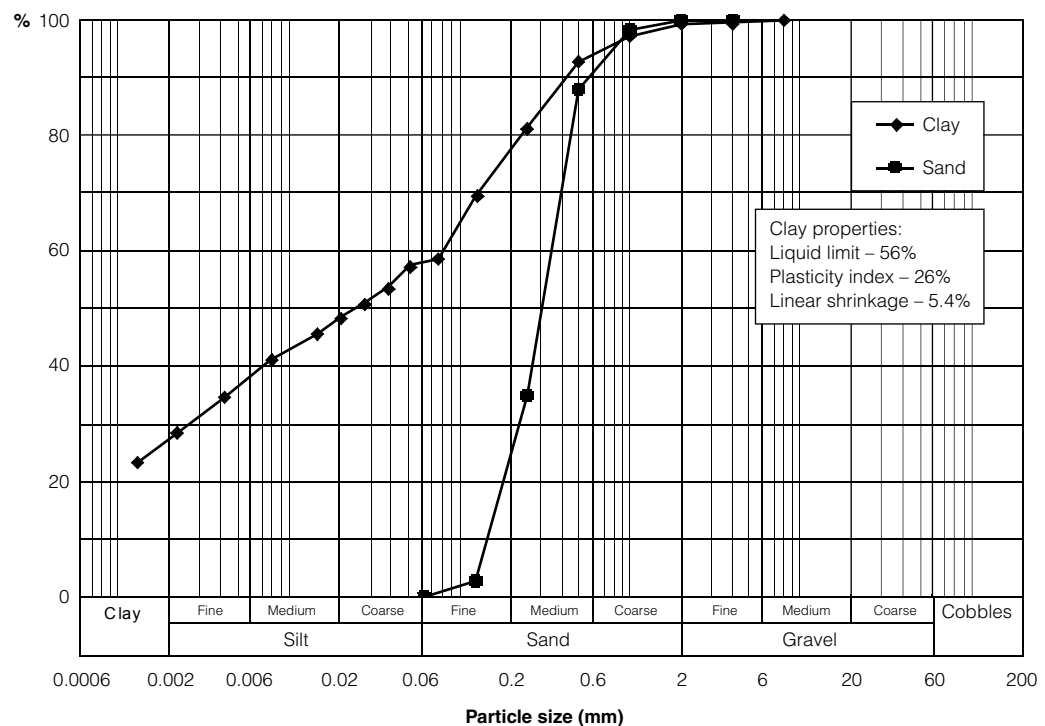


Table 2 Average properties of Eco-brick

Property	Unfired Bricks
Dimensions—l × w × h (mm)	224 × 106 × 67
Voids—no. and diameter (mm)	10 × 22
Mass per brick (g)	2295 (dry)
Gross unit weight (kN/m ³)	15.5
Net unit weight (kN/m ³)	18.5
Initial rate of absorption kg/m ² /min According to ASTM C67	0.56 (without PVA) 0.76 (with PVA)
Compressive strength (N/mm ²)	4.8

There is no apparent correlation between mortar compressive strength and bond strength for the different mortars. The cement:sand mortar has the highest compressive strength but a very low bond strength with the unfired clay bricks when no bonding agent is used. With the exception of the sand:cement mortar, the compressive strengths for the mortars were below that of the brick (see table 2), which is normally desirable in masonry. For all bricks, the use of PVA bonding agent increased bond strength.

All the joints, with exception of the sodium silicate mortars, exhibited an interface failure when no bonding agent was used. This changed to a majority of joints exhibiting failure within the mortar joint after the interface strength had been increased with the bonding agent. Failure of the sodium silicate-mortared joints was through the face of the bricks rather than along the interface or mortar; bond strength was therefore limited by brick strength, indicating that the sodium silicate mortar mix used is perhaps too strong for these bricks.

The Eco-brick specified proprietary mortar, mix 5, a clay:sand:lignosulphonate mix, provided notably stronger bond than other clay:sand mortars without the use of bonding PVA agent. The grading of this mix differs from that of

the other mortars, which for commercial reasons cannot be reported here but very clearly demonstrates the importance of mortar grading on developing bond strength.

The clay:sand mortars used without a bonding agent and with thick (300 mm) walls in traditional earth masonry construction have low bond strengths. These materials cannot be used in a thin (100 mm) wall without a substantial reduction in load-carrying capacity. In order to produce a similar structural capacity under lateral loading for a 100 mm thick wall, the bond strength must be increased to 0.20 N/mm². The lignosulphonate mortars used with PVA bonding agent and the sodium silicate mortar achieved this value, and these are considered the most promising mortars for further investigation. The use of a synthetic PVA bonding agent is not necessarily ideal, and alternative natural adhesives are to be investigated further. The use of any bonding agent will slow the construction process and increase costs, unless this could be applied as part of the brick manufacture process.

Conclusions and Recommendations

The majority of the embodied energy in fired bricks comes from the firing process, and an 85 percent saving in manufacturing energy can be achieved if the bricks are used in an unfired form. In order for this to have a significant effect on energy usage, the unfired bricks will have to move into mainstream markets where thin (100–105 mm) wall thicknesses are desirable. In order to achieve this, a significant increase in bond strength is needed.

A number of different mortars were tested with unfired clay bricks, with and without the use of a PVA bonding agent applied to the bed faces of the bricks. Clay and sand mortars used for traditional, thicker, unfired masonry walls were determined to have inadequate bond strength for thin (100 mm)

Table 3 Summary of mortar compressive and masonry bond wrench strengths

Mix	Mortar Description	Average Mortar Compressive Strength (N/mm ²)	Average Bond Strength (without PVA) (N/mm ²)	Average Bond Strength (with PVA) (N/mm ²)
1	3:2 (sand:clay)	2.0	0.002	0.012
2	3:1 (sand:clay)	2.5	0.009	0.11
3	3:1 (sand:cement)	11.0	0.002	0.35
4	3:1 (sand:clay) + 5% lignosulphonate	3.3	0.052	0.52
5	Eco-brick proprietary mortar	2.2	0.26	N/A
6	Sodium silicate mortar	3.2	0.47	N/A

walls. The use of lignosulphonate additive to a clay:sand mortar and a sodium silicate mortar increased the bond strength to sufficient levels.

The two most promising mortars are being investigated further, looking at the effect of different mix percentages and the effect of time and environmental conditions on performance. The interface between the unfired clay bricks and mortars also requires further investigation. The future of unfired clay bricks in thin (100 mm) walls appears promising.

Acknowledgments

The authors wish to acknowledge the support of the Technology Strategy Board; colleagues at the University of Bath; and the following partners: Ibstock Brick, Errol Brick Company, Hanson Construction Products, Arc Architects, Lime Technology Limited, and the Brick Development Association.

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PART SIX

**Seismic and Other
Natural Forces**

**Séismes et autres
phénomènes naturels**

Impact of Climate Change on Earthen Buildings

Peter Brimblecombe, Alessandra Bonazza, Nick Brooks, Carlota M. Grossi, Ian Harris, and Cristina Sabbioni

Abstract: *Unfired building materials and other elements of vernacular architecture are particularly sensitive to climate. Computer models predict climate change over the twenty-first century and suggest that changing water relations (especially precipitation) will critically damage earthen heritage in the future. Although the changes in precipitation are not widely understood, it is estimated that the Sahel may be drier; however, heavier seasonal rainfalls may also be severe and can potentially overflow gutters and damage unfired earthen materials. In conditions of intense rainfall, earthen architecture requires diligent attention to maintenance and care in its restoration to sustain it. High temporal resolution in climate data is required to predict the intensity of wind-driven rain/sand. Nonetheless, this represents an important challenge as water and particle abrasion can damage earthen architectural surfaces.*

Résumé : *Les matériaux de construction en terre et autres éléments non cuits de l'architecture vernaculaire sont particulièrement sensibles au climat. Des modèles numériques prévoient des changements climatiques au XXI^e siècle et tendent à indiquer que la modification des relations avec l'eau (notamment par les précipitations) va dans l'avenir entraîner de sérieux dégâts au patrimoine en terre. Bien que l'on ne comprenne pas encore bien les modifications que subissent les précipitations, on pense que le Sahel va probablement s'assécher de plus en plus. Néanmoins, une plus forte pluviométrie saisonnière pourra aussi causer des dégâts et risque d'occasionner des débordements de gouttières et des dégâts aux matériaux de construction à base de terre crue. En cas de très fortes pluies, il convient de veiller attentivement à l'entretien et à la restauration de l'architecture de terre. Il faudra disposer de données climatiques de haute résolution temporelle pour déterminer*

l'intensité de la pluie et/ou du sable portés par les vents. Il s'agit malgré tout d'un important problème car l'abrasion par l'eau et les particules risque d'endommager les surfaces architecturales en terre.

The importance of climate change to cultural heritage is now widely recognized. It has been the subject of funding at a national level with projects such as Engineering Historic Futures (Cassar 2005) and at a European level with NOAH's ARK (Sabbioni et al. 2006). The UNESCO World Heritage Centre has promoted a review published as a World Heritage Report, *Climate Change and World Heritage* (Collette 2007). In addition, there has been a recent call within the European Union Framework Programme 7 Area 6.3.2.1., Assessment and Conservation of Cultural Heritage, which asks for "reliable methods and modelling tools for damage assessment of the near and far impact of climate change." The year 2008 witnessed the first world conference on global climate change and its impact on structures of cultural heritage at the Tourism Activities Centre in Macau.

Despite the intensity of interest, there is a surprising lack of research on the special pressures climate places on heritage. Much of the work reported seems to rely on reviewing existing literature and Intergovernmental Panel on Climate Change (IPCC) summaries rather than undertaking new research. However, a few projects, such as the European Commission's NOAH's ARK, have tried to look at future climate and draw on heritage climatologies that are especially relevant to the protection of monuments and landscapes. This project was limited to a strategic analysis of materials in a European context: stone materials, metals, wood, and glass (Sabbioni et al. 2006).

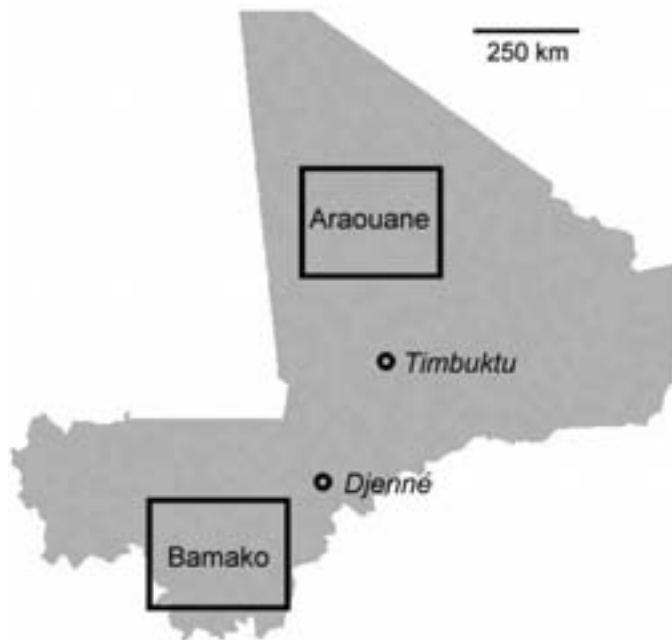


FIGURE 1 Map of Mali showing the locations mentioned in the text and the two Hadley grid cells used in the climate analysis.

At the earliest stage it was clear that NOAH's ARK would not be able to address specific sites or cover the materials of vernacular architecture, despite the fact that England's *Sunday Express* worried that global warming was putting the wattle and daub of historic pubs at risk (Winter 2005). This example seems to link widely shared cultural experiences to the issues of climate change and our notion of heritage. It reminds us of the great importance and immediacy of vernacular architecture. Given the rich earthen heritage of Mali, this paper focuses its climate analysis on this country (fig. 1).

Heritage Climatology

This paper considers damage to earthen buildings in terms of the specific climate variables to which they are most sensitive. The effects of rising carbon dioxide in predicted temperature increases are very well known. Increases of just a few degrees are critical for many aspects of our lives and the health of ecosystems, such as agriculture. However, a few degrees' change in the temperature of monumental heritage seems much less important, as building materials are hardly susceptible to this small variation (Brimblecombe and Grossi 2007). Now, though, we have to look at temperature in a subtler way, in terms of how it influences seasonal climate and how those

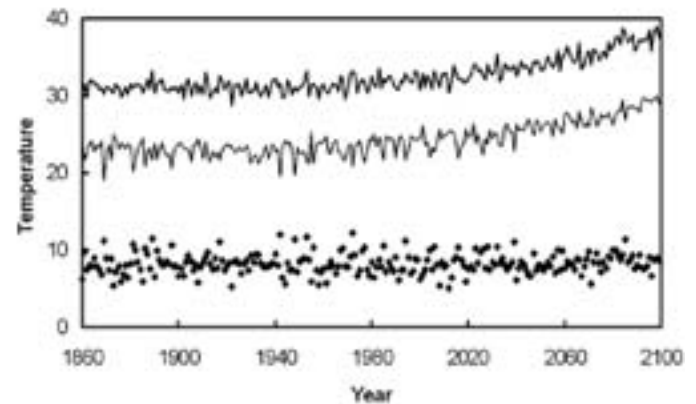


FIGURE 2 Temperature predictions from modeled HadCM3a2 output for the region around Bamako, Mali (see fig. 1), showing the highest (dark line) and lowest (light line) monthly temperatures and the annual range of monthly temperatures (diamonds).

changes in weather patterns can affect large structures. The Djenné mosque of Mali, for example, could well be affected. Figure 2 shows that although the temperature of the hottest and coldest months is likely to increase in southern Mali as derived from the Hadley model (HadCM3a2), the annual range (i.e., difference between the maximum and minimum monthly temperatures) seems unlikely to change much. The use of range, rather than temperature, represents a simple example in terms of a heritage climate.

Vernacular Materials

The impact of climate on earthen materials is different from that on stone and metals, which are so often considered in studies of built heritage. Kerali (2001) has delineated the mechanisms that adversely affect the durability of compressed earth building blocks as related to water, temperature, and chemical effects. They are as follows:

- *Water:* (a) is a solvent (i.e., causes leaching of cements or stabilizers, typically lime and vegetable materials); (b) is abrasive as heavy rain; and (c) causes swelling.
- *Temperature:* (a) fluctuations cause expansion and contraction of the fabric; for example, cracks may propagate across the surface of blocks and allow moisture ingress; and (b) increases result in drying and shrinkage.

- *Catalytic and chemical action:* rising temperatures result in increased reaction speeds, potentially leading to expansion (e.g., sulfation processes including ettringite formation with cement stabilizers).

We must also consider abrasion because mud and clay materials are not especially resistant. In this paper the potential for damage is treated under three headings: (1) temperature, (2) water, and (3) abrasion. Chemical factors do not receive much attention here as our focus is on climate impacts.

Temperature

Projects such as NOAH's ARK and Engineering Historic Futures have studied the effects of climate change on materials, as well as broad conservation strategies for adaptation. These early projects, however, have not been able to detail issues of change at specific sites. As previously mentioned, a change in temperature range may have only a minor effect on most sites over the coming century; however, these small changes can be amplified in a number of ways. One of the more significant is when a phase change occurs, such as water freezing or salt solutions crystallizing. Frost frequently accelerates disintegration and decay of building stones, yet in a warmer world this phenomenon is likely to decrease at more temperate climates (Grossi, Brimblecombe, and Harris 2007) and will hardly be important in the tropics.

Extreme temperatures, perhaps $>50^{\circ}\text{C}$, at the surface of the material can occur under intense solar radiation. In earthen materials this can lead to thermoclastic deterioration from repeated expansion and shrinkage. These fluctuations cause internal stresses that can compromise the compressive strength of the blocks and reduce overall structural strength.

Water Interactions

Here we speak of water interactions, rather than precipitation, because it is important to consider the effects of water both as vapor and as a liquid (e.g., Brimblecombe, Grossi, and Harris 2006). Meteorological parameters, such as relative humidity, are especially relevant to the degradation of wood and clay-containing materials. Damp conditions can enhance biological growth (Rapp, Peek, and Sailer 2000). Humidity cycles can cause swelling and shrinkage of the clay binder, a key mechanism in the deterioration of clay-containing materials. Changing humidity can also affect salt weathering (Goudie and Viles 1997). Here we want to focus on liquid water, which is an important factor

in drier environments where earthen buildings are common. Water is clearly an essential component of building and maintaining monumental earthen buildings, such as in the annual resurfacing of the mosque at Djenné (Vogel 2007).

Predicting rainfall in global models is often difficult, especially when compared to forecasting future temperature. The small spatial extent of some rainstorms, especially in desert regimes where rainfall can be sporadic, presents a problem. Moreover, humidity levels tend to be extremely variable among different models. Predicted annual rainfall in the Hadley cells (fig. 1) centered on Bamako and Araouane 270 kilometers north of Timbuktu is shown in figure 3a. We can see that the model projects a slight decrease in rainfall toward the end of this century. There may also be a decrease in the number of days with

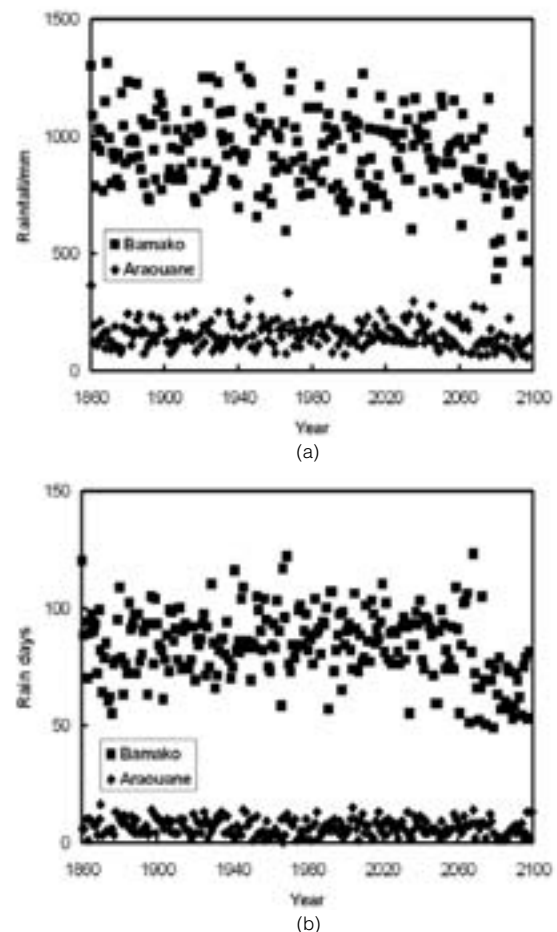


FIGURE 3 (a) Output from HadCM3a2 model for annual precipitation in the Bamako region (squares) and Araouane in northern Mali (diamonds). (b) Output from HadCM3a2 model for number of rain days each year (>0.1 mm) in the Bamako region (squares) and Araouane in northern Mali (diamonds).

rain (fig. 3b), which may be a more significant deterioration factor than the total rainfall amount in terms of its damage to mud walls. This can arise because it is possible that the number of rainfall events are more significant than the amount of rainfall. However, the likely declines are positive in terms of protecting heritage. This is in line with the view that Sahelian rainfall may decrease, especially in the northern Sahara (Brooks 2004). There is also a possibility that higher temperatures over the southern Sahara could bring 1 to 2 millimeters of additional daily rainfall in the Sahel by 2080 (Haarsma et al. 2005).

Abrasion

The moisture susceptibility and friability of earthen building materials makes them highly prone to damage by abrasive processes. In a damp environment, such as England's, clay and chalk buildings are protected from rain by the overhang of the roof. In the cases of thatched buildings this can be as much as 750 millimeters (Pearson 1992). Wind-driven rain, however, undermines any protection offered by an overhang and can impinge directly on the exposed walls, causing considerable damage. Its intensity has sometimes been quantified as the product of precipitation and wind velocity ($P \cdot v$). This is hard to calculate on the basis of daily average meteorological data since higher time resolutions are needed, but perhaps hourly interval readings will work. Data on future climate at this temporal resolution are possible through the use of weather generators (Kilsby et al. 2007), but these are typically precipitation driven, which limits their use in the Sahel due to its markedly low seasonal precipitation. Future research is planned to explore the possibility of weather generators driven by non-precipitation parameters such as clouds and insolation.

Another issue that hampers estimating the impact of wind-driven rain is the $P \cdot v$ parameterization. This formula may underrepresent its real impact. In particular, wind-driven rain intensity may be more sensitive to velocity and have impacts that require an exponent to velocity greater than unity. Wind-driven water penetration also affects thatching, wood, and other porous materials, even stone.

A parallel process, wind-driven sand, can have aggressive effects and cause damage on both soft and hard building materials. Furthermore, it causes unwelcome accumulations against walls, such as those seen in Timbuktu (Sidi 2007). Evidence of its erosive potential are known at the sphinx in Egypt and the temples of Agrigento in Sicily. Estimating the extent and impact of wind-driven sand in the future is difficult as it is very sensitive to wind gusts. Some parameters represent it as

proportional to the cube of wind velocity, but this is likely to have high error; however, the use of weather generators could help in estimating this process.

Management

Climate changes often seem subtle, with just a few degrees' change in temperature or a small percentage change in precipitation; however, the importance of these changes can be amplified when the parameter shifts across transition points where a hygroscopic salt undergoes a phase change. For this reason we need to define heritage climatologies. Although some work has been done in a European context on stone, metals, wood, and glass, little has focused on vernacular materials such as earth. Earthen architecture is sensitive to rain and standing water, which makes future rainfall an important determinant of damage. The nonlinearity of wind velocity in controlling the impact of wind-driven rain and wind-driven sand makes its prediction very difficult—though critical, since we know that it can cause severe erosion.

Predictions and modeling of future climate change and its effects will allow long-term heritage management to be planned more strategically. Even qualitative predictions of future damage can help focus planning on the mitigation of critical deterioration mechanisms in specific geographic areas. In Timbuktu, for example, this can include the creation of buffer zones for sand accumulation and its regular removal.

Future research that informs long-term management must rely on improving regional models so that heritage climate can be projected for a specific site. The work needs to overcome the low spatial resolution and temporal detail found in existing climate predictions. Furthermore, the issue of error inherent in different modeling approaches has implications for the way managers can reliably interpret the data about heritage climates. Climate research needs to reduce uncertainty by expanding projections at local scales, especially for sites with significant heritage assets. There is also a need to assign probabilities of damage by using ensembles of climate models applied to heritage sites. Despite these limitations, it is important to provide managers with future scenarios based on climate models and potential damage processes that form the basis of science-based mitigation and adaptation strategies.

Acknowledgments

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Landscapes (<http://noahsark.isac.cnr.it/>), which projected climate change effects into the future. We greatly benefited from our colleagues in the NOAH's ARK project who contributed much to our understanding.

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Seismic Strengthening of Adobe Structures Using Low-Cost Materials

Mohammad Shariful Islam and Kazuyoshi Iwashita

Abstract: *Seismic deficiencies in adobe structures are often due to the brittleness and low tensile strength of the adobe block, poor bonding between the block and the mortar, and lack of structural integrity. The current study tests natural fibers, cement, and bamboo as reinforcing materials to improve the seismic resistance of adobe structures. While jute and straw are effective at improving the ductility of adobe, hemp is not, and straw causes significant loss of strength. Jute, as well as jute and cement together, improves mortar strength, while cement alone is not effective for the same purpose. Use of a bamboo grid improves both the overall building strength and structural ductility.*

Résumé : *Les défauts de résistance sismique des structures en adobe sont souvent dus à la friabilité des blocs d'adobe et à leur faible résistance à la traction, à la faible cohésion entre es blocs et le mortier, et au manque d'intégrité structurale. Cette étude teste des fibres naturelles, du ciment et du bambou en tant que matériaux de renforcement de la résistance sismique de structures en adobe. Alors que le jute et la paille sont efficaces pour améliorer la ductilité de l'adobe, le chanvre ne l'est pas et la paille induit une perte de résistance considérable. Le jute – ainsi qu'un mélange de jute et de ciment – améliore la résistance du mortier, alors que le ciment seul n'est pas efficace à cet égard. Le recours à un treillis en bambou améliore à la fois la résistance du bâti et la ductilité structurale.*

The history of adobe construction is almost as long as the history of civilization itself. However, collapse of adobe structures in earthquakes has resulted in significant loss of life and monetary resources, especially in developing countries. In spite of this, it is expected that adobe construction will con-

tinue to flourish, especially in developing countries because it is affordable and suitable alternatives do not always exist. Unfortunately, in some geographic areas little is known about how to improve the seismic performance of adobe buildings and increase their earthquake resistance. Therefore, the development of earthquake-resistant reinforcement for adobe structures is an important issue.

Seismic deficiencies of adobe structures are primarily due to the brittleness and low tensile strength of the block and poor bonding between the adobe blocks and mortar. Hence to improve seismic performance, it is necessary to increase block strength, ductility, and toughness, as well as mortar bond and strength.

The effectiveness of concrete and wooden reinforcement and wire and polypropylene mesh for improving the seismic performance of adobe structures has been investigated by various researchers (Scawthorn and Becker 1986; Tolles 2002; Paola et al. 2006). However, structural reinforcement with these materials may not be feasible for reinforcing adobe structures in developing countries due to their high cost and requirement for skilled design and construction (Islam and Kanungo 2007).

The current study tests natural fibers (i.e., straw, hemp, and jute), cement, and bamboo as reinforcing materials to improve the seismic resistance of adobe structures. In addition to evaluating these reinforcing materials on the basis of uniaxial and shake table tests, we evaluated them with respect to affordability, availability, and ease of construction and installation.

Natural fibers such as straw and grass are traditionally used to reinforce adobe. Several efforts have been made to analyze the impacts of earth/straw mixtures on building

performance (Ghavami, Filho, and Barbosa 1999; Binici, Aksogan, and Shah 2005; Bouhicha, Aouissi, and Kenai 2005). These studies have focused on strength characteristics, crack and moisture resistance, and the thermal conductivity of fiber-reinforced adobe. Fibers may also be effective in preventing shrinkage cracks and improving the elasticity, tensile strength, ductility, and toughness of the adobe material; however, earlier studies have not concentrated on these properties.

Cementing materials such as cement and gypsum are traditionally used for stabilizing adobe blocks. The effects of gypsum on adobe have been investigated (Binici, Aksogan, and Shah 2005; Degirmenci 2005), but these studies focused on the strength characteristics and the chemical and water resistance of adobe. Cementing materials might be effective in improving block and mortar strength, as well as bonding strength. Earlier studies did not look into the effectiveness of cementing materials in improving the bonding strength, ductility, and toughness of adobe.

Bamboo is cheap and widely available in many parts of the world. A grid of bamboo added to an adobe wall might be an effective way to distribute stress and may improve the ductility of the wall.

Test Program

Materials

Soils: Locally available Japanese soils were used to make adobe specimens. To attain the general adobe composition, Japanese Acadama clay (specific gravity, $G_s = 2.65$; liquid limit, $LL = 145\%$; plastic limit, $PL = 67\%$), Toyoura sand ($G_s = 2.51$; $U_c = 1.39$), and Bentonite ($G_s = 2.51$; $LL = 232\%$; $PL = 31\%$) were mixed in the proportion 2.5:1.0:0.6.

Reinforcing materials: Natural fibers (straw, hemp, and jute), cement, and bamboo were selected as reinforcements. Fully dried rice straw, jute, and commercially available hemp

were used after chopping it into short pieces (figs. 1a, 1b). Ordinary portland cement was added in a proportion of 9% by weight. Bamboo grids were made from pieces approximately 1.5 to 2.0 cm in diameter.

Preparation of Specimens and Models

Block specimen: Soils were first mixed with the reinforcing materials, and then water was mixed in vigorously by hand until the mixture was homogeneous. The mixture was poured into a steel mold 5 cm in diameter and 10 cm high. Three separate layers were added, and each was tamped with a plastic rod to eliminate voids. After 7 to 10 days the specimens were taken from the molds and stored to dry.

Sandwich specimens: To evaluate the effectiveness of the fibers and cementing materials on bond and mortar strength, sandwich specimens were prepared joining two adobe blocks with a layer of mortar 0.5 cm thick and oriented 60° to the horizontal (fig. 1c).

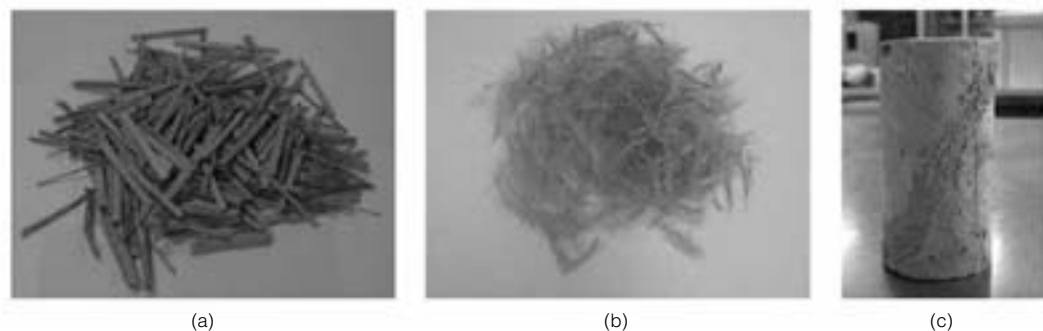
Model construction: Models were constructed on the shake table. Adobe blocks/bricks were joined with mortar beds 1.5 cm thick. The models were cured for 45 to 60 days before testing.

Experimental Setup

Uniaxial test: Uniaxial compression tests were conducted on blocks and sandwich specimens to evaluate the effectiveness of the fibers and cement on block as well as mortar properties. The tests were conducted using a series of devices, including a loading device, a digital measuring device, and a personal computer. For each group at least three specimens were tested to ensure repeatability of the test results.

Shake table test: Shake table tests were conducted on model structures to evaluate the effectiveness of the proposed reinforcing materials on the shear and out-of-plane behavior. Models were subjected to unidirectional sinusoidal excitations

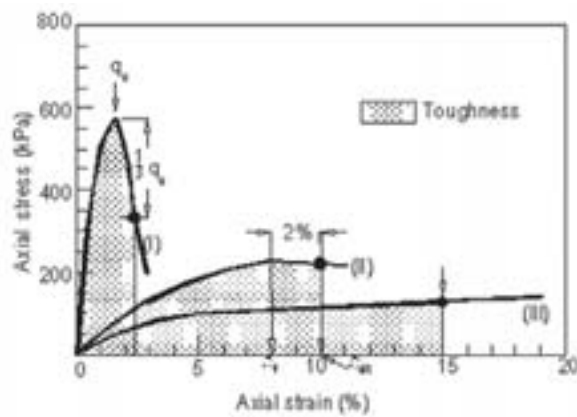
FIGURE 1 Photographs of (a) chopped straw; (b) chopped jute; and (c) sandwich specimen.



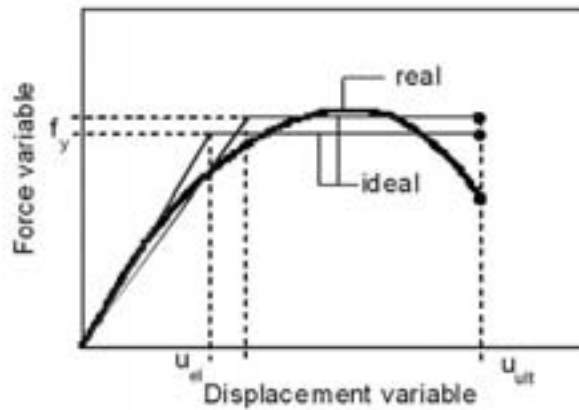
for an arbitrarily selected frequency of 15.0 Hz, varying the amplitudes of ground motion.

Parameters Used

Strength, failure strain, ultimate failure strain: Compressive strength (q_u) has been defined as the peak stress on the stress-strain curve. If there is no peak on the stress-strain curve up to 15% strain, then stress corresponding to 15% strain has been taken as the compressive strength. Failure strain has been defined as the strain corresponding to the peak stress, or 15% strain in the absence of a peak in the stress/strain curve. Figure 2a shows the strength and failure strains. As presented in figure 2a, ultimate failure strain corresponds to the



(a)



(b)

FIGURE 2 (a) Definition of compressive strength, q_u ; failure strain, ϵ_f ; and ultimate failure strain, ϵ_{ult} (point marked by arrow on the stress-strain curve indicates the compressive strength and corresponding strain is failure strain; strain corresponding to the dot on the stress-strain diagram is ultimate failure strain); and (b) definition of ductility.

$2/3q_u$ (where q_u is compressive strength), at 2% from the peak and 15% for case I, case II, and case III, respectively.

Ductility: Ductility (μ_D) is defined as the relationship of a total elasto-plastic response deformation related to the deformation in the elastic limit as stated in equation 1. Strains corresponding to $q_u/2$ and the ultimate failure point have been taken as the elastic limit and ultimate limit of displacement, respectively (fig. 2b).

$$\mu_D = \frac{u_{ult}}{u_{el}} \quad (1)$$

where u_{el} and u_{ult} are elastic strain and ultimate strain, respectively.

Toughness: Toughness has been calculated as the area under the stress-strain curve up to the ultimate failure point as shown in figure 2a.

Results and Discussions

Improvement of Block Properties

The effects of selected natural fibers on adobe block properties were evaluated through uniaxial compression tests. Typical stress-strain relationships of adobe blocks are presented in figure 3. While jute and straw effectively improve the ductility of adobe, hemp is ineffective in this respect. The addition of straw results in significant loss of strength, by about 50%. The highest value for toughness (15.39 kPa) was obtained from a jute-reinforced specimen. This value is about 50% higher than that of the unreinforced specimen, at 10.09 kPa. Although straw is effective at improving the ductility of adobe, the toughness of

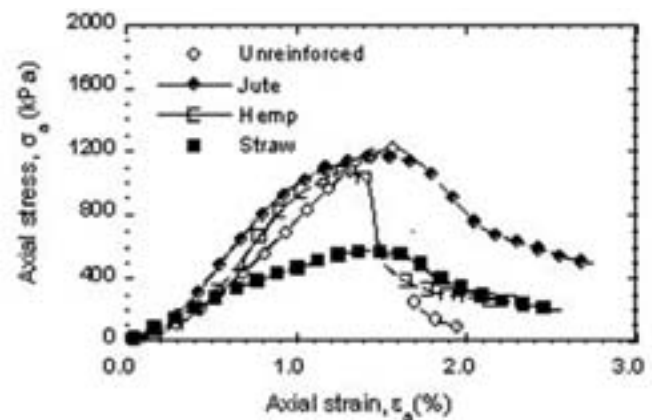


FIGURE 3 Typical stress-strain relationships of block specimens under uniaxial compression.

the straw-reinforced specimen at 8.48 kPa is about 15% lower than that of the unreinforced sample. The best values for jute were obtained by adding 2.0% jute by weight in lengths of 2 to 3 cm. In the case of straw, it was observed that 1.5% straw (by weight) in 1 to 2 cm length made the most significant improvements in the ductility of adobe block.

Photographs showing the failure patterns and detail views of the shear bands of the straw- and jute-reinforced specimens are presented in figure 4. It is seen that while unreinforced adobe breaks into smaller pieces, reinforced specimens survive at stress input levels exceeding those of the unreinforced adobe (figs. 4a, 4b). The close-up views of the shear bands reveal that fibers prevent crack growth in the shear band (figs. 4c, 4d).

From the above discussion the following conclusions can be reached.

- Unreinforced adobe is brittle.
- Jute is the best option among the tested fibers for improving the ductility and toughness of adobe block.

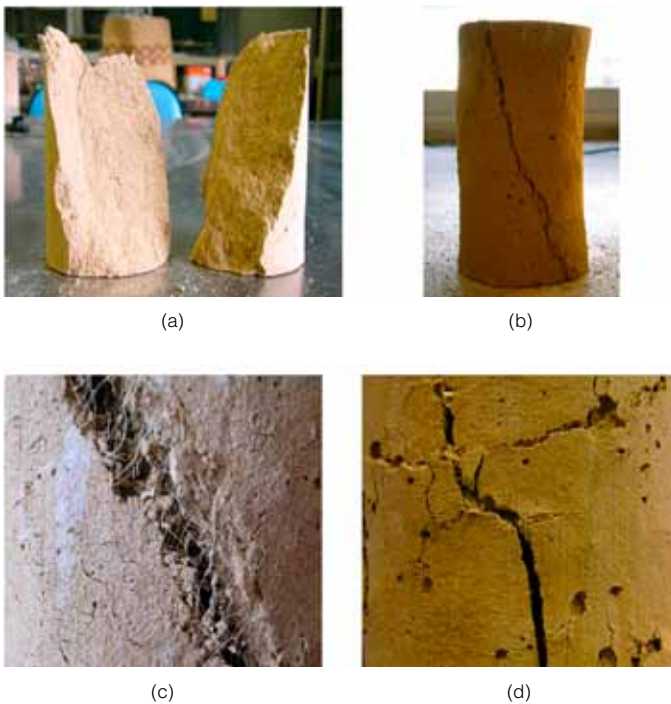


FIGURE 4 Photographs showing failure pattern of (a) unreinforced and (b) jute-reinforced block. Close view of shear band of (c) jute-reinforced and (d) straw-reinforced specimens.

Jute’s properties of flexibility and better adhesion between adobe and jute are assumed to be the reasons for its better performance.

Improvement of Mortar Properties

The effects of jute and cement on bond strength and mortar strength as evaluated by uniaxial compression tests are presented. Composition and test results of sandwich specimens are presented in table 1. Typical stress-strain relationships of the specimens are presented in figure 5a. It is observed that unreinforced mortar is very weak. Cement alone does not effectively improve the strength of the sandwich specimens; however, jute and jute and cement in combination effectively improve mortar strength. Although jute improves the strength of sandwich specimens, failure of the reinforced specimens is

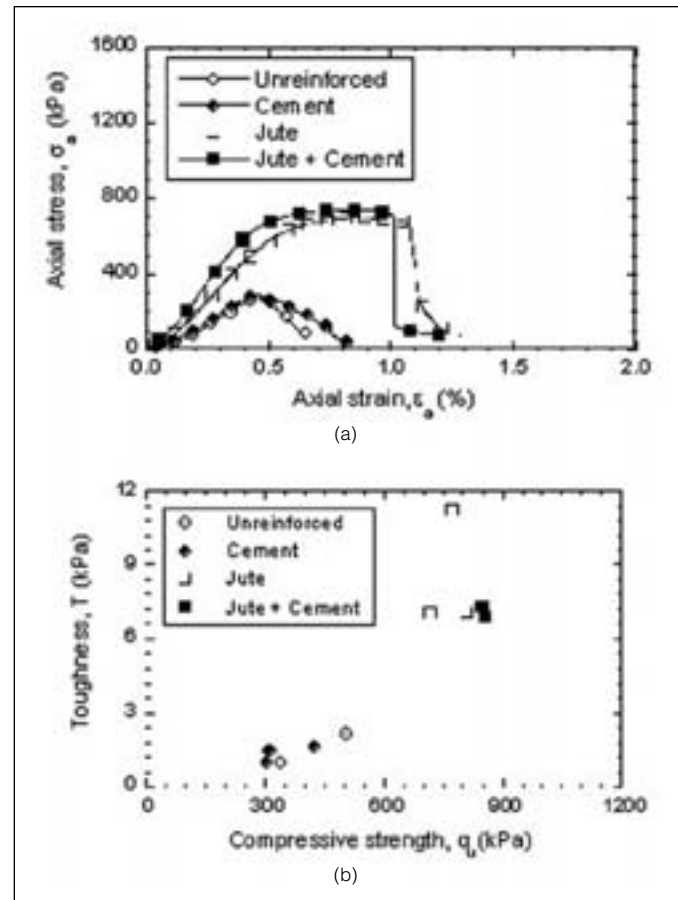


FIGURE 5 (a) Typical stress-strain relationships of sandwich specimens under uniaxial compression; and (b) relationship between compressive strength and toughness of sandwich specimens.

Table 1 Description and test results of sandwich specimens

Group	Reinforcement		Comp. Strength (kPa)	Ductility $\mu_D = \mu_{ult}/\mu_{el}$	Toughness (kPa)
	Block	Mortar			
BMS-1	Jute	Unreinforced	340 ~ 505	1.90 ~ 3.20	1.02 ~ 2.16
BMS-2	Jute	Cement	305 ~ 425	2.10 ~ 3.55	0.95 ~ 1.67
BMS-3	Jute	Jute	720 ~ 810	2.59 ~ 3.57	7.00 ~ 11.20
BMS-4	Jute	Jute + cement	850 ~ 855	2.52 ~ 3.83	6.87 ~ 7.28

usually sudden rather than gradual. The relationship between compressive strength and toughness is presented in figure 5b. It is clear that jute alone and jute and cement together are similarly effective at improving both the strength and the toughness of sandwich specimens. Addition of jute and cement together increases the strength slightly more than is the case with jute alone. However, ductility and toughness are very similar to those of the case using only jute. This indicates that cement does not have any significant role in improving the performance of the system. It is clear that jute alone is effective to improve the seismic performance.

Failure patterns of the sandwich specimens are presented in figure 6. Shrinkage cracks in the unreinforced mortar (fig. 6a) are the primary cause of poor seismic performance. Cement is not effective in preventing shrinkage cracks in the mortar. Jute alone and jute and cement together are both effective in preventing shrinkage cracks in the mortar (fig. 6b) and at improving bond and mortar strength.

From the above discussion, we can conclude the following.



FIGURE 6 Photographs showing failure pattern of sandwich specimens prepared with (a) unreinforced and (b) jute-reinforced mortar.

- Shrinkage cracks in the unreinforced mortar, which are associated with drying, are the main cause of poor seismic performance.
- Jute alone and jute and cement together are similarly effective at preventing shrinkage cracks in mortar and in doing so are also effective at improving bond and mortar strength.

Improvement of Structural Performance

Jute-reinforced mortar: In order to test the impact of jute fiber amendments on seismic performance, two models were constructed for shake table testing. Composition of the blocks and mortar of the models are presented in table 2. Model L-1 was made of unamended mortar; model L-2 was constructed of mortar incorporating jute fiber. The effects of jute on shear and out-of-plane bending behavior can be evaluated by comparing the performance of models L-1 and L-2. Significant drying cracks were observed in the mortar of model L-1; there were no cracks in the mortar of model L-2.

Models L-1 and L-2 were subjected to unidirectional sinusoidal excitations parallel to the short dimension of the models. In testing of L-1, failures near the center of the top course occurred when the base acceleration reached 250 Gal (fig. 7a). Further increases in acceleration resulted in additional movement. At that stage model L-1 was removed from the shake table for reasons of safety. Shake table testing of model L-2 was continued at increasing levels of input acceleration. Separation between blocks and mortar in the lowest course occurred at an input base acceleration of 850 Gal (fig. 7b). During the test it was observed that as soon as separation between blocks and mortar occurred in the lowest course, out-of-plane collapse was about to occur. However, the test was stopped due to the limitation of the shake table capacity. This shows that although the addition of jute results in strength improvement, jute is not effective in resisting sudden flexural failure.

From the shake table test results it can be concluded that

Table 2 Description of shake models

Model Designation	Block	Mortar	Structural Reinforcement
L-1	Burnt brick*	Cement	—
L-2	Burnt brick	Jute + cement	—
L-3	Jute	Jute	—
L-4	Jute	Jute	Bamboo grid

Note: In the case of jute reinforcement, 2.0% jute by weight was used; in the case of cement reinforcement, 9.0% cement by weight was used.

*Commercially available burnt brick was used.

**FIGURE 7** Failure pattern of (a) model L-1 and (b) model L-2.

- jute fiber improves mortar and bonding strength; and
- jute fiber in the mortar is not effective at preventing the sudden bending failure of adobe structures.

Bamboo grid: The composition of the blocks and mortar of the models is presented in table 2. Models L-3 and L-4 were subjected to a unidirectional sinusoidal wave (15.0 Hz) parallel to the short dimension of the models. Separation occurred between the block and mortar of model L-3 when the input base acceleration reached 450 Gal, as shown in figure 8a. Model L-3 was removed from the table and the test continued at increasing acceleration levels. Separation occurred between the block and mortar between the first and second courses of model L-4 when acceleration levels reached 850 Gal. Input levels were increased to 1,200 Gal, but model L-4 did not collapse. However, the test was discontinued because of the limitations of the shake table capacity. The bamboo grid effectively improved the strength of the model, and the model proved to have sufficient ductility to withstand the maximum acceleration input levels available for this shake table (fig. 8b).

**FIGURE 8** Failure pattern of (a) model L-3 and (b) model L-4.

Conclusion

The effectiveness of low-cost and locally available reinforcing materials to improve the seismic performance of adobe structures has been evaluated through laboratory and shake table tests. The primary findings of this investigation are as follows:

1. Jute and straw are effective at improving the ductility of adobe block, whereas hemp is not. The addition of straw results in reduced strength. Jute is most effective at improving the ductility and toughness of adobe blocks.
2. Shrinkage cracks in unreinforced mortar are the main cause of poor seismic performance. Jute is effective at preventing shrinkage cracks and so improves mortar strength and bonding. Cement is not similarly effective.
3. Although the addition of jute fiber improves block and mortar strength, it does not result in construction that is more resistant to sudden bending failure.
4. The addition of bamboo grids can improve the strength and the structural ductility of adobe construction.

5. Building with jute-reinforced blocks and mortar and incorporating bamboo grids in the construction can substantially improve the seismic performance of adobe structures.

Acknowledgments

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The Application of Stability-Based Seismic Retrofit Techniques to Historic Adobes and Housing in Developing Countries

E. Leroy Tolles, Stephen J. Farneth, and Dominic M. Dowling

Abstract: *This paper summarizes a range of seismic retrofit strategies on historic adobe buildings in California and looks to broader applications of these strategies for adobe structures around the world. The fundamental principle behind this research is to maximize the use of the inherent properties of adobe buildings and to minimize the intervention. This paper describes the background research that has led to the development of these techniques, provides examples of retrofits as applied to historic buildings, and illustrates recent examples of retrofits to rural adobe houses in developing countries.*

Résumé : *Cette présentation résume un ensemble de stratégies d'adaptation et d'intégration d'améliorations antisismiques destinées à des bâtiments historiques en adobe en Californie, dans une plus large perspective d'application à des constructions en adobe à travers le monde. Le principe fondamental qui sous-tend cette recherche est de développer au maximum l'utilisation des propriétés inhérentes des constructions en adobe et de minimiser l'intervention. La présentation décrit la recherche qui a conduit au développement de ces techniques et propose des exemples d'intégration d'améliorations appliqués aux bâtiments historiques ainsi qu'à des maisons rurales en adobe dans des pays en voie de développement.*

Background

This paper summarizes a range of seismic retrofit strategies for historic adobe buildings in California and looks to broader applications of these strategies for adobe structures around the world. The stability-based retrofit techniques are based on the research conducted by the Getty Conservation Institute during the 1990s as part of the Getty Seismic Adobe Project

(GSAP) and more recent research, completed in 2006, conducted at the University of Technology, Sydney, Australia.

The fundamental principle behind this research is to maximize the use of the inherent properties of adobe buildings and to minimize intervention. Although these techniques were developed for historic buildings, they are equally applicable to existing vernacular structures or new structures in developing countries. The utility of this approach for historic buildings is based primarily on the concept of minimum intervention. The value of this approach for new or existing vernacular houses is simply that minimal intervention can provide life safety at a very low cost.

Case studies in this paper highlight a range of installations on historic buildings, including a single-story building with thick adobe walls, several two-story adobe buildings with thick adobe walls, and a single-story adobe building with thin adobe walls built in the 1910s. These projects represent the full range of techniques and their applications that were researched during the GSAP program.

The stability-based approach provides an opportunity to retrofit vernacular adobe houses in developing countries in a cost-effective manner. Exterior vertical and horizontal strapping provides the easiest method for application in this setting. The expected cost of materials for these solutions ranges from U.S.\$50 to U.S.\$100 for a simple one-story, two-room house using galvanized or stainless steel straps or cables. An even lower cost is possible if local materials are used.

Research Summary

Research on the seismic performance of adobe buildings has been conducted around the world for the past few decades.

Early research was conducted at the University of Mexico in the 1970s. The largest single location for adobe research has been the Catholic University in Peru, started in the 1970s and continuing today. In the 1980s the U.S. National Science Foundation (NSF) supported research on adobe construction in which testing was conducted at Stanford University and at the University of California, Berkeley. All this research was directed toward applications for adobe houses located primarily in rural areas of developing countries.

A stability-based approach was developed from the Ph.D. research conducted by Tolles at Stanford University as part of the 1980s research supported by NSF. During this research it became clear that wall thickness has a significant impact on out-of-plane stability. It was observed that very minor improvements to a building could significantly improve dynamic out-of-plane stability of the walls (Tolles and Krawinkler 1989).

GSAP was a unique effort supported by the Getty Conservation Institute during the 1990s. As a multiyear project, it was significant in breadth, but what made the project unique was the multidisciplinary character of the research. The project team included engineers and an architectural conservator and historian, Edna Kimbro. In addition, the advisory committee was composed of architects, a conservation contractor, and other professionals involved in all aspects of historic adobe conservation and maintenance.

GSAP led to the more complete development of the stability-based approach to understanding the seismic behavior and seismic retrofit of adobe buildings. The project investigated a wide range of techniques and tools for use on historic adobe buildings. The use of external straps was motivated by observations of the use of external barbed wire on rural housing in Guatemala, as documented by Marie Elena Molina de Garcia at the Adobe 90 conference in 1990 (Molina de Garcia 1990). In addition to investigating the impact of different retrofit techniques, researchers analyzed model buildings with height-to-thickness ratios of 5, 8, and 11. For typical adobe buildings, walls with height-to-thickness ratios of 5 are quite thick; walls with ratios of 11 are considered quite thin.

The 1994 Northridge earthquake that struck the Los Angeles region during the middle of this research provided additional information to the GSAP research program. Many historic adobe buildings were seriously damaged and documented by the GSAP research team (Tolles et al. 1996). A summary of the damage typologies for adobe buildings is presented in figure 1.

The GSAP research effort included tests on many small-scale and large-scale models of adobe buildings with a variety

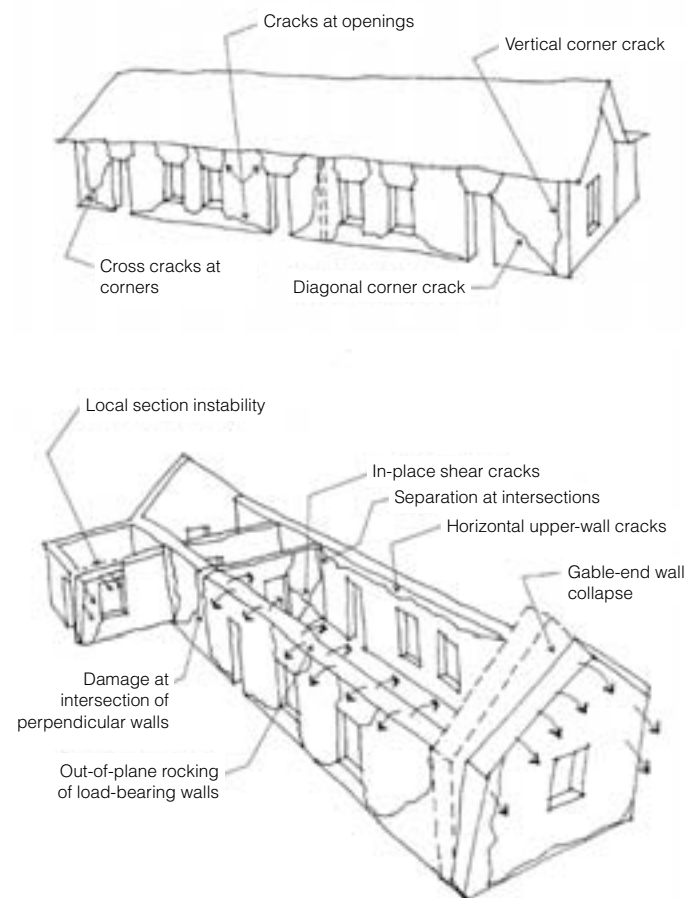


FIGURE 1 Typical failure typologies observed in adobe buildings. From Tolles et al. 1996.

of retrofitting techniques. Nine small-scale models and two large-scale models were tested on shaking tables to investigate the efficacy of a variety of seismic retrofit techniques (Tolles et al. 2000). The general goal of this research was to develop strengthening and conservation techniques that were structurally effective, minimally invasive, and cost-effective. A photograph of the large-scale, retrofitted model building that was tested in Skopje, Macedonia, is shown in figure 2. The final product of the GSAP research effort was a set of guidelines to assist in both the planning and the engineering design for the seismic retrofit of historic adobe buildings (Tolles, Kimbro, and Ginell 2002).

While the effort to continue the research for historic adobe buildings was advanced by the GSAP research, Dominic Dowling was developing retrofit methods for use on rural adobe houses in developing countries. In 2002 he coordinated



FIGURE 2 Large-scale model building tested as part of the GSAP research program. From Tolles et al. 2000

the design and construction of an adobe child-care center in El Salvador using internal reinforcement. He returned to Sydney to continue his Ph.D. research at the University of Technology, Sydney, Australia, where he worked to develop methods that are simpler and more practical to implement. In 2008 his efforts led to the retrofit of three adobe houses in El Salvador and the training of local masons in his retrofitting techniques. This retrofitting system is based on the use of an external reinforcement system that can be used on either new or existing buildings.

Theoretical Background

Adobe bricks are simply sun-dried blocks made from clayey soils. The bricks are placed in masonry walls using the same or similar soil for mortar. The walls are typically thick, with the ratio of wall height to wall thickness (slenderness ratio) ranging between 4 and 10. The walls are massive and the material is relatively weak. As a result, during earthquakes the walls will crack at moderate levels of ground motion. The primary objective of a retrofit system is stabilizing the cracked sections of an adobe building after the cracks have developed.

Thick adobe walls have substantial inherent stability. The retrofit design and the expected performance are greatly influenced by the slenderness ratio of the walls (height relative to thickness). The wood blocks in figure 3 clearly show the great difference in the basic geometry of walls with slenderness ratios of 4, 7, and 10 (the higher the number, the more slender the wall).

The condition of the adobe walls, especially at the base, plays a vital role in wall performance. It is critical to take

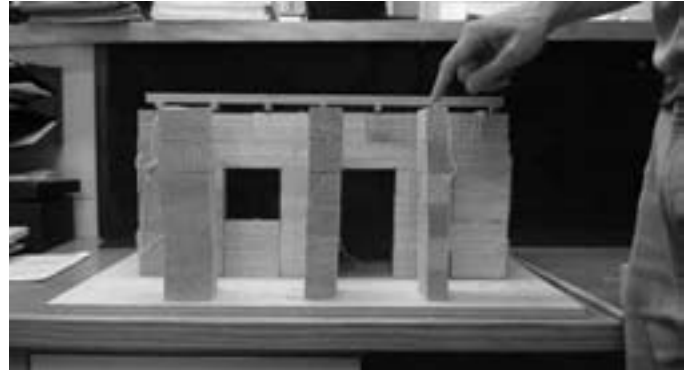


FIGURE 3 Comparison of slenderness ratios typical of adobe walls. Left to right slenderness ratios are 4, 7, and 10. Courtesy of ELT & Associates, 2007

advantage of the wall's thickness. Thickness is important because the wall literally rocks back and forth in the out-of-plane direction. If the base of the wall is in poor condition, it will lose its ability to rock, as well as any advantage gained from its overall thickness. Therefore, it is critical to examine the condition of the adobe at the base of the walls and repair or replace the adobe as necessary, as shown in figure 4.

Although adobe bricks and walls are brittle, adobe buildings can still be ductile. Retrofit systems can prevent the principal modes of failure shown in figure 2 and manage



FIGURE 4 Maintenance of the base of adobe walls is critical to their seismic performance.

the performance of cracked wall sections to prevent instability and provide safety for the building occupants. Adobe buildings have much inherent stability due to the thickness of the walls, and with well-planned retrofit measures, the durability of these buildings can be greatly improved and safety provided even during very strong seismic events.

The primary goal of a retrofit system is collapse prevention rather than damage prevention. The first step is life safety; the retrofit has to provide overall stability. After that, damage prevention can be addressed. Stability design is the focus; strength design and damage prevention are secondary.

Application to Historic Buildings

One of the largest concentrations of historic adobe buildings in the United States is in California. These include both single-story and two-story buildings. A number of these buildings have now been retrofitted with stability-based design measures. The slenderness ratios of the walls in these buildings is

typically less than 6, which makes the need for intervention less than that for buildings with thinner walls.

One example of an implemented retrofit system is the Las Flores Adobe on the Camp Pendleton Marine Corps Base near Oceanside, California. The main portion of the building is two stories. A diagram of the building with significant structural details is shown in figure 5.

The first-story adobe walls of the two-story section are over 0.85 meter thick and the slenderness ratio is 3.5. The second-story walls and the walls of the single-story portion of the building are 0.55 meter thick, and the slenderness ratio is just over 5. All the walls of this adobe building are thick, which makes the building relatively simple to retrofit.

The primary elements of the retrofit system are (a) anchorage of the roof and second floor framing to the walls; and (b) providing continuity elements at the floor and roof levels that tie the building together. The details of the retrofit design are shown in figure 5. The wood porch that surrounds the building had collapsed and was reconstructed during the retrofit and restoration of the building.

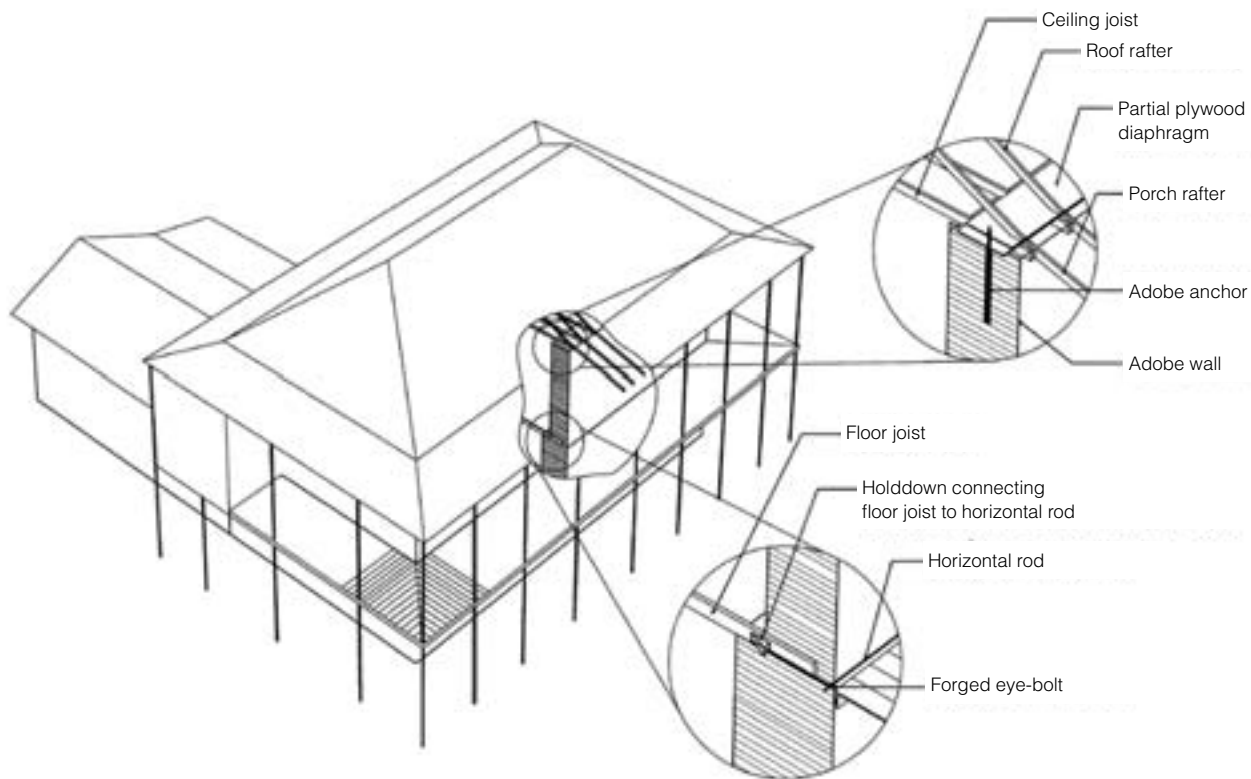


FIGURE 5 Retrofit details at the Las Flores Adobe in Camp Pendleton, California. Details for connections at the roof and floor levels and partial plywood diaphragm. Courtesy of ELT & Associates, 2002

Sometimes a higher level of intervention is warranted or desired by the owners or managers of the buildings. One of the costlier interventions investigated in the GSAP research was the use of small-diameter center core elements. Center core rods can be used in areas of an adobe building that are more sensitive to damage, when the walls are thinner or when the desire is to limit damage during larger seismic events. Center core rods in brick or stone buildings often are placed in holes that are 10 to 15 centimeters in diameter. These are rather large and strong center core elements that could overpower the adobe walls and result in the loss of a relatively large amount of adobe material. The GSAP investigated the effectiveness of using rods that were 1.2 centimeters in diameter and placed in holes that were 4 to 5 centimeters in diameter with epoxy grout. More recent work in the field has also used a nonshrink, nonmetallic cementitious grout that is both more cost-effective and easier to work with in the field. The center cores can be placed at 2 to 3 meters on center with two or three shorter anchors placed in between the full-height anchors.

Center core rods were a significant part of the retrofit strategy in a 1920s adobe at Rancho Camulos. Rods were used because the slenderness ratio was 8 and the walls had numerous window and door openings, many of them larger than those typically found in adobe walls. Center cores were also used on one of the gable-end walls at the De la Torre Adobe in Monterey and the Castro Breen Adobe in San Juan Bautista, where these walls were considered more susceptible to collapse than the other walls of the building. In addition, the Castro Breen Adobe is a two-story building, and it was difficult to anchor the gable end walls to the second-floor level. The use of center core rods allowed the gable-end walls to span from the foundation to the second-floor ceiling level without intermediate anchors at the second-floor level.

Applications to Rural Housing

The application and implementation of seismic retrofitting in rural housing is probably the most challenging area. Recent efforts in Peru, Central America, and India are starting to show that the retrofits are practical and implementation is possible. Table 1 shows the number of deaths from moderate to large earthquakes where there are significant numbers of earthen buildings.

Tolles and Dowling have been working with a U.S.-based nongovernmental organization (NGO) that is interested in developing solutions appropriate for the retrofit of adobe houses in the Middle East. The specific building type

Table 1 Deaths caused by recent major earthquakes in regions with earthen buildings

Date	Location	Number of Deaths
1972	Nicaragua	8,000
1976	Guatemala	23,000
1990	Iran	50,000
1999	Turkey	17,000
2001	India	20,000
2003	Iran	31,000
2005	Pakistan	80,000

is found in Iran. Due to the very thick earthen roofs in this area, the local NGO would like to perform shaking table tests on the suggested methods before wide-scale implementation. The proposed solution is shown in figure 6. The basic system is composed of a network of horizontal and vertical straps on the walls and horizontal straps or cables to connect across the building at the roof level.

Dowling has developed a solution that is both cost-effective and simple to implement. The system is composed of vertical cane or similar local materials, combined with horizontal wire along both faces of the walls. Through-wall cross ties connect the meshing system on each side of the wall. The

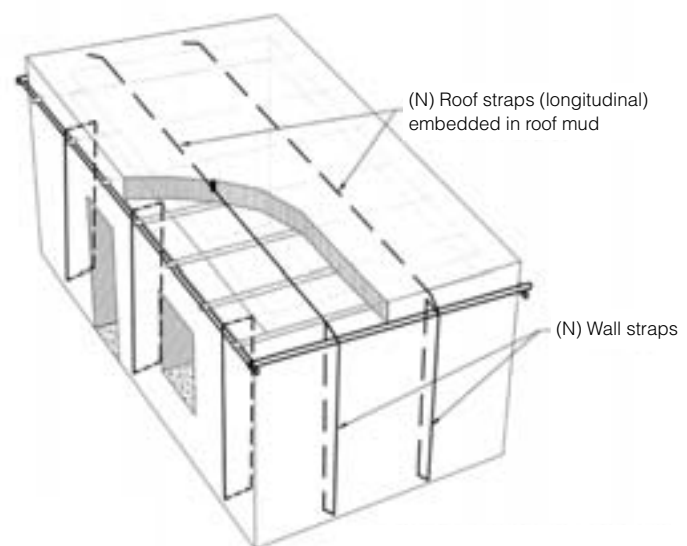


FIGURE 6 Proposed retrofit design for flat-roofed adobe houses in Iran. The primary reinforcing elements are tension-only elements made of steel wire/cable or synthetic materials. Courtesy of ELT & Associates, 2007



FIGURE 7 1:2 scale adobe house, damaged but intact after a series of severe shake table tests. Courtesy of University of Technology, Sydney, Australia, 2005

retrofit elements are also tied or anchored to the roof system. In early 2008 Dowling completed a program to retrofit several adobe houses in a rural area of El Salvador and, in the process, trained seven local masons in the theory and practice of the retrofit technique. His research was conducted at the University of Technology, Sydney, and completed in 2006. Figure 7 shows the retrofitted model house after it sustained significant damage (Dowling 2006); figure 8 is an example of successful retrofit in El Salvador. Dowling is currently working



FIGURE 8 Reinforced adobe house, El Salvador. Courtesy of QuakeSafe Adobe, 2007

to organize a similar implementation and training program in India. The material cost for both of these solutions is between U.S.\$50 and \$100.

Summary

Research over the past few decades has led to the development and refinement of seismic retrofit systems for both historic and new adobe buildings in rural areas of developing countries. The systems for historic adobe buildings are bound by the need for minimal intervention and those for rural housing are primarily constrained by cost. The most effective means for retrofitting both types of buildings is to take advantage of their wall thickness, which allows the buildings to crack during moderate to large earthquakes, and to install simple measures to manage the performance of the cracked building so that collapse is prevented (or significantly delayed) and the lives of the occupants are protected.

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Using Polymer Grid as Seismic Flexural Reinforcement in Historically Significant Adobe Buildings

Daniel Torrealva, Mary Hardy, Cecilia Cerron, and Yvan Espinoza

Abstract: *This paper investigates the use of polymer grid as seismic reinforcement in historically significant adobe buildings. Adobe houses reinforced with a polymer grid (applied externally to both sides of the wall) were tested on a unidirectional shaking table. Experimental results showed excellent structural behavior: the grid embedded in the mud plaster worked well from the initial through final stage of testing. The grid works as a composite material by taking the tension as the adobe takes the compressive stresses. In-plane cyclic shear tests and out-of-plane bending tests on reinforced walls have also been performed to determine basic engineering characteristics. This retrofit method promises to be a viable solution for both new and existing adobe construction.*

Résumé : *Cette communication étudie l'utilisation d'un grillage en polymère comme renforcement parasismique dans des bâtiments historiques en adobe. Les maisons en adobe renforcées avec un grillage en polymère (appliqué extérieurement des deux côtés du mur) ont été testées sur une table vibrante unidirectionnelle. Les résultats expérimentaux ont prouvé l'excellent comportement structural : le grillage enchâssé dans l'enduit à base de terre a donné de bons résultats du début jusqu'à la fin des essais. Le grillage fonctionne comme un matériau composite en résistant à la tension, alors que l'adobe subit la compression. Des essais de cisaillement cycliques dans le plan et des essais de déformation hors plan sur des murs renforcés ont également été réalisés afin de déterminer les caractéristiques d'ingénierie de base. Cette méthode d'adaptation promet d'être une solution viable pour les bâtiments en adobe, nouveaux ou existants.*

Among the many losses produced by earthquakes, the loss of earthen heritage is especially significant. Cases such as the Bam citadel in southern Iran, which was almost completely destroyed by an earthquake in 2003, focused attention on the problem of reducing the seismic vulnerability of historic earthen buildings while at the same time satisfying the minimum-intervention criteria for conservation.

Structural interventions in historically significant buildings must achieve engineering goals while protecting heritage values. International conservation charters call for the preservation of original construction materials, along with evidence pertaining to historic construction technologies and architectural typologies. Therefore, structural interventions that improve life safety and assure survival of the monument for the future must be executed in a way that preserves the building's physical integrity. Since other compatible materials and techniques may be developed in the future, structural interventions should not only be kept to a minimum but also be durable and reversible to the greatest extent possible. In other words, the objective is to achieve maximum safety with minimum intervention.

In this context and as part of a joint research project between the Getty Conservation Institute and the Catholic University of Peru carried out in 2004–5, an industrial polymer geo-grid was used as external reinforcement for earthen buildings. Earthen model houses at three-quarter scale of the original were externally reinforced with biaxial geo-grid on both sides of the wall and connected through it with nylon threads. The models were then subjected to several seismic simulation tests in one direction to demonstrate the effectiveness of the polymer reinforcement in maintaining the stability of the building even in strong motion. This intervention technique

promises to be a viable solution for new and historic earthen buildings, except when wall plasters and other coverings are character-defining features.

Geo-Grid Alternative

In 2004 the Catholic University of Peru initiated a series of experiments in which several polymer grids were tested as possible seismic reinforcement for earthen buildings. After the static and dynamic tests (the variables were the type of grid and its reinforcement configuration) it was concluded that the biaxial geo-grid placed on both sides of the wall, and connected through it with polystyrene threads and plastered with mud mortar, is a highly compatible and efficient reinforcement that eliminates the seismic vulnerability of earthen buildings. The next step was to investigate the mechanical characteristics of this new mud-grid composite material through its behavior during horizontal in-plane cyclic shear tests and out-of-plane bending tests.

Seismic Simulation Test on Square Houses

Construction Procedure

The reinforcing geo-grid requires standard properties of strength and stiffness. The grid tested (fig. 1) is fabricated from high-density extruded sheets punched with a precise and regular pattern of circular holes. The grid is then stretched in both directions at controlled temperature and tensile force in order to obtain a biaxial grid with square openings, rigid joints, and flexible ribs.

As a first step the plaster of the wall must be removed before the grid is placed on both sides of the wall. To fix the grid to the wall, it is necessary to drill 3/8-inch holes at vertical and horizontal distances of 40 cm and tie both sides with



FIGURE 1 Piece of geo-grid. Photo: Daniel Torrealva



FIGURE 2 Square house reinforced with geo-grid, with mud plastered on one half of the module and not on the other half. Photo: Daniel Torrealva

polyester twine. It is not necessary to fill the holes after tying. Commercially available geo-grids come in rolls 3 to 4 m wide by 50 to 75 m long. The geo-grid must be placed on the walls in such a way that it covers the wall surface continuously in the horizontal direction. Finally, the grid must be covered with a mud-based plaster. In the test model only half of the house was plastered to determine the influence of the plaster on performance (fig. 2).

Experimental Results

The model was subjected to seven seismic motions with peak accelerations of 0.15 g, 0.30 g, 0.60 g, 0.80 g, 1.0 g, and two motions of 1.2 g. The sequence was derived from a record of the Peruvian earthquake of May 31, 1970. The tests demonstrated that placing an external polymer grid on both sides of the wall, connected through its thickness, is an effective way to avoid partial or total collapse of adobe buildings, even in severe earthquakes.

If the grid is not covered with mud plaster, the initial strength is the same as that of the unreinforced wall, but the grid starts working after the wall is cracked. When the wall cracks, the grid confines the different broken wall sections, avoiding partial or total collapse. Mud plaster applied over the grid greatly increases the initial shear strength and the stiffness of the wall. By controlling the lateral displacements, it is highly effective in preventing cracking of the wall.

Seismic Simulation Tests on a Nubian Vault

As part of a Health Ministry project carried out in rural areas by the nongovernmental organization Amares, we had the opportunity to test the effectiveness of this reinforcing technique on an earthen Nubian vault. Two Nubian vault models were subjected to the same series of dynamic simulation tests on the shaking table. Model 1 (fig. 3) was a bare model, and Model 2 was externally reinforced with the geo-grid but without plaster. The plaster was not placed on the wall surfaces because of weight limitations. The test series was the same as the one used in the square house model. The direction of shaking was coincident with the transversal section of the vault (fig. 4).

The reinforced vault resisted greater seismic intensity motions than the unreinforced vault. The application of the geo-grid prevented the collapse of the retrofitted vault and improved the inelastic deformation capacity of the earthen vault. The unreinforced vault collapsed when subjected to moderate seismic motions.

Shear Strength of Adobe Walls

With respect to earthquake resistance, one of the main features of structural earthen walls is the in-plane shear strength that can be measured in cyclic horizontal shear tests by distributing the horizontal force across the net horizontal cross-sectional area of the wall. Three walls of the same architectural



FIGURE 3 Nubian vault, without reinforcement of geo-grid and without mud stucco. Photo: Daniel Torrealva

configuration were tested in different projects. Blondet et al. (2005) reported on comparative tests of a bare wall and a grid-reinforced wall without plaster. A third wall was tested in 2007 with grid reinforcement and plastered with mud (fig. 5). The results show that reinforcing the wall with geo-grid and mud plaster resulted in an increase in initial strength of 40 percent



FIGURE 4 Nubian vault without reinforcement of geo-grid and without mud stucco after seismic simulation test.

Photo: Daniel Torrealva



FIGURE 5 Wall with reinforcement of geo-grid and plastered with mud stucco. After cyclic shear test.

Photo: Daniel Torrealva

and an increase in the ultimate strength of 150 percent with respect to the unreinforced wall. In the absence of plaster, the reinforcement only provides additional displacement capacity relative to the unreinforced wall. In addition, covering the geo-grid with mud plaster resulted in a significant increase in the absorbed and dissipated energy, with increased capacity for horizontal displacement. At high energy inputs, large portions of the plaster detached from the wall, diminishing the horizontal force while maintaining a displacement capacity similar to the unplastered model's (fig. 6).

Out-of-Plane Bending Resistance of Adobe Walls

Another important structural characteristic of an adobe wall is its out-of-plane bending capacity, which can be measured by conducting out-of-plane horizontal force tests. Three 0.80 by 1.60 m walls with a thickness of 0.25 m were subjected to loading and unloading tests. The walls were horizontally supported at the bottom and top, resulting in a simply supported bending type of behavior. The tests confirmed that the grid embedded in the plaster creates a composite material where the adobe wall takes the compression forces and the grid takes the tension forces (fig. 7); these work in unison until detachment of the plaster, which occurred at the ultimate stage of testing. The reinforced panel can undergo twenty-five times more horizontal displacement than the unreinforced panel (fig. 8). In addition, there is a significant increase in bending capacity.



FIGURE 7 Wall tested in flexure out of plane, last phase. Photo: Daniel Torrealva

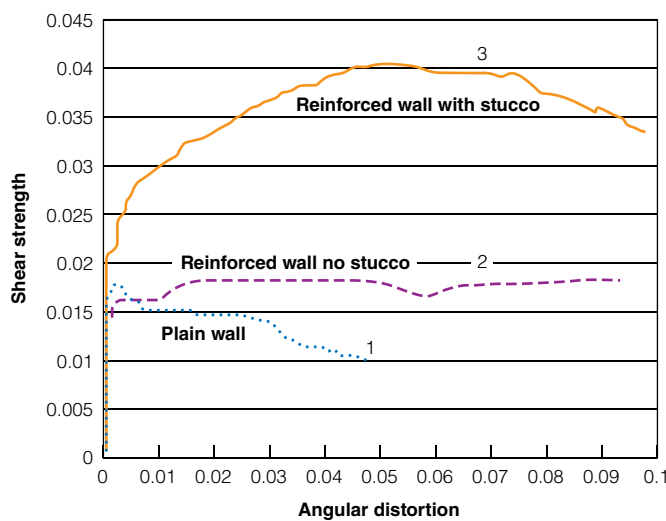


FIGURE 6 Shear strength (MPa)–distortion evolvement curves for three walls.

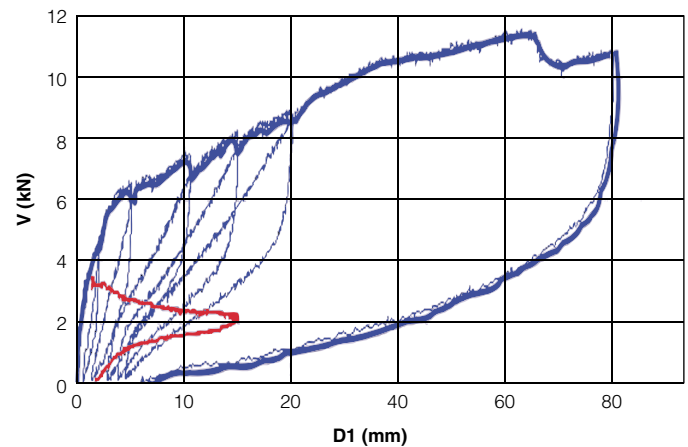


FIGURE 8 Force-displacement evolvement curves for unreinforced and reinforced walls.

Conclusion

Geo-grid reinforcement placed externally on the wall surface is very effective in drastically reducing the seismic vulnerability of earthen buildings, even those with different architectural configurations. As a result of its compatibility with natural soil and its high tensile strength, stiffness, and durability, the biaxial geo-grid is suitable for use as an externally applied seismic reinforcement on earthen buildings.

Geo-grid embedded in mud plaster creates a composite material providing tensile resistance and displacement capacity to the whole structure. It is now possible to compute the shear and bending stresses mathematically. This technique, although intrusive from the point of view of conservation, can be applied to houses in historic centers, rural housing, and historic buildings where the wall finish is not a character-defining feature. By providing a means to satisfy the safety requirements of the construction codes, this technique can help to legitimize earth as a construction material and allow the tradition of building with earth to continue in earthquake-prone countries.

Many other seismic simulation tests have been performed varying the reinforcement configuration, grid type, and orientation of the house regarding the direction of shaking. All of them have demonstrated that uniform and compatible external reinforcement placed continuously on the walls drastically reduces the seismic vulnerability of earthen buildings and can even eliminate it.

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An Experimental Study of the Use of Soil-Based Grouts for the Repair of Historic Earthen Walls and a Case Study of an Early Period Buddhist Monastery

Julio Vargas, Bhawna Dandona, Marcial Blondet, Claudia Cancino, Carlos Iwaki, and Kathya Morales

Abstract: *Earthen buildings are highly vulnerable to seismic events. The limited ductility of earthen materials and their inability to fully absorb energy produced by earthquakes causes cracks in the walls and structural damage. The paper addresses the action to be taken after structural cracks have formed. The first part is a case study analyzing the damage that occurred to an Early Period (ninth–eleventh century) Buddhist monastery in Ladakh, India, after a recent earthquake. The earthen walls have significantly lost their original strength and stiffness, which can lead to structural instability, fabric loss, and total collapse. The second part of this paper presents preliminary results of an experimental testing program performed in Peru demonstrating how the original strength of significantly cracked adobe walls can be restored by injecting unamended earthen grouts into the cracks and voids.*

Résumé : *Les bâtiments en terre sont très vulnérables aux séismes. La faible ductilité des matériaux en terre et leur incapacité à totalement absorber l'énergie produite par les séismes entraînent des fissures dans les murs et des dommages des structures. Cette communication traite de la démarche à suivre après l'apparition de fissures structurales. La première partie concerne une étude de cas sur l'analyse des dommages subis par un monastère bouddhiste de la première période (IX^e–XI^e siècle) situé à Ladakh, Inde, après un récent séisme. Les murs en terre ont en grande partie perdu leur résistance et leur dureté d'origine, ce qui pourrait entraîner une instabilité structurale, une perte de matériau et un effondrement total. La deuxième partie de l'article présente les résultats préliminaires d'un programme expérimental réalisé au Pérou qui montre comment la résistance d'origine de murs en adobe gravement fissurés peut être restaurée par injection de coulis de terre non amendée dans les fissures et les vides.*

Earthen buildings are primarily classified as unreinforced masonry structures. They are extremely vulnerable to earthquakes and prone to sudden collapse during a seismic event. Historic earthen sites located in seismic areas are at high risk of being heavily damaged and, over time, of collapsing. In the past many architects and conservators vouched for the strength of traditional earthen structures simply because they had survived past earthquakes. The reality is that a seismically damaged earthen structure is like a person who has suffered many heart attacks: having survived earlier attacks is no guarantee that, without intervention, the next will not be fatal (Tolles, Kimbro, and Ginell 2002).

This fact was made tragically clear after the earthquake in Bam, Iran, that occurred just after the 9th International Conference on the Study and Conservation of Earthen Architecture, Terra 2003, in December 2003; in Kashmir, Pakistan, and India in 2006, where the epicenter was located very close to the Mangyu Monastery (discussed below); and in Pisco, Peru, in August 2007, which severely damaged many historic earthen buildings.

For decades structural engineers, architects, and conservators have been studying suitable techniques for seismic retrofit of historic earthen structures. The Getty Seismic Adobe Project (GSAP), conducted by the Getty Conservation Institute (GCI) from 1992 to 2002, developed guidelines for the design of stability-based seismic retrofits (Tolles et al. 1996; Tolles et al. 2000; Tolles, Kimbro, and Ginell 2002); however, several of these techniques are difficult to implement for earthen structures with decorated surfaces or where there is limited access to technology and appropriate materials for center core rods, plastic pipes, and nylon straps.

After reviewing these limitations, the Earthen Architecture Initiative (EAI) of the GCI held a colloquium at the Getty Center on April 11–13, 2006. The event brought together fifty professionals from around the world with expertise in the seismic strengthening of historic earthen architecture. Formal papers and panel discussions focused on case studies, research, and testing of seismic retrofitting methodologies, guidelines, and building codes that balance safety with conservation of cultural heritage. One of the recommendations resulting from that event was further investigation of repair techniques for seismically produced structural cracks that maximize the preservation of historic fabric.

Previously, the GCI, in collaboration with Julio Vargas, had become an adviser to Bhawna Dandona on her master's thesis in historic preservation at the University of Pennsylvania. Dandona's study focused on preparing a structural assessment of the Early Period Buddhist monastery of Mangyu to better understand the origin of structural cracks and explore possible repair techniques (Dandona 2005).

Site History

Mangyu is an exceptional example of Early Period monastic architecture dating from 1000 to 1300 C.E. (Khosla 1979). Mangyu Monastery is located in Ladakh, India, also known as "Little Tibet," and is considered part of the western Himalayan region. Its proximity and strong cultural connection to western Tibet make it a valuable living record of the social and cultural history of the region in the twelfth century. Due to its religious, architectural, and artistic merit, it is considered one of the most significant sites in the region.

The Himalayan region and mountain belts were formed as a result of continental drifts and seismic activity and form one of the three chief tectonic subregions in India (Murty 2004). Mangyu lies in Zone IV, which is seismically very active, posing substantial risks to the region's buildings and their occupants with respect to life safety and building preservation (Murty 2004).

Structural Diagnosis

Prior to making recommendations for building interventions, a structural assessment and diagnosis of the monastery was completed. Inspection revealed that the slenderness ratio (height/width) of the walls is low, which has helped prevent the building from collapsing during earthquakes (Tolles, Kimbro, and Ginell 2002). Also, small openings supported by

wooden lintels with proper bearings on both sides offer some structural stability. However, building strength has been compromised to some extent because the wall-roof connections are missing and the structural elements rest directly on the load-bearing walls without a wall plate or bond beam. There is also considerable moisture damage at the base and top of the walls, and there are significant structural cracks, which are among the most critical factors affecting the building's stability. Generally, cracks appear when applied stresses exceed the tensile strength of the wall materials. As previously mentioned, cracking is a cumulative process; with each successive seismic event, cracks become more severe and/or prevalent, decreasing the structure's stability. The main types of cracks observed at Mangyu include cracks at corners and intersections of perpendicular walls, at openings, and below beams (fig. 1).

Vertical cracks observed near wall intersections seem to be active and have likely formed from the lack of connections between the walls. In addition, there are diagonal cracks in the walls where corners are unrestrained. Since there is no mechanical connection between the roof and the walls in the building (the roofing system simply rests on the load-bearing walls), loads—which increase considerably in an earthquake—are transferred directly to the walls. The consequences are cracks in the upper middle regions of the walls, independent of the cracks found in the corners (fig. 2).

Most of the walls are uneven and out of plumb and have prominent bulges, probably due to the lack of connections between the roof and the bearing walls. In some locations, roof elements, including the primary beams, joints, and brackets, have slipped and shifted from their original position, causing stress to the whole structural system. In addition, moisture damage from roof leaks decreases the load resistance of the

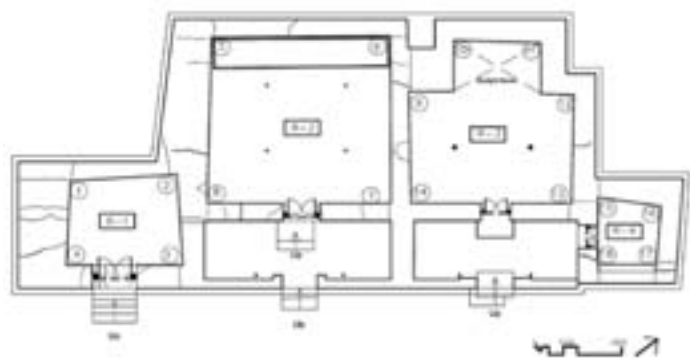


FIGURE 1 Plan delineating cracks in the walls. AutoCAD © drawings: Bhawna Dandona

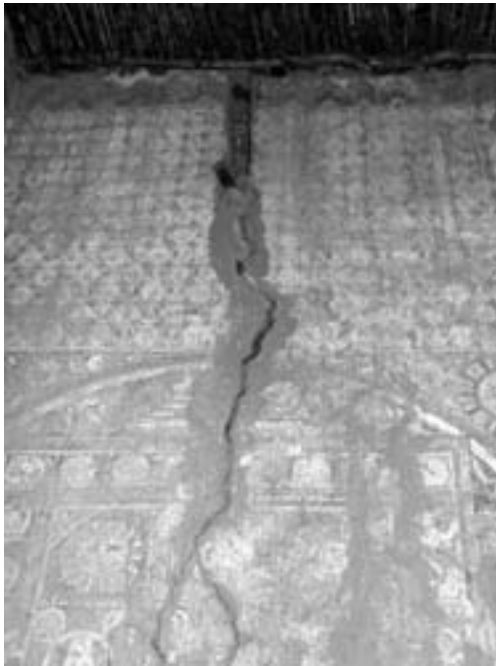


FIGURE 2 Vertical cracks starting at ceiling. Photo: Bhawna Dandona



FIGURE 3 Erosion at the base of the wall. Photo: Bhawna Dandona

upper part of the wall and affects the wooden structure of the roof, which could lead to wall collapse. Furthermore, moisture from capillary rise weakens the bases of the walls (fig. 3).

Criteria for Intervention

Condition assessment indicated the need for significant structural intervention, but intervention at this level can seriously alter, even damage, the decorated surfaces. It was important to design an intervention protocol to safeguard the building's integrity. Based on a review of literature devoted to grouting for the repair of nonstructural cracks, the following repair criteria were selected: minimal intervention, retreatability, use of locally available material, ease of application, cost-effectiveness, and recovery of structural strength and continuity.

Testing

The goal of the testing program was to determine the feasibility of repairing cracked earthen walls by grouting with unamended soil, or mixtures of soil stabilized with cement, lime, or gypsum (Vargas 1979; Mattone et al. 2005). Adobe masonry consists of courses of sun-dried blocks joined by mud mortar.

The strength of the masonry comes largely from the adhesion and resistance of the mortar. There are many alternatives for improving the quality of mortars to attain masonry that is more resistant to seismic and other movement (Vargas 1979). The mortar joints are generally the weak areas of the wall, as cracks from shrinkage during drying reduce the adherence of the mortar to the blocks. It is possible that a similar phenomenon occurs with grouts injected into the fissures in the walls. The quality of construction also has a great influence on the strength of adobe walls.

It seems reasonable to assume that the strength of the masonry walls repaired with soil-stabilized grouts is a combination of the grout and the original mortar properties. However, while it is logical to use a stabilized soil for grouting in order to obtain greater wall strength, it is important to investigate the use of more compatible soil-based grouts to recover some of the original resistance of the wall.

We decided to investigate the effects of mortar thickness and the addition of mortar amendments on the strength of adobe masonry. One hundred fifty indirect tension tests were performed on adobe "sandwiches" made of adobe blocks joined together with a layer of mortar made of clay-based, unmodified soil collected from the Pontificia Universidad Católica del



FIGURE 4 Indirect tension test.

Perú (PUCP). The soil composition is approximately 52% sand and gravel and 48% silt and clay and is classified as CL (lean clay) by the Unified Soil Classification System (USCS). Ten different soil mixes, combined with various amendments and of five nominal thicknesses (2 to 10 mm), were tested; three sandwiches were made of each mix and thickness. The mortars studied consisted of (1) unamended soil; or (2) soil stabilized with cement in 5%, 7%, and 10% ratios, soil stabilized with lime (5%, 7%, and 10%), and soil stabilized with gypsum (5%, 10%, and 20%).

Diagonal compression tests were conducted on fifty samples. Fifteen of those sample sandwiches were repaired by injecting various grout mixtures made with the same materials and in the same proportions as those used for the mortars.

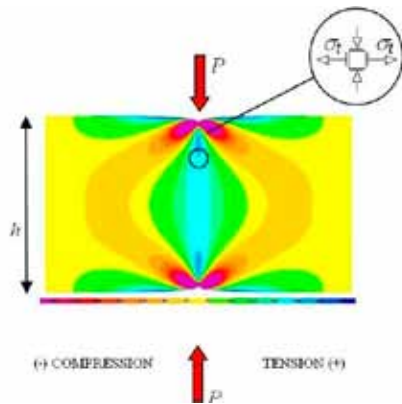


FIGURE 5 Distribution of normal horizontal stresses.

The indirect tension test consists of vertical compression of a sandwich of two adobe blocks joined by mortar, forming a vertical and centered joint (fig. 4). The force applied causes fairly uniform tension stresses at the mortar-block interface. The tensile strength of a sandwich is expressed by $\sigma_t = \alpha (P/A)$, where P is the breaking force, A is the area of the mortar interface ($A = lh$, where h is the height and l is the length of the sandwich), and α is a dimensionless factor to estimate the maximum tension stress at the interface (fig. 5).

The results of indirect tension tests revealed that assemblies cured for seven days and made with thinner mortars achieved greater strength. It was difficult to make assemblies with mortar joints less than 2 mm thick because they failed due to the irregular faces of the block. To understand the influence of mortar thickness on the strength of adobe masonry, an additional series of assemblies were built with thinner mortars. After forty-eight hours, the samples were disassembled and the number and width of cracks were recorded. Results showed that the number of cracks was approximately the same in all the opened assemblies, but crack width was narrower in thinner mortars (fig. 6).

The strength of assemblies prepared with mortars made with soil and gypsum (5%, 10%, and 20% by weight) was generally higher than those obtained with lime or cement additives. However, only the addition of 20% gypsum resulted in strength values that exceeded those of mortars made with natural PUCP soil (fig. 7). This result may be attributable to volume increase of the gypsum, thereby avoiding the drying shrinkage and cracking of earthen mortars. Decreases in microcracking may result in strength improvements of the mortars.

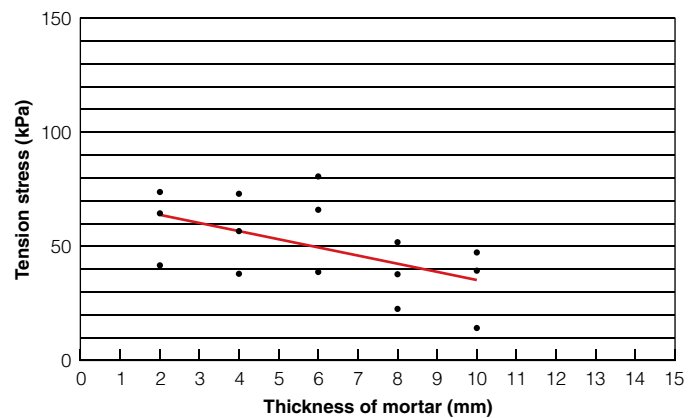


FIGURE 6 Tension stress in the mortar-adobe interface. The thinner mortars tend to improve tension strength.

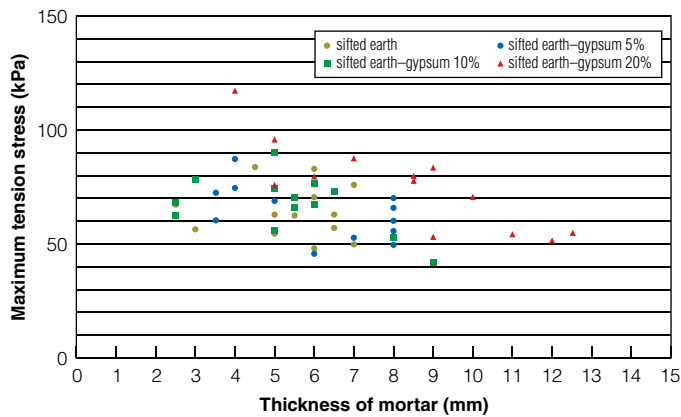


FIGURE 7 Results of indirect tension tests on adobe assemblies with different stabilized soils. Only the mortars with 20% gypsum achieve greater strength than those of sifted soil.

Testing of Repaired Assemblies

To investigate if the mortars that produced stronger assemblies were also suitable as injection grouts to repair adobe masonry, a number of adobe masonry specimens were tested in diagonal compression, repaired by injection of soil-based grouts, and tested again to measure the degree of strength recovery. Since gypsum was the only stabilizer that produced an increase in the strength of the adobe masonry, we decided to test grouts formulated with unamended PUCP soil and soil stabilized with gypsum.

The diagonal compression test consists of applying a compressive force at two opposite corners of a small square masonry wall. The behavior of the specimens is representative of the seismic behavior of adobe masonry (Vargas et al. 1986). The distribution of forces is similar to that applied during the indirect tension test; therefore, the type of failure expected is a crack between the points where the force is applied (generated by the dominant tension stresses) (fig. 8a). The adobe masonry specimens were tested in diagonal compression until failure. They were then rotated and grouted.

The injection repair process was as follows:

1. Cracks were superficially sealed with gypsum, leaving opening holes of 3 mm diameter to later inject the grout.
2. After the gypsum cured, water was injected into the holes to increase grout adhesion and improve flow.
3. The grout was injected through the holes until all of them were filled.

4. The gypsum was removed and the exterior surface retouched to achieve an acceptable finish.

After curing for approximately three to four weeks (depending on the weather), the repaired specimens were moved back to the laboratory and tested again in diagonal compression until failure. Values were compared to those obtained from testing of the original, unrepaired samples (fig. 8b).

Results showed that the repaired specimens were stronger than the originals, and the cracks did not occur in the original locations. The most interesting and important result was that the assemblies repaired with unamended grouts were 20% stronger on average than the original samples. This shows that additives were not required to fully recover the strength of the cracked adobe walls (fig. 9).

Conclusions and Recommendations

1. Mangyu Monastery needs immediate intervention. Most of the deterioration to be addressed was caused by structural cracking and damage due to moisture penetration.
2. The goal of repairing should be to restore structural continuity with uniform distribution of loads along the walls and maximum retention of the decorated surfaces.
3. The results obtained in the PUCP experimental program indicate that it is possible to repair structural cracks in historic earthen buildings by means of injection of unamended soil-based grouts.

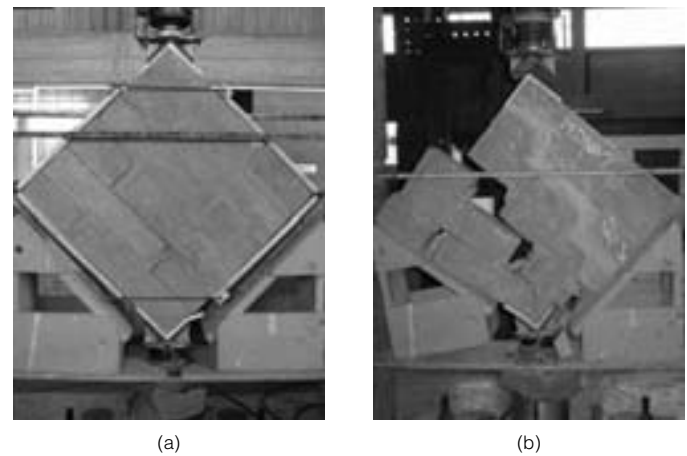


FIGURE 8 (a) Diagonal compression test: tested wall section; (b) cracking of the repaired wall section followed a path distinct from the original.

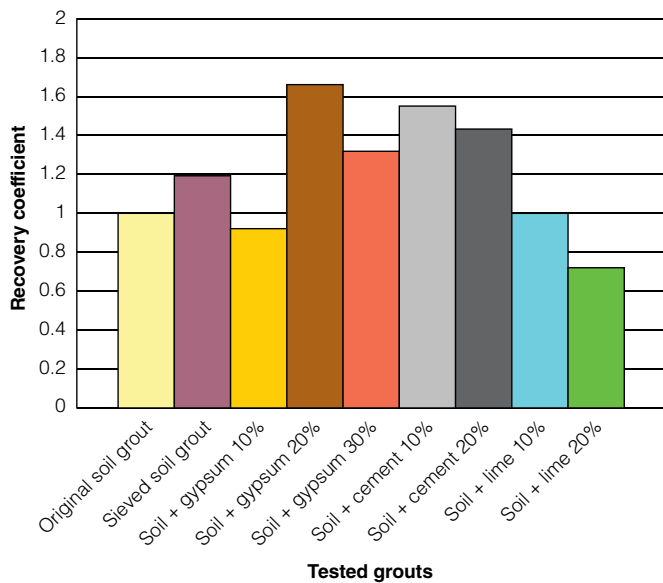


FIGURE 9 Results of the diagonal compression test of repaired small square adobe masonry walls with different soil-based grouts.

4. The use of unamended PUCP soil-based grouts was effective in restoring the original strength of wall specimens subjected to diagonal compression tests.
5. Good quality of workmanship is essential to ensure the effectiveness of the repair.
6. Adobe masonry built with thinner mortar joints is stronger. This may suggest that the repair of thinner cracks with soil-based grouts may be effective in strength recovery.
7. The strength of repaired adobe walls was increased by adding cement or gypsum to soil-based grouts. Material compatibility issues may prevent the use of these materials in historic monuments. Results of tests on lime-amended grouts were inconclusive and should be further investigated.

The use of soil-based grouts for in situ repairs at Mangyu Monastery and similar sites has tremendous potential. Additional research is needed on techniques to repair thinner cracks in thicker adobe walls and on how to make structural repairs without significantly altering the decorated surfaces. This experimental research proposes new repair protocols that are consistent with currently accepted stability-based interventions developed by GSAP and its partners.

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Study of the Structural Behavior of Traditional Adobe Constructions

Humberto Varum, Aníbal Costa, Dora Silveira, and Maria Fernandes

Abstract: *In the Aveiro district (Portugal) adobe is found in abundance in rural and urban buildings. Many of these buildings, however, have extensive structural damage. Due to a lack of information concerning the mechanical properties and structural behavior of adobe masonry in this area, we developed an experimental program at the University of Aveiro. The mechanical behavior of adobe units, earthen mortars, and small wallets was studied. Laboratory and in situ tests on full-scale walls were performed. Test results provided insight into the behavior and structural fragility of adobe and earthen architectural elements and will help in future assessments of existing buildings and increasing their structural strength.*

Résumé : *Dans la région d'Aveiro (Portugal) il existe de très nombreuses constructions rurales et urbaines en adobe. Nombre de ces bâtiments présentent cependant des dégâts importants des éléments de structure. Pour répondre au manque d'information sur les propriétés mécaniques et le comportement structural de la maçonnerie en adobe dans cette région, nous avons développé un programme expérimental à l'université d'Aveiro. L'étude a porté sur le comportement mécanique des constructions en adobe, des mortiers de terre et des petits murs doublés. Des essais en laboratoire et in situ ont été réalisés sur des murs à l'échelle réelle. Les résultats ont fourni des renseignements sur le comportement et la fragilité structurale de l'adobe et des éléments architecturaux en terre, ce qui va faciliter à l'avenir l'évaluation des bâtiments existants et le renforcement de leur résistance structurale.*

In the past earth was a very common construction material in Portugal. Adobe and rammed earth were used predominantly until the first half of the twentieth century, when cement

became the most common building material. Rammed earth was more prevalent in the south and adobe in the littoral center, especially in the Aveiro district (Oliveira 1992; SAT 1992). According to information obtained from the municipality, about 25 percent of the existing buildings in Aveiro city are made of adobe. It is estimated that the proportion is as high as 40 percent in the district. Adobe can be found in various types of construction: rural and urban dwellings, many of which are still inhabited (fig. 1); service buildings such as churches, schools, and warehouses; boundary and garden walls; and water wells. A substantial number of urban adobe buildings have cultural, historical, and architectural significance, some of them in the Art Nouveau style. A more detailed description



FIGURE 1 Example of an existing rural adobe dwelling, located in the Aveiro district. Photo: D. Silveira, 2008

of the predominant construction types can be found in Varum et al. (2006).

Adobe buildings in the Aveiro district were built based on knowledge accumulated from experience transmitted from generation to generation. The builders, though, were not necessarily concerned with seismic safety. The rehabilitation and strengthening of existing adobe construction to withstand seismic activity has been disregarded for decades. These structures are not properly reinforced, so when earthquakes occur they are left with numerous structural anomalies and deficiencies. Structural rehabilitation of existing adobe construction is urgently needed. This presents difficulties due to the lack of information concerning the mechanical properties and behavior of adobe masonry in this area. Mechanical characterization of existing adobe masonry is essential for rehabilitation and strengthening projects, as well as for the design of new adobe construction (Hernandez, Barrios, and Pozas 2000).

Experimental Program

A research group from the Department of Civil Engineering at the University of Aveiro has been involved in an experimental program to characterize the structural behavior of existing adobe buildings. Adobe and mortar samples were taken and analyzed, and then the performance of reduced-scale wallets constructed in the laboratory was measured. The structural, nonlinear response of adobe walls was also investigated in a series of full-scale tests conducted both in the laboratory and in situ.

Compression and Splitting Tests on Adobe Specimens

For the experimental testing program, a set of adobe samples was collected from eight houses and eight boundary walls in different locations in the Aveiro district. Cylindrical cores, with diameters ranging between 60 and 95 mm, were extracted from the collected adobe samples. These cylindrical cores had a height approximately two times their diameter. A total of 101 cylindrical specimens, 51 collected from houses and 50 collected from boundary walls, were subjected to mechanical tests. Eighty-three specimens were tested in compression (figs. 2, 3) and 18 in splitting tests.

Tests results revealed that the adobe specimens varied significantly in compressive strength, with values varying from 0.32 to 2.46 MPa. In general, tensile strength was found to be equal to approximately 20% of the compressive strength. Results also indicated that samples with larger fractions of small-dimension particles were consistently stronger in com-



FIGURE 2 Compression testing of an adobe specimen. Photo: Pereira, 2008

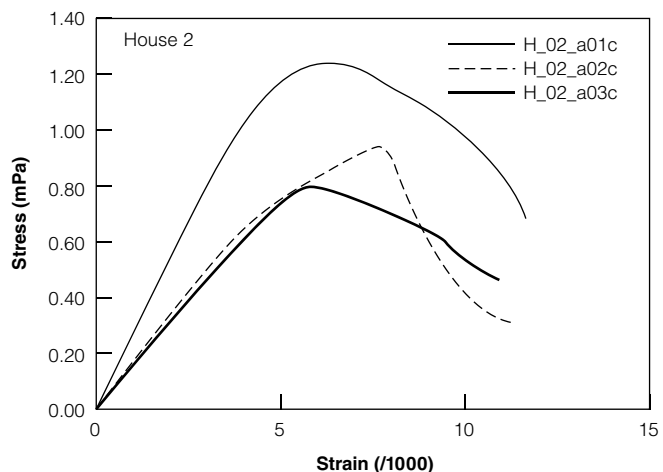


FIGURE 3 Stress versus strain relations obtained in compression testing of adobe specimens. D. Silveira, 2008

pression and tension. A detailed description and the results of the mechanical properties testing program can be found in Varum et al. (2007a).

Compression Tests on Mortar Specimens

Ten mortar samples (two plaster and eight bedding mortar) taken from three different houses were tested in compression.

The load applied by the compression testing machine was transmitted through two square steel plates, 40 mm on each side. Results obtained for unconfined average strength were 1.68 MPa (house 1), 1.07 MPa (house 5), and 0.45 MPa (house 12).

Compression and Shear Testing of Small Wallets

To estimate the compressive and shear strength of traditional adobe walls, thirteen small wallets, $17 \times 17 \times 10$ cm, were constructed and subjected to compression tests. Stress was applied in the perpendicular and diagonal directions with respect to the bed joints (figs. 4–6). To construct the wallets, prismatic blocks extracted from actual adobe samples were adhered with mortar that had a composition similar to the traditional material. The wallets were constructed at a reduced scale (1:3).

Compressive and shear strength values obtained from testing the samples were between 0.77 and 1.57 MPa and between 0.05 and 0.19 MPa, respectively. The wallets made from less resistant adobe blocks presented lower shear and

FIGURE 4 Shear testing of a small wallet. Photo: Pereira, 2008

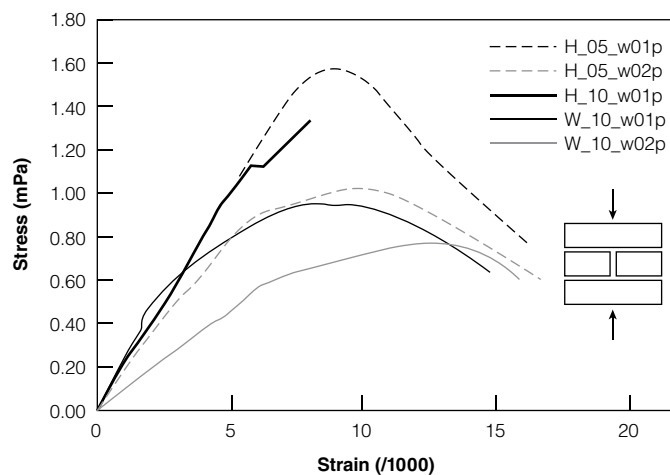


FIGURE 5 Stress versus strain relations obtained in compression testing of small wallets. D. Silveira, 2008

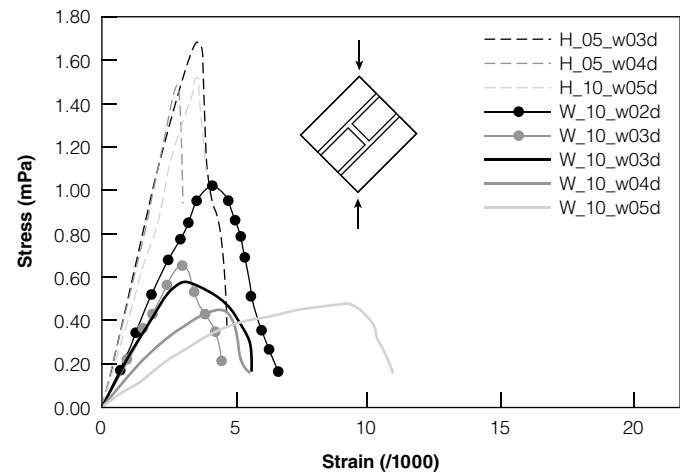


FIGURE 6 Stress versus strain relations obtained in shear testing of small wallets. D. Silveira, 2008

compressive strength values. Transversal modulus of elasticity and shear strength for each series of samples tested were about one-tenth of the corresponding modulus of elasticity and compressive strength values obtained in compression tests perpendicular to the bed joints. A detailed description of the testing procedures and results can be found in Varum, Costa, Pereira, et al. (2007).

Tests on Full-Scale Adobe Walls

Tests were conducted on adobe wall specimens (one in the laboratory and another in situ) to characterize the mechanical behavior of this masonry when subjected to cyclic actions such as those induced by earthquakes. The wall tested in the laboratory was initially subjected to a nondestructive dynamic test to determine the natural frequencies of the assembly in each direction. These measurements allowed a dynamic characterization of the adobe masonry wall and provided data for calibration of numerical models. In a second test the wall was subjected to a constant vertical load combined with in-plane horizontal forces applied cyclically (fig. 7). During the test displacements were measured at four points on each side of the wall.

The wall tested in situ was subjected to dynamic characterization tests and to two tests that focused on cyclically applied horizontal forces, namely, an in-plane, semidestructive test; and an out-of-plane, destructive test. A detailed description of the procedures and the test results can be found in Varum, Costa, Velosa, et al. (2006).

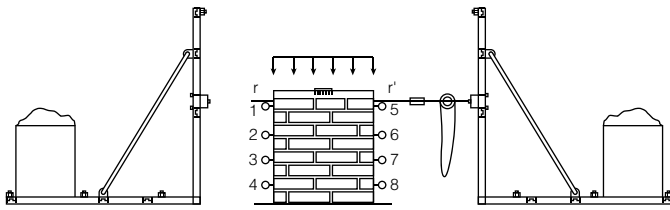


FIGURE 7 Laboratory in-plane testing layout: wall specimen, reaction frames, horizontal displacement transducers, dynamometer, and horizontal loading system. Pereira, 2008

Results of Laboratory Tests on Full-Scale Adobe Walls

The wall tested in the laboratory was constructed with adobe blocks taken from an existing wall and with mortar having a traditional composition. The boundary conditions at the base of the wall prevented lateral displacement and rotation.

The natural frequencies in the two horizontal directions (transverse and longitudinal) were measured with a seismograph. A frequency of 10.94 Hz in the transversal direction was measured. Based on this value, the average modulus of elasticity was estimated to be 316 MPa. Subsequently, a vertical load of 2.86 kN was applied to the top of the wall, and in-plane horizontal forces were imposed in cycles of increasing amplitude until the point of collapse. A maximum horizontal force of 3.2 kN was applied. Failure occurred with the opening of a horizontal crack at the base of the wall.

Results of In Situ Tests on Full-Scale Adobe Walls

The wall tested in situ was first subjected to dynamic tests. A frequency of 2.20 Hz in the transversal direction was measured, and from it an average modulus of elasticity of 101 MPa was estimated. For the cyclic tests on the wall, in-plane horizontal cyclic forces were imposed with increasing amplitude. In a second phase of testing, out-of-plane horizontal forces were applied to the wall in cycles of increasing amplitude but without inversion of the force signal until the point of collapse. A maximum horizontal force of 10.7 kN was applied in-plane. This force was not increased to the point of collapse so that the out-of-plane test could be performed. A maximum horizontal force of 0.69 kN was applied out-of-plane. The failure mode observed was characterized by rotation at the wall base, with damage spread over the wall height.

Work in Progress and Final Considerations

The most important results obtained from our experimental work address (i) the strength and stiffness of adobe units and mortars and (ii) the strength, stiffness, energy dissipation capacity, and common collapse mechanisms of adobe walls. These results provide a basis for interpreting observed structural pathologies, calibrating numerical models, assessing structural safety, and designing strengthening solutions adequate for existing adobe construction. The results also support design values for construction of new buildings.

The research and testing presented in this paper are part of a project focused on rehabilitating and strengthening some of the adobe structures in the Aveiro district. For this project, the following treatment methodology is used:

- i) detailed survey of existing construction and of the most prevalent structural and nonstructural pathologies;
- ii) mechanical characterization of the building materials;
- iii) structural characterization of the buildings and evaluation of structural safety; and
- iv) development of techniques for repair and structural strengthening.

Although this research is focused on adobe construction of the Aveiro district, it may have application in other regions of Portugal where there is a substantial amount of earthen construction (namely, in Beira Litoral, Algarve, and Alentejo), as well as in other parts of the world.

In addition to the work presented here, the Department of Civil Engineering at the University of Aveiro is carrying out the following projects.

- i) *Detailed survey of existing earthen construction types in the Aveiro district and of prevalent structural and nonstructural building pathologies.* The survey includes the creation of maps showing the distribution of adobe construction in the district; building histories including construction dates, rehabilitation work, and other interventions, abandonment dates and identification of the buildings that are still in use; architectural descriptions, including analysis of floor plans/layout, thickness of walls, dimensions of adobes, wall opening dimensions and their relative positions; prelimi-



FIGURE 8 Strengthening of an adobe wall with a polymeric mesh and a coat of traditional earthen plaster. Photo: Pereira, 2008

nary structural characterization, including identification of roof and foundation systems, the type and quality of the connections between structural elements, and structural irregularities; and assessment of the current state of conservation.

- ii) *Study of the mechanical behavior of adobe arches.* Three adobe arches with the same span but different geometries were built in the laboratory from adobe blocks taken from an existing building and mortar with a traditional composition. Each arch was subjected to vertical symmetrical loading, vertical nonsymmetrical loading, and vertical point loading until they collapsed. The results are currently under analysis.
- iii) *Study of adobe masonry strengthening solutions.* The wall tested in the laboratory was strengthened by wrapping it with polymeric mesh prior to applying a coat of traditional earthen plaster (fig. 8). The structural response of the wall when subjected to cyclic horizontal displacements is currently under investigation; any improvements in performance will be evaluated.

Acknowledgments

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Consolidation and Reinforcement of Destabilized Earthen Structures in Bam after the Earthquake of December 2003: Some New Approaches

Rasool Vatandoust, Eskandar Mokhtari, and Mahmoud Nejati

Abstract: The earthquake of December 2003 in the historic desert city of Bam resulted in the loss of many lives and the destruction of a significant portion of its earthen cultural heritage, in particular, Arg-e Bam (the Citadel). This paper presents the methods developed and used to conserve the remaining earthen structures in Bam. Among the subjects covered are the geological, environmental, and seismological studies undertaken since the earthquake; analysis of the adobe used in construction of the Citadel; and current production of suitable adobes and mortar for restoration work. Other important issues investigated include joining architectural elements and developing grouts to consolidate and reinforce unstable structures.

Résumé : Le séisme de décembre 2003 dans la ville historique de Bam a fait de nombreuses victimes et a détruit une grande partie de son patrimoine culturel bâti en terre, particulièrement Arg-e Bam (la Citadelle). Cet exposé présente les méthodes développées et utilisées pour conserver les vestiges en terre qui subsistent à Bam. Parmi les sujets évoqués figurent les études géologiques, environnementales et sismologiques réalisées depuis le séisme, l'analyse de l'adobe utilisé pour la construction de la Citadelle, et la production actuelle d'adobes et de mortiers adaptés pour les travaux de restauration. L'exposé aborde également les importantes questions de l'assemblage des éléments architecturaux et de la mise au point de coulis d'injection destinés à consolider et à renforcer les structures instables.

Bam, with its earthen heritage, is one of the most important historic sites in Iran. The city was largely intact before the earthquake of December 2003 (fig. 1). During the earthquake, many historic buildings were damaged to different degrees,



FIGURE 1 The Bam Citadel, aerial image before the earthquake of December 2003.

depending on the building type, the direction of the ground movement, and other factors. Since then, the consolidation and reinforcement of the historic structures thus destabilized and damaged have been among the main activities of the Bam Cultural Heritage Recovery Project (fig. 2). This paper describes and analyzes the earthquake-damaged historic structures of Bam and the Citadel. It also briefly introduces engineering and technical issues encountered in the Bam project, the types of structural damage affecting the damaged buildings, and the latest methods for stabilizing these structures. The final part of the paper draws conclusions from the research and discusses the knowledge and experience gained in the years after the earthquake.



FIGURE 2 The Bam Citadel, aerial image, July 2007. Conservation measures after the earthquake.



FIGURE 3 Differing extent of destruction in various parts of the Citadel and diverse dynamic behaviors in the bedrock and structures built on soft soil (Caravansarai, Stable, and Payambar mosque).

Planning for the Consolidation, Reinforcement, and Restoration of Bam’s Historic Buildings

What makes Bam an extremely challenging project is that the relationship between structural engineering and the preservation of historic buildings—in particular, earthen monuments—has never been clarified in the context of cultural resource management in Iran. In addition, the issues and problems encountered in Bam are complex; they cannot be solved using a single strategy. Successful strategies must include provisions for unanticipated problems, harsh weather, and conditions peculiar to the city of Bam and the Citadel, and it is vital that the technical work be constantly monitored, revised, and adjusted. Most of the projects in Bam require the involvement of engineers, archaeologists, architects, and conservators. The role and extent of involvement of each are project-specific, determined in each case by the nature of the problems to be addressed.

In the aftermath of the earthquake, the Bam Cultural Heritage Recovery Project has sought to answer the following questions: (1) Why were some of the buildings so severely damaged while others were not, despite similarities in construction, materials, and load-bearing conditions? (2) Are earthen structures inherently too weak to withstand earthquakes, or was the Bam earthquake so strong that buildings constructed of other materials, such as concrete and steel, were also susceptible? (3) Is it possible to reinforce and consolidate earthen structures so that they can withstand an earthquake as strong as that which occurred in Bam? (4) If

so, are the methods of reinforcement consistent with the conservation goals for historic buildings?

Damage Assessment

A damage typology for the Bam Citadel requires in-depth analysis of deterioration factors, distinguished through structural evidence, and the causes directly related to the architectural complexity of the individual buildings, imprecise interventions before the earthquake, lack of documents, and, finally, the complicated structural reactions to the earthquake. Considered together, these factors make development of such a typology a serious challenge (fig. 3). In an earthquake, resonance—that is, the behavior of site soils and the relation between the frequencies of the foundation and the soil—can be one of the most destructive factors. In the Bam Citadel, most of the structures lack foundations, and with the exception of the Governor’s Quarters (built on a stone bed), most of the structures are constructed on a bed of secondary soils.

Dynamic Loads and Damage in the Bam Earthquake

The following factors can be considered causes of significant damage to earthen buildings:

- The capacity of local soil conditions to enhance seismic motions, as well as the relationship between ground acceleration and the resonant frequency of a

particular structure. When those frequencies are similar, exaggerated movement and failure can occur.

- The strength (peak ground acceleration nearly equal to 1 g) and the three-dimensional (two horizontal directions and one vertical) force of the ground motions.
- The relatively long duration of the earthquake (almost 13 sec).
- Buildings' detailing, including the joints between ceiling/roof structures and walls, the relationship between wall thickness and height, and the siting of buildings with respect to the direction of the earthquake loads.
- Previous interventive conservation and restorations work resulting in reduction of the buildings' earthquake resistance.

Previous Interventions

Earlier restoration work, although meticulously done, has largely been concerned with architectural surfaces: appearance of the buildings and matching the repairs with the original in order to retain integrity and authenticity of the site. The seismic performance of the structures was not thoroughly taken into account. Many of these repairs were lost in the earthquake.

Although basically isometric forms and shapes in some of the earthen structures in Iran produce sufficient resistance to incoming shocks, a number of previous interventions within the Citadel resulted in changes to the original plans, increasing the side effects of the earthquake loads. There are a large number of instances within the Citadel, such as the Caravansarai, where incorrect and unsuitable new elements caused further destruction of the structures.

Earthen Materials and Structures

Earthen materials are not very resistant to the lateral loads exerted in an earthquake and are easily damaged, as can be seen in Bam. Early builders used advantageous wall thickness, slenderness-to-height ratios, strategic positioning of window and door openings, and geometric patterns in laying the adobe in the roofs and walls.

Regardless of the strength of the building materials, the form of the structure has a direct effect on its seismic resistance. The Citadel architecture was composed of a variety

of forms, such as vaults, ceilings, and walls, each of which responds differently to an earthquake. The fact that most of the structures in the Bam Citadel lack foundations and were built on a bed of soil was undoubtedly a major reason that structures were destroyed during the 2003 earthquake.

Natural Factors

Weather and environmental conditions are among the factors influencing the extent of erosion and deterioration of the structures of the Citadel. Weathering can contribute greatly to reducing the dimensions of the walls and the other features or cause further flaws and cracks. Termite attacks, seasonal winds of up to 130 km per hour, and sandstorms can also result in poor earthquake resistance of buildings.

Stabilization and Improvement of the Seismic Resistance of Structures

Planning for stabilization and strengthening of the Citadel buildings damaged in the earthquake focused initially on the causes of damage. Only by determining reasons for the structural failure has it been possible to outline a clear plan for the conservation and restoration of the buildings that will assure their survival in future earthquakes. Determining the primary causes of failure in each case was important because each building was responding to a somewhat unique set of structural conditions. However, two issues arose in nearly every repair project conducted within the Citadel or the city: (1) improvement of mechanical features of the soil and (2) materials and methods of injection grouting and stitching of damaged structural elements. A later section of this paper addresses the production of grouts and adobes and elaborates on the repair techniques developed for stabilization of damaged structures within the Citadel.

The following measures have been taken to improve the performance of repair materials.

- Survey, study, and selection of a suitable soil deposit to acquire a high-quality material for adobe production;
- Evaluation of various additives to improve the mechanical properties of adobe;
- Improved methods for the production of adobe; and
- Development of two methods for injecting repair grouts.

Repair Techniques Developed for Stabilization and Seismic Improvement of Earthen Structures

Repair techniques developed for the Bam project include the following:

- Injection grouting of cracks less than 2 cm wide, such as those found in the Sistani House, the Stable, and the walls of the house of the Commander of the Army.
- Tension elements such as glass and palm fibers used prior to the injection process become post-tensioning elements with back plates, such as in the Sistani House and the Stable of the Citadel. Once the tension elements are inserted into the walls they are grouted in place. Depending on the load carried by the element and the level of damage to the structure, tension elements can be installed with or without the back plates.
- Installation of center cores and other vertical and horizontal reinforcements deep into the walls, such as at the Sistani House. Vertical elements are inserted into the soil beneath the structure to a depth of 1.5 m along the walls. The glass fibers are fixed into the walls after the injection of the mud grout. In this way, the ruptures will be integrated with the rest of the body. They will also act as a solid body during a subsequent earthquake.
- Stabilization of walls, ceilings, and vaults using a mesh made of artificial fibers. Mesh sheets have been applied to the Stable and the Citadel. The material is applied to the outer walls of the structure with special joints that prevent the structure from collapsing during the tremors. Finally, the mesh sheets are covered with clay-and-straw mortar (*kah-gel*), as can be observed in figure 4.
- Connection of the structure to the ground with tension elements (cables) made of artificial fibers, such as in the Sistani House or the Payāambar mosque. The addition of tension elements in the walls of the Sistani House, which are anchored to the foundation soils at depths greater than 1.5 m, creates halters that prevent the structure from vertical movement, which can result in the lateral resistance of the structure (fig. 5).
- Replacement in kind of damaged mud bricks, such as at the Payāambar mosque and throughout the Citadel.



FIGURE 4 Reinforcement of the internal surfaces of the dome and walls in the Stable of the Citadel with geo-grids.

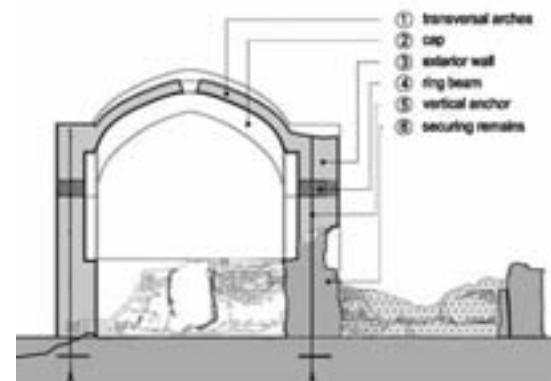


FIGURE 5 Installation of ring beam to provide integrity and harmonious structural response to the earthquake loads, Sistani House.

- Implementation of repairs that address specific structural inadequacies, such as decreasing the weight of specific parts of the structure to reduce loads or creating additional structural elements in the building, such as buttresses, or increasing wall thickness, such as in the barracks or the Payāambar mosque. The walls of the Payāambar mosque had thinned in some areas prior to the earthquake of December 2003, which made these areas vulnerable to the effects of the tremors. These areas have now been reinforced and consolidated.

- Consolidation of the building in order to prevent structural resonance, such as the consolidation of the walls of the Governor's Tower. Some of the damage in the Citadel was due to the different seismic reactions of the various soil layers, especially in the Governor's Tower. Figure 6 shows the consolidation of the lower part of the tower by means of a steel support system.
- Stabilization by using adobes reinforced with palm fibers. Efforts have been made in the Sistani House to improve the mechanical properties of the mud bricks used in repair and reconstruction. It is expected that improving the mechanical properties of the adobe will increase the ductility of the structure. Here two of the rooms have been reconstructed and new mud bricks have been used in a pilot project.
- Stabilization of the vaults and ceilings through the installation of ring beams, such as at the Sistani House and the Payāambar mosque. Inserting ring beams is among the methods of stabilization that can have positive effects on the seismic resistance of earthen structures while preserving their integrity. Specific elements, including glass fibers and mud grout compatible with the old parts of the wall, are inserted into these beams for reinforcement. These beams are located under the floor, as shown in figure 6.

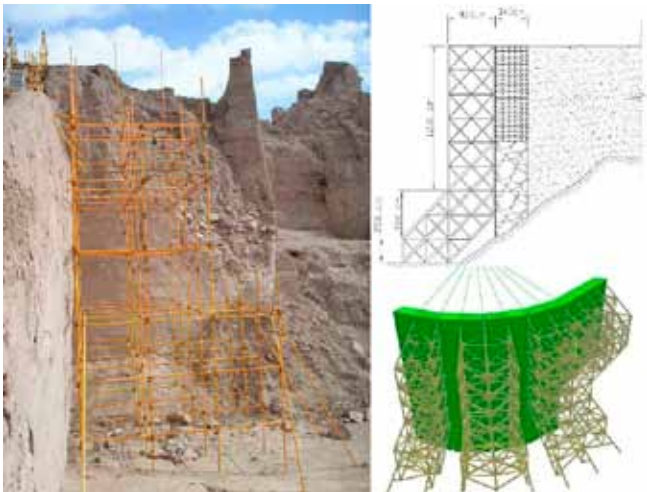


FIGURE 6 Damage to the wall in the Governor's Tower and fixing of the proposed retaining structure.

Conclusion

The Bam Cultural Heritage Recovery Project has been challenging and complex, yet it has provided many opportunities for scholars and researchers in various fields to develop and improve the technical and scientific knowledge needed to conserve and restore earthen architecture. Results of the studies conducted in Bam will be useful in conservation projects throughout the country and in other parts of the world.

Structural stabilization, reinforcement, and consolidation of weakened earthen buildings are major challenges to engineers, architects, and conservators. Although a great deal of progress has been made in conserving, protecting, and restoring the earthen heritage of Bam after the earthquake of December 2003, the work is still ongoing and will result in additional research and the development of new repair strategies. Researchers will continue to focus on classifying and analyzing types of damage in order to develop specialized repair techniques. These will be tested in the laboratory to the greatest extent possible and implemented in the Citadel once consistent results are obtained.

Conservators, restorers, architects, and engineers have long debated the relative merits of using traditional methods of construction and repair on the one hand and new methods involving modern materials and techniques on the other. The authenticity and integrity of historic sites are of the utmost importance in selecting specific approaches to repair and restoration. In Bam considerable attention has been focused on the values associated with the use of traditional building materials and methods of construction and repair while attempts have been made to incorporate, patiently and with care, new engineering techniques and knowledge. The cooperation of various national and international institutions such as CRAterre (France), the Ministry of Cultural Heritage (Italy), Dresden University (Germany), and the Milan Polytechnic University (Italy) have been vital in helping the project meet its goals.

PART SEVEN

**Challenges and
Opportunities of
Conservation and
Development**

**Défis et opportunités
de la conservation et
du développement**

Earthen Architecture Construction in Southern Ecuador

Maria de Lourdes Abad Rodas

Abstract: *This paper presents case studies from Cuenca, Ecuador, that involve restoration and adaptive reuse of earthen buildings for present-day uses (two of the buildings have national significance). It also discusses new residential construction that I designed using adobe and bahareque. I believe that the conservation and maintenance of our cultural heritage rely on actively working with the site's owners, advocates, the local community, and the builders/craftsmen. Through our work we have verified that it is possible to maintain and develop our ancestral building traditions while preserving our cultural and local identity.*

Résumé : *Cette communication présente des études de cas de Cuenca, Équateur, portant sur la restauration et la réhabilitation adaptative de bâtiments en terre en vue d'utilisations modernes (deux des bâtiments font partie du patrimoine national). Je présente également un nouvel ensemble résidentiel que j'ai conçu en adobe et bahareque. À mon avis, la conservation et l'entretien de notre patrimoine culturel doivent être menés en étroite collaboration avec les propriétaires du site, les parties prenantes, la communauté locale et les constructeurs/artisans. Notre travail montre qu'il est possible de maintenir et de développer nos traditions ancestrales de construction tout en préservant notre identité culturelle et locale.*

This paper presents case studies from Cuenca, Ecuador, that involve restoration and adaptive reuse of national heritage buildings for present-day uses, as well as new residential construction with adobe. My goal is to help preserve our national cultural heritage and find workable connections between our activities as professional architects and our cultural and architectural vernacular traditions.

Cuenca, in southern Ecuador, is a city at 2,500 meters elevation. Before Spanish conquest and colonization, this region was inhabited by the Cañar Indians, who were ruled by the Incas. Cuenca was founded on the ruins of Tumipamba, the second capital of the Inca Empire, after Cuzco. Early Spanish settlers used many of the worked stones from the Inca city for building, as well as adobe and other earthen materials. They also redesigned the city plan according to the Laws of the Indies. Cuenca's Historic Center, where many of the buildings are made of earth, was declared a UNESCO World Heritage Site in 1999. This recognition has helped Cuenca's citizens revive our sense of belonging and cultural identity.

Recently, private initiatives, foundations, and social organizations, as well as the local community, have been working together to save our cultural heritage. We have drafted protective laws and regulations to ensure the preservation of important buildings and construction traditions; however, we lack sufficient economic resources to be effective in every case. There are many problems inherent in the conservation of earthen construction: not only is financial support limited, but there is widespread lack of knowledge about and experience in using appropriate treatment materials and methods on fragile or ephemeral architectural patrimony.

A frequent problem in trying to preserve urban patrimony, in particular, earthen structures, is lack of time. Clients often demand rapid completion of these projects, especially when public institutions are involved. I have found, however, that by working directly with the building owners and neighbors and by helping them to see the value of careful restoration, they are able to understand the process and often agree to proceed with good judgment.

The following restoration and adaptive reuse case studies are presented to show how we are documenting traditional construction methods, describing our cultural patrimony, revitalizing our cultural identity, and helping to preserve our buildings in their cultural landscapes.

The Metals Museum

In 1989 Dr. Lucia Astudillo purchased the building now known as the Metals Museum. It was constructed as a private residence in the 1920s (fig. 1). In 1996 it opened as a cultural center and exhibition hall. The Metals Museum is an earthen structure made of wattle and daub. The ground floor consists of wood latticework filled with adobe bricks; the second and third floors have the standard cane latticework filled with mud and straw. The main building is 12 meters high, with a central skylight rising to 18 meters. The roof is red tile. The walls are plastered with a smooth mud and straw mix, finished with a fine paste of horse dung and kaolin in equal proportion.

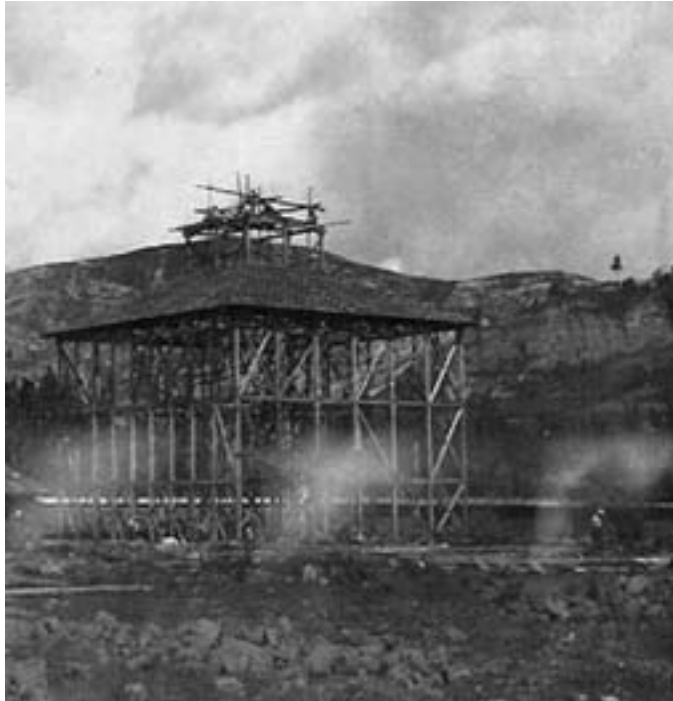


FIGURE 1 The Metals Museum at the beginning of construction. Photo: Rodrigo Puigmir y Bonin, 1923

The objectives of this project were to reinforce the wooden framework, reduce the natural humidity of the site, replace the adobe walls on the ground floor, which had collapsed from the dampness, install modern fixtures suited to the building's new use, and recycle as much of the old construction material as possible. The wooden floor joists resting on the foundations were rotten. We replaced them with reinforced concrete and did the same with some of the wood pillars. The upper floors were reinforced with wood beams. Perimeter drains were added to control subsurface dampness. All the leftover materials from the original building were recycled (adobe, wood, tiles, brick tiles from the floors). The old floorboards were sanded and reused.

The Quinta Bolívar, 2004

The Quinta Bolívar building belongs to the municipality of Cuenca. According to historical records, the Liberator, Simon Bolívar, stayed here during his military campaigns to achieve the independence of Venezuela, Colombia, Peru, Bolivia, Panama, and Ecuador. The municipality proposed opening a cultural center, museum, and Bolivarian library in the building.

The earthen house is constructed of wattle and daub. It was in very poor condition due to lack of maintenance (fig. 2). It had structural problems, collapsed walls in the interior patio, invasive vegetation, and decay of the wood floors and roof. To stabilize the structure we repaired the interior patio and added perimeter walls with adobe buttresses. In addition, the existing adobe and wattle-and-daub walls were reinforced, new adobe walls were added, and the roof and floors were replaced. Last, perimeter drains were installed around the structure to control surface water runoff.

In response to certain political interests, the municipal authorities reduced the time allotted for this project.



FIGURE 2 The Quinta Bolívar before restoration. Photo: Lourdes Abad R., 2004

Consequently, the mud plaster did not have enough time to dry before being whitewashed, and cracking of the finished walls was unavoidable.

Migration and Heritage

In the past century there has been a massive emigration of Ecuadorians to the United States and Europe. As a consequence there has been a major change in architectural fashion in Cuenca and some of the surrounding communities. For example, around Cuenca and in the southern region in general, most new construction is unrelated to the surrounding natural and social context. Many of the houses, often oversized and made of inappropriate materials, are vacant, awaiting the return of their owners. This process is transforming the cultural landscape, especially in southern Ecuador, with an attendant loss of cultural identity, ancestral knowledge, and local building techniques.

Fortunately, there are still many rural communities that retain knowledge of traditional construction technologies. They still build their homes from earth, especially the poorest families and those without a relative working abroad. In light of this situation, whenever I have the opportunity to work in a rural context one of my primary concerns is to design buildings that take the climate, geography, winds, and cultural history into account. A building should fit into the cultural landscape while allowing for site-specific and appropriate creative adaptations. I was able to apply these principles to projects in Cañar and Yunguilla, both of them near Cuenca.

The Cañar House

The Cañar House is located in the town of Cañar, 90 kilometers from Cuenca. The setting is a high plateau, at 3,200 meters elevation, with an average temperature of 14°C. It is owned by Judy Blankenship and Mike Jenkins, U.S. citizens who have lived and worked in the area for the past ten years. Over this period they have observed changes in the surrounding habitat brought about by emigration. With these changes in mind, they evaluated the pros and cons of earthen construction and decided on a traditional house design incorporating modern technological improvements.

The walls were built of wattle and daub, a mix of mud and straw packed into a wooden latticework. This type of construction is naturally seismic-resistant and insulated (fig. 3). The house design centers on an interior patio, which provides good natural lighting, solar heating, and ventilation. It also re-



FIGURE 3 The Cañar House, constructed of wattle-and-daub, a mixture of mud and straw packed into a wooden latticework. Photos: Lourdes Abad R., 2006

creates the traditional space that was once used for craftwork, drying the harvest, and family interaction.

The building foundation was made of reinforced concrete, and the roof was weatherproofed with an impermeable membrane. Hot water runs through copper pipes, and the structure's wood frame was made of local eucalyptus timber. The weight-bearing structural elements included pillars, beams and tie beams, cross beams, X-shaped beams, lintels, and braces.

For the lattice we used guadua cane in strips 2 to 3 centimeters wide. To prepare the guadua cane, we scraped off the layer of soft fiber that attracts termites and soaked the strips in salt water. This is a common method of preserving the guadua in the country.

We used soil excavated at the construction site. Analysis of the soil revealed it to be generally composed of 75% sand, 10% silt, and 15% clay. After sifting the soil, we added water and 2% straw as a stabilizer and let the mixture soak for seventy-

two hours, stirring frequently. The mud was packed into the latticework during communal work parties composed of neighbors, friends, and workers. We used the central patio and the outside perimeter of the house to prepare the adobe.

Prior to finishing with a mud plaster, we let the walls dry completely (to test the level of humidity we bored holes at various levels to sample the interior conditions). The finish plaster was composed of 70% sand, 10% silt, and 20% clay, with the addition of 2% straw as a stabilizer. We prepared a large amount of this plaster and let it soak and rot for three days before applying it to the walls. One layer was applied, 3 centimeters thick. Over the mud plaster we applied a very fine layer of sieved soil, of the same kind we used to fill in small cracks; the purpose of this layer is to obtain a fine surface texture.

The Yunguilla House

The Yunguilla House is 64 kilometers from Cuenca at an elevation of 1,400 meters. The area has a subtropical climate and vegetation, with an average temperature of 20°C. The house is owned by Lynn Hirschkind, an anthropologist who has lived in rural Cañar communities and is aware of the need to protect cultural heritage. She also appreciates the special qualities of earth construction.

The house design incorporates a passive system of climate control that uses the insulating properties of the adobe, wind direction, and solar orientations to its advantage (fig. 4). The house is constructed primarily of adobes, with the third floor in *bahareque*. Fortunately, there was good soil for adobe



FIGURE 4 The Yunguilla House during construction. Photo: Lourdes Abad R., 2005



FIGURE 5 The Yunguilla House, making the adobes. Photo: Lourdes Abad R., 2006

available nearby. Analysis of the soil revealed it to be generally composed of 65% sand, 12% silt, 15% clay, and less than 3% organic matter. We added straw and 2% asphalt to stabilize the mix (fig. 5).

We strengthened the house framework with reinforced concrete foundations, with the purpose of equal distribution of the forces on the foundations and head of the walls. To accomplish this, concrete beams 15 by 45 centimeters were laid in the foundations, and wood beams 20 centimeters in diameter were used at the head of the walls, floors, and roof. The walls were covered first with a mix of mud, straw, and asphalt and then finished with a wash of horse dung and white earth or kaolin in a 1:1 proportion. We painted the interiors of both houses with a lime-based solution of colored earth and 10% polyvinyl acetate as a binder. First we soaked the earth in water overnight. After sieving the hydrated earth, we mixed it with lime (without sand) and added water until we obtained the desired texture; the mix was 80% lime and 20% earth.

Restoration and Replication of Facade Ornamentation

During the colonial period, domestic architecture was modest, with little decoration. It was derived from the typical Andalusian house: patio, back court, and garden surrounded by living quarters and only a few openings through to the exterior walls. After independence from Spain, the Cuenca region was economically depressed. In the 1860s there was a surge in economic growth from the export of quinine and Panama

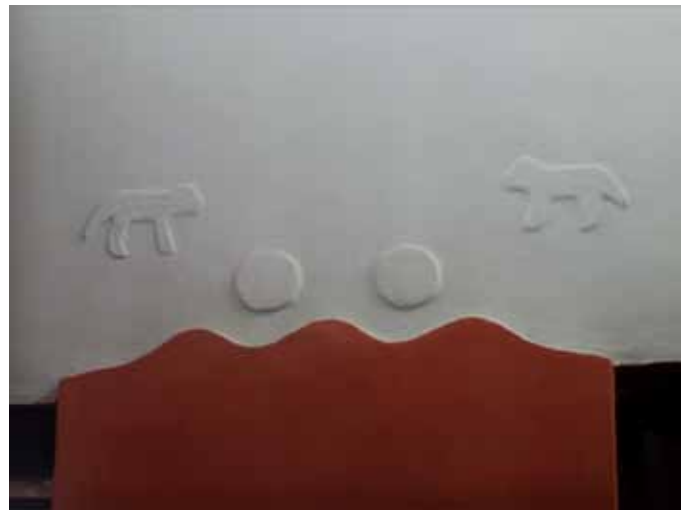
hats. Cuenca was suddenly transformed by European, especially French, influences.

Craftsmen learned how to satisfy the sophisticated tastes of the export merchants, who favored profuse architectonic decorations. These included floral elements, elaborate moldings, cornices, entablatures, friezes, and polychromatic tiles and panels for ceilings, footings, walls, eaves, and plaster moldings. Poor families decorated their houses with floral elements similar to those of the wealthier homes but using mud, straw, plaster, lime, and earth-based paint.

The Historic Center of Cuenca is obliged to conserve, restore, and maintain the ornamental facades of its buildings. For new buildings on the outskirts of the city, we proposed using both high- and low-relief ornamentation such as figures taken from pre-Columbian textiles, ceramics, and ceremonial symbols. The figures represent the four basic elements of the universe: birds represent air; fish evoke water; felines and domestic animals symbolize earth; and snakes signify eternal renewal and fire. Other traditional symbols are marine birds, dogs, mountain lions, fish, condors, and the Southern Cross (fig. 6).

Conclusion

Knowledge of traditional construction techniques and use of earth as a building material are still present in rural areas far from urban influences. For centuries local knowledge of earthen building materials and technologies has efficiently met cultural and biological needs. In addition, building with earth involves renewable resources and recycling as a natural part of its practice. We should observe and rescue this traditional knowledge for use in a modern context. We need to provide information about improved techniques of earthen



(a)

FIGURE 6 The use of high and low reliefs on the Yunguilla (a) and Cañar (b) Houses. Photos: Lourdes Abad R., 2005-7



(b)

construction and take advantage of local architectural designs of passive climate control to demonstrate that a sustainable architecture made of earth is possible.

The sense of belonging to a community and having a well-defined identity is realized when the local community is engaged in a project and when its members actively contribute and participate by drawing on their traditional knowledge. In this way they value and revive their cultural identity.

A Manual for the Conservation and Restoration of Traditional Sardinian Architecture

Maddalena Achenza

Abstract: *This paper concerns the Manual for the Conservation and the Restoration of Traditional Sardinian Architecture, which has been ordered by the Region of Sardinia (Italy) and prepared by the Department of Architecture of the Faculty of Architecture of Cagliari. This complex work is the first of its kind for earthen architecture of this type in Italy and represents the results of over twenty years of research carried out by different professionals. The paper is structured in two parts: the first part introduces Sardinian architecture and culture and the goals of the manual; the second is specific to regional building typologies and their preservation, which is the content of our work.*

Résumé : *Cette communication traite du « Manuel pour la conservation et la restauration de l'architecture traditionnelle sarde » commandé par le Département d'Architecture de la Faculté d'Architecture de Cagliari, pour le compte de la Région Sardaigne (Italie). Ce travail complexe est le premier de ce genre en Italie concernant le bâti en terre. Il représente le résultat de plus de 20 ans de recherches effectuées par différents professionnels. La communication comporte deux parties : tout d'abord, une présentation de l'architecture et de la culture sarde, et des objectifs du manuel ; puis, un aperçu des typologies régionales en matière de construction, et leur préservation, objet de notre travail.*

Sardinia is the second-largest Italian island, after Sicily, with a population of about 1.6 million. Except for a few large towns, the urban environment is represented by a multitude of small villages, often with fewer than ten thousand people. Most of these villages more or less maintain their cultural identity, which is strongly represented by their stone and earthen architecture. At least one-third of the island's architectural pat-

rimony is traditional earthen buildings, most of which are inhabited, and therefore kept alive, even if increasingly devalued. The building technique used for both load-bearing and non-load-bearing walls is adobe; no other is to be found. Earth is also used for mortars, plasters, and floors of adobe and stone buildings alike.

Sardinia, which has one of the highest concentrations of earthen buildings, represents the architectural panorama of the country and demonstrates excellence in traditional building typologies and details. The earth building area is concentrated in the Campidano plain, an area of about 100 by 40 square kilometers, running north to south from Oristano to Cagliari, the regional center. The region, once agriculturally rich, is mostly concentrated into small, rural villages of about ten thousand inhabitants (fig. 1).

The most frequent building type in Sardinia is the courtyard house. This is the typical Mediterranean typology built to respond to the area's climate. The defining feature of courtyard houses is the south-facing porch, where most social activities take place (fig. 2). Depending on the area, there are varying combinations of courtyard houses. There is the fore courtyard, where the house is placed at the rear of the grounds, or the rear courtyard, where the house is in front facing the road (fig. 3). A combined solution is the double courtyard, where the front courtyard is the more "public" one and the rear courtyard is a private garden.

The urban tapestry that results from this assembly of building types is a very Mediterranean one. These courtyard houses can be compared with North African *medinas*, which combine spaces that are full and empty, built and open, public and private, all separated by continuous walls. The Sardinian courtyard house is introspective: rooms open to the interior

FIGURE 1 Territorial map showing settlement in southwestern Sardinia. Map adapted by Department of Architecture, Faculty of Architecture of Cagliari.



courtyard but are closed to the exterior. Only the entryway reveals information about the owner through its level of craftsmanship, the materials used (stone, fired brick, or earth), and the display of the family logo (fig. 4).

All the southern villages built on the plain use this type of domestic architecture and site plan: long, closed walls are cut by occasional entrances that lead into the courtyard, with an end that is framed by the porch and the house. The courtyard is also the place where work tools, animals, and goods are deposited before moving them to the appropriate service-side buildings such as the stable, storage shed, or barn.

Floor plans for these examples are quite simple. The first story has a common central room and one or more bedrooms on each side. Upstairs is a storage room for more valuable goods (e.g., oil, grain). The forecourt house is a one- or two-story building that faces the road and is sometimes embellished to look like a town building in the style of Cagliari (the capital). The status of the family is evident through the openings in the facade, the iron balconies, the entrance door, and the molding that crowns the building. The entrance leads to one or two rooms that open on the sides; one of these is the

reception or formal room. In the rear are the kitchen and the servants' quarters, which open to a courtyard of fruit trees and a well for the needs of the family. The bedrooms are upstairs (fig. 5).

In addition to the courtyard house, the island has some large villas owned by wealthy families from Cagliari that are used as holiday country residences. For instance, Villa Tola in S. Sperate was built by Gaetano Cima, an important nineteenth-century Neoclassical-style architect who was born and raised in Cagliari. Examples like this are not rare and prove that adobe was the common building material for large and small buildings, for the poor and the rich, for private and public uses, and for residence and industry (fig. 6). The only exception was the church, which was usually built of stone.

In the past twenty years this earthen architectural legacy has been the focus of conservation efforts. The process was started by public administrations, followed later by private citizens. Since then numerous buildings have been brought to life after suffering abandonment for more than fifty years. Private preservation ventures have become more frequent. They focus on initiatives directed at both residential and productive uses.



FIGURE 2 Front-courtyard house in Serramanna. Photo: Department of Architecture, Faculty of Architecture of Cagliari.



FIGURE 3 Casa Sanna in Solarussa. Photo: Department of Architecture, Faculty of Architecture of Cagliari.

These projects have led to a revival of adobe production and other related building activities. Traditional adobe production does not use machines except for mixers and lifts, and no written standards or guidelines are followed. The adobe products are not controlled in any phase of production or in the building process. The result of this vernacular approach is



FIGURE 4 Adobe buildings along a road in Serramanna. Photo: Department of Architecture, Faculty of Architecture of Cagliari.

often unpredictable and without guarantee of the quality and final appearance.

It is in this context that we generated a section related to earth building in our general handbook, the *Manual for the Conservation and the Restoration of Sardinian Traditional Architecture*, which was prepared by the Department of Architecture of the Faculty of Architecture of Cagliari under orders of the Region of Sardinia. It was conceived as an integral part of the Regional Landscape Plan launched in fall 2006 with the following aims:

- to preserve, safeguard, valorize, and impart the environmental, historical, and cultural identity of the Sardinian territory to future generations;
- to protect and safeguard the cultural and natural landscape and its biodiversity; and



FIGURE 5 Adobe buildings along a road in Serramanna.
Photo: Department of Architecture, Faculty of Architecture of Cagliari.

- to ensure environmental protection and promote forms of sustainable development.

The manual was drafted by a working group led by Antonello Sanna, professor and head of the Department of Architecture of the Faculty of Architecture of Cagliari, who has been researching local traditional architecture for more than twenty years. The interdisciplinary group includes architects, urban historians, structural engineers, and chemists. The manual is divided into three main themes: earth, stone, and wood building. Material specifications are included in each section. The section of the manual dedicated to building with earth has five chapters:

1. Urban structure and texture.
2. Typologies of popular architecture.
3. Building elements and characters.
4. Consistency and use of popular architecture—degradation and rehabilitation.
5. Rehabilitation and restoration of earthen architecture, with case studies.

In the first chapter the geographic area characterized by earth building is identified as the Campidano, an alluvial plain running north to south. Some detail is dedicated to geography and the landscape; territorial architecture: the interaction between the main centers and earthen settlements; the village, its structure and matrix; and formation and transformation of building types.

The second chapter, “Typologies of Popular Architecture,” describes in detail the courtyard house and the variations that characterize this earthen building type. The description is divided geographically into northern, central, and southern Campidano and the neighboring Cixerri valley. The chapter discusses how the courtyard house influences other types of low-density urban forms through its systematic alignment of the buildings toward the south (southeast and southwest) to take advantage of the sunlight and the limitations on the view into neighbors’ homes. These few rules grant the basic needs for good neighborhood relations by reducing problems related to shadows (produced by neighboring buildings) and privacy between houses. Generally, public and private spaces are well separated by a continuous wall, and living units are built on the perimeter of the court. The perimeter structures are for single-family use and respond to the needs of an agropastoral society. They are both places to live and places to work. In addition to the core buildings, there are also a certain number of annex buildings (e.g., cellars, mills, storage places, barns) that usually reflect the prosperity of the family. The house is actually a farmhouse, and the courtyard becomes a highly specialized extension of the cultivated fields.

The third chapter gives an extremely detailed description of each building element in all its local variations: the wall, the connection between wall and basement, the roof, the openings, and so on. Here it becomes evident how the earthen construction techniques have become highly specialized and refined. These building techniques have become so efficient that people are building solid earthen houses with



FIGURE 6 Picci brick factory in Quartu Sant'Elena.
Photo: Department of Architecture, Faculty of Architecture of Cagliari.



FIGURE 7 Different walls, same textures. Photo: Department of Architecture, Faculty of Architecture of Cagliari.

walls that are at least one-third the width of those of mountain stone houses.

Floor plans for the courtyard houses are based on a single-cell module, repeated in sequence for a bigger house. Normally the house is built against the outside wall, having as a result a front or a rear courtyard. But sometimes the house is positioned in the middle of the lot, so as to divide the courtyard into two spaces more or less open to people who are not strictly members of the family. The basement is usually built of stone and rises above the ground to promote drying and minimize the rise of capillary moisture. The adobe bricks of consistent dimensions are laid on top of the stone in header courses (fig. 7). This pattern is repeated and rarely varies, leading to the walls' consistent appearance, style, and construction technique.

In all courtyard buildings, earth is the basic ingredient of the mortars and plasters. The plasters are sometimes painted with a lime wash and colored with natural additives such as saffron, blood, or mineral pigments.

These typologies underwent a change with the introduction of the palace type during the nineteenth and twentieth centuries. New typologies are usually based on the courtyard house but are integrated into the urban context by responding to new functional and social needs (especially those of the growing number of rural bourgeoisie). The most evident effect is the introduction of the front road building. In this style the courtyard house becomes inverted, turning its face to the public road with decorated facades, openings, and balconies that reflect an “upgraded” lifestyle (fig. 8). This new model is perfectly inserted in the ancient urban setting and coexists

gracefully with the traditional courtyard house. The common building material is still adobe; the differences are in the reinforcements for the corners, posts, architraves, and cornices and the use of imported building materials, especially iron, for balconies and balusters.

The same type of detailed description is presented for openings, intermediate floors, and roofs. These elements are described in depth in the *Manual*. In addition, it contains a rich technical catalogue of all listed variations of layout and design.

The last two chapters of the manual focus on restoration of the aforementioned building types. Common building pathologies are analyzed, and the interventions are described in detail through four case studies.

The book concludes with a treatise on earth as a building material. Various aspects related to earth's mechanical and physical properties are presented in scientifically accurate and comprehensible language. Simple testing procedures (with pictures and drawings) are offered to guide the user in choosing the correct type of earth to make adobes and build with them. Selections of international standards specific to adobe construction are included.



FIGURE 8 Palace-type building. Photo: Department of Architecture, Faculty of Architecture of Cagliari.

Earthen Architecture, Sustainability, and Social Justice

Erica Avrami

Abstract: *The growing discourse on sustainability underscores the need for significant reform in the ways we design, construct, and manage the built environment. The preservation of earthen architectural resources and vernacular traditions is increasingly germane in this dialogue. However, balancing the dominant norms of design and construction with the non-normative reality of earthen architecture requires weighing the environmental and economic rationales with issues of social justice. This paper explores how earthen architecture and its conservation can contribute to sustainability through a multipronged approach that capitalizes on its role in global society.*

Résumé : *L'ampleur du débat sur la durabilité montre bien la nécessité de réformer profondément la manière dont nous concevons, construisons et gérons l'environnement bâti. Ce débat met notamment en exergue la préservation des ressources architecturales en terre et des traditions vernaculaires. Cependant, concilier les normes dominantes de conception architecturale et de construction avec la réalité non normalisée de l'architecture de terre exige une prise en compte d'arguments environnementaux et économiques, et de questions de justice sociale. Cette communication montre comment l'architecture de terre et sa conservation peuvent contribuer à la durabilité par une approche multiforme qui tire parti de son rôle dans une société mondialisée.*

The conservation of earthen architecture has always had a natural partner in new earthen construction. Preservation—as both a *product* (heritage resources) and a *process* (the tradition of building with earth)—is hinged on the continued use of earth as a viable form of construction. Although this is implicitly understood within the field, the dynamic between

the two areas of study and practice has yet to be effectively developed.

The growing discourse on sustainability has presented new opportunities for developing stronger connections between conservation and new construction. Climate change, resource consumption, and population shifts—and their underlying economics—have made apparent, if not dire, the need to revolutionize the way we, especially in the industrialized world, live. The associated challenges of urban growth, construction waste, energy use in buildings, and so on compel explicit transformations in how we design, construct, and manage the built environment.

The function of existing architecture is becoming increasingly significant and controversial as many communities struggle to maintain continuity and manage growth, yet meet the demands of necessary change. But much of the discourse about sustainable design and construction has focused on cutting-edge design and technology, without adequately assessing the environmental, economic, and social costs and benefits of building new versus adapting existing structures and construction methods.

Earthen architecture has yet to establish a significant voice in this sustainability dialogue. This paper examines the challenges faced by the field and explores opportunities for engaging more effectively in policy making and practice.

Defining Sustainability

Twenty years ago the Brundtland Commission Report defined sustainability in the following terms: “Development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (WCED 1987:

43). Two decades hence the principles of sustainability are still debated, but three so-called pillars have emerged as inter-related aspects of sustainability: *environmental*, *economic*, and *social*.¹ While the concept of sustainability has been framed in this tripartite way, the environment and economics have been the primary drivers of innovation to date. With regard to earthen architecture, each poses challenges and opportunities, most notably, the social aspect.

Environmental Sustainability

The built environment in general is a significant user of energy and resources and generator of waste. As estimated by the UN Environment Programme:

- Construction consumes approximately 50% of all the resources humans take from nature;
- The building and construction sector consumes 25–40% of all energy used; and
- Construction and demolition waste accounts for 30–50% of all waste generated in higher income countries. (UNEP-DTIE 2003: 6)

Being based on a recyclable building material that does not require excessive processing (compared, for example, to steel or concrete) seems to bode well for earthen architecture. But the distribution of energy use over building life cycles may not adequately support the case for earth. Of the five phases of energy consumption over the life span of a building (embodied, gray induced, operating, demolition, and recycling), the operating phase consumes the most, at 80 percent, for heating, cooling, lighting, ventilation, cooking, and so on (UNEP 2007). While earthen architecture fares very well with regard to the other life cycle phases, this constitutes a relatively small percentage of energy use on average. In general, because energy consumption during the operating phase is so much greater than that during other phases, much of the research and development in the design and construction industry have focused on innovations to reduce energy use during this period, such as improved windows; high-performance heating, cooling, and ventilation systems; and alternative energy sources (solar panels, photovoltaics).

Of course, these are averages for buildings of all types in all sorts of climates and contexts. However, data sets regarding the energy consumption of earthen buildings—which could be compared to these global statistics—are not well developed. This sort of data compilation and research is pro-

foundly limited because earthen architecture does not have an “industry” or widespread academic constituency that can undertake them.

Economic Sustainability

Without a large, revenue-generating industry or a prolific academy, it can be difficult to demonstrate the economic rationale for earthen architecture. It is a low-cost and highly accessible form of building, and the U.S. Department of Energy estimates that approximately half the planet’s population lives in a home built of earth (USDoE). Clearly, there is a *market* for earthen architecture. However, it remains external to the traditional centers of power in the design and construction world.

This has much to do with who constructs earthen architecture. Over the years many of the institutions and professionals involved in promoting and preserving earthen architecture have worked toward making it a legitimate “discipline” with regard to research, development, education, and professional practice. They have helped to establish standards and industrialize manufacturing. However, earthen architecture remains largely vernacular or informal in nature, meaning that it is owner/occupant constructed using local materials and often does not involve planners, architects, engineers, and other such professionals. It is also more prevalent in lesser developed countries. Thus the “stakeholders” of earthen architecture are quite different from those in the industrialized design and building sector. In most instances, their motivations are less about production and profit, and more about meeting the very material need for shelter. Indeed, this suggests that many, if not most, of the people and processes associated with earthen architecture remain external to the globalizing political economy of design and construction.

Social Sustainability

The aforementioned economic realities relate directly to issues of social sustainability and dominant culture. Vernacular or informal architecture on the whole must contend with many misconceptions. The “grand tour” antecedents and Beaux Arts traditions of architecture have served to create a Eurocentric culture in the field that has been effectively globalized. There is *Architecture* and *architecture*. With regard to scholarship, because they lie outside the trajectory of Greco-Roman-centered architectural history, these vernacular or, in particular, earthen traditions are not well represented in university curricula. With regard to general perceptions, earthen

architecture is considered primitive, not necessarily because of the inherent qualities of the material and design, but precisely because of who constructs it. This viewpoint is common with respect to the developing world, where local resources and know-how rather than top-down design and planning tend to be the building blocks for place-making.

Responding to the principles of professional architecture practice (as defined by the dominant culture), building codes in many countries prohibit construction in earth, and the lack of industry- and university-based research and development precludes standardization and improvement of earthen materials and techniques. Thus these ideologies about what constitutes *Architecture* have influenced regulation of the built environment to a point where the homes of a significant portion of the world's population are basically regarded as substandard or non-normative by professional, industry, and state entities.

This scholarly cum industry exclusion of earthen architecture and the publics who practice it illuminates some salient issues regarding self-determination and social justice. On the one hand, a case can be made for the important role of state and professional institutions in regulating land use, design, and construction, so as to protect life and limb through safe practices, to ensure that decision making is environmentally and socially sound, and to enhance the health and quality of life of communities through appropriate infrastructure. However, one might also argue that dominance by the "developed" world about how to design and construct disenfranchises those in the "less developed" world by devaluing their right to determine the built conditions of their homes.

We in the heritage field are accustomed to grappling with such tensions. Indeed, a fundamental premise of conservation is that engagement with one's own heritage and that of others can promote social sustainability through inter- and intragenerational equity. But what if, as in the case of earthen architecture, that heritage is largely bound up in a process of building that is outside prevailing paradigms? Those of us educated in the disciplines of planning, architecture, engineering, and the like may see great potential in bringing earthen architecture closer to such paradigms (through standardization, industrialization, scholarly and scientific research, etc.). But it is possible that in doing so we are failing to fully capitalize on this profound aspect of earthen architecture. Because of its vernacular nature, earthen architecture represents a once-ubiquitous social process, one that is in effect subjugated by increasing control over the built environment by government, industry, and the professional community. How do we strike a balance between the dominant norms of design and construc-

tion and the non-normative reality of earthen architecture without losing the essence of this heritage?

Opportunities and Challenges of Sustainability

In some ways the sustainability discourse poses even greater challenges to striking a balance because concerns regarding climate, energy, and other resources will increasingly necessitate management of the design and construction industry. In addition, these concerns along with demographic shifts are having profound effects on existing built environments as population levels rise and rural-to-urban migration continues. As pressure mounts to build higher and more densely, heritage resources and processes will be at greater risk but may likewise provide opportunities for more innovative ways to address sustainability.

Agenda 21 on Sustainable Construction and the pursuant discussion paper, *Agenda 21 on Sustainable Construction in Developing Countries*, have homed in on this notion. As the former notes:

A decade ago, the emphasis was placed on the more technical issues in construction . . . and on energy related design concepts. Today, an appreciation of the non-technical issues is growing and these so-called "soft" issues are at least as crucial for a sustainable development in construction. Economic and social sustainability must be accorded explicit treatment in any definition. More recently also the cultural issues and the cultural heritage implications of the built environment have come to be regarded as pre-eminent aspects in sustainable construction. (CIB 1999: 18)

The latter expands on this notion by suggesting:

It may be that, through their cultural heritage, innovative home-grown solutions and adaptability, the developing countries are holding one part of the key to sustainability. (CIB and UNEP-IETC 2002: 73)

But while the importance of heritage is recognized, how it is integrated into new approaches and solutions has not been effectively operationalized as yet.

There have been some promising experiments, for example, the postearthquake reconstruction effort in Pakistan. UN-Habitat took the novel approach of bypassing the use of construction companies, nongovernmental organizations, and the like as funding channels and redevelopment agents and

instead gave money directly to home owners to rebuild their properties themselves. A series of centers were established to educate home owners in safer construction techniques. The program basically invested in the vernacular model, convincing the World Bank to alter construction standards and allow traditional building techniques. Although the program has had its critics and challenges, two years after the disaster 150,000 homes have been rebuilt, 200,000 are under construction, and 250,000 more will be completed in the next year. Considering that two years after the Sri Lanka tsunami only 50,000 homes had been rebuilt and that more than 250,000 people are waiting to return to their homes two years after Hurricane Katrina, we have to presume that this approach holds potential (Page 2007).

The Role of Heritage

This is where we in the conservation field have a critical role to play. We must promote a purview of heritage that includes both existing structures and ongoing building traditions and operationalizes its role in the broader discourse about sustainability and the built environment. However, to cast heritage as an agential element in sustainable approaches to postdisaster recovery, urban expansion and redevelopment, and the like means stepping outside of our conventional paradigm and finding creative solutions for different contexts. There is no universal approach that will fit all. Globalization and related architectural acculturation—coupled with technology driven by comfort, convenience, and profit—have resulted in a situation in the industrialized world in need of drastic remediation. Design and construction practices in the United States, Europe, and many other industrialized regions are simply not environmentally sustainable in the long term. Less developed countries in some respects are not as deeply entrenched in this dilemma. The possibility for leapfrog technology and blending vernacular and preindustrial traditions with the best practices of the industrialized and expert-driven models could make for significant innovation. At the heart of this opportunity is the need to refocus on the social aspects of sustainability and to make heritage conservation a conduit for change rather than a means to prevent it.

For conservation professionals, this means looking beyond the technical and fabric-related issues and focusing much more on the social processes that underlie our work and perpetuate its benefits. Building economic and environmental rationales for conservation of earthen architecture and its new constructions is crucial to forging convergence of these fields

and will likewise better position them in the broader context of design and construction discourse and practice. However, in doing so, we must be careful not to buy into a model that forgoes some of the most significant social values related to earthen architecture. Striking a balance will require renewed attention to the social sustainability aspects of this heritage process and its role in an increasingly globalizing and industrializing world.

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Note

- 1 These are also referred to as the three P's of sustainability: planet, profit, and people.

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Revalorisation des architectures de terre en Ouganda : Un challenge pour un développement durable

Olivier Moles, Barnabas Nawangwe, Alexandre Douline et Philippe Garnier

Résumé : Dans le passé, l'enseignement de l'architecture s'est souvent limité aux principes de construction et à l'esthétique. L'université a pour mandat d'encourager les architectes à élargir ces limites pour que leur travail ait un impact positif sur l'avenir de la société. Or, l'enseignement de la technologie, tel qu'il existe dans le cursus d'architecture, n'est pas véritablement adapté aux matériaux et techniques disponibles et appropriés en Afrique. Cette présentation synthétise les raisons pour lesquelles les architectures de terre sont une des voies qui peuvent permettre à l'Ouganda, et plus largement à l'Afrique, de résoudre ces problèmes.

Abstract: In the past, training in architecture was often limited to construction principles and aesthetics. The university's mandate is to encourage architects to broaden these limits so that their work can have a positive impact on the future of society. Yet technology as it is taught in the architecture curriculum is not really adapted to materials and techniques available and appropriate in Africa. This paper summarizes the reasons earthen architecture could be a means of enabling Uganda and Africa at large to meet these challenges.

Cette présentation retrace l'histoire d'un programme, mis en place en Ouganda entre 1999 et 2006, fondé sur les cultures constructives locales pour développer des architectures contemporaines répondant à l'évolution du cadre de vie des populations du pays.

Ce programme est basé sur le constat suivant : la mondialisation entraîne l'essor d'une architecture contemporaine qui ne tient pas compte de l'ensemble des spécificités culturelles, environnementales et économiques propres aux diverses populations des pays dans lesquels elles se dévelop-

pent (fig. 1). Ces architectures servent de références aux populations locales, représentent la part la plus importante du marché officiel de la construction et orientent le contenu des filières d'enseignements liées au monde de la construction. Toutefois, ce marché ainsi ciblé n'absorbe pas l'ensemble des professionnels formés et il est loin de répondre aux besoins de chacun. Cela entraîne les conséquences suivantes :

- des artisans se trouvent sans emploi et sans solutions dans des secteurs entiers de la population ;
- des élites émigrent ;
- l'ensemble de la population perd confiance dans l'intelligence de ses savoirs et savoir-faire vernaculaires.

Or, l'épuisement prévu de certaines matières premières non renouvelables, les problèmes de pollution, le besoin pour chaque pays d'adapter les compétences de ses professionnels aux besoins de l'ensemble de sa population obligent à repenser ces modèles architecturaux.

En même temps, nous constatons que, consciemment ou non, les groupements humains ont toujours su produire, adapter et faire évoluer leur habitat selon leurs besoins, goûts et capacités, en faisant le meilleur usage des matériaux dont ils disposaient pour faire face aux contraintes auxquelles ils étaient soumis (fig. 2). Cette constante adaptation des sociétés humaines aux évolutions de l'environnement naturel et technique, dans le respect de leurs valeurs, n'est ce pas le fondement même du développement durable ?

Ceux qui ont compris l'intelligence de ces architectures et qui les ont mises en œuvre correctement, les ont éventuellement enrichies grâce aux nouveaux matériaux, aux nouveaux savoirs, aux techniques et technologies d'aujourd'hui. Ils



FIGURE 1 Centre ancien de Riyad en 1990. Photo : Thierry Joffroy. © CRATerre

ont su créer une architecture contemporaine qui répond aux besoins de modernité, de réduction de l'entretien, de standard esthétique, tout en respectant environnement, culture, capacité technique et économique de chacun (fig. 3).

Le problème est que du fait de l'enseignement reçu, nos élites d'intellectuels et d'artisans ne sont pas préparées à ce type d'approche. Il est urgent de réajuster les programmes de formation de l'ensemble des filières de formation technique et universitaire pour tirer le meilleur profit de ces savoirs.

En Ouganda, le Pr Barnabas Nawangwe, doyen de la Faculté de Technologie de l'Université de Makerere (MAK), fait le constat suivant : « L'université a pour mission



FIGURE 2 Mosquée malienne, San, Mali, 2007. Photo : Thierry Joffroy. © CRATerre



FIGURE 3 Architecture contemporaine en France, 1990. Photo : Thierry Joffroy. © CRATerre

d'encourager les architectes à élargir les limites de la réflexion et de l'apprentissage pour que leur travail ait un impact positif sur l'avenir de la société qu'ils sont appelés à servir. Les étudiants doivent arriver à faire ressortir les fondements culturels des civilisations africaines et à combler le fossé qui existe entre ces derniers et les modèles occidentaux qui sont devenus la norme d'une soi-disant architecture internationale. »

Il saisit donc deux opportunités consécutives pour atteindre cet objectif. Un premier programme (1999–2001), qui permet aux Départements d'Architecture de Makerere de mettre au point des maquettes pédagogiques sur l'enseignement des architectures de terre et de l'habitat économique. Un second programme suit (2001–2006), lancé par une ONG de développement ougandaise, Rukararwe Partnership Workshop for Rural Development (RPWRD), qui constate que l'évolution des technologies associées à l'habitat (brique cuite dans ce contexte) est l'un des importants vecteurs de déforestation du district de Bushenyi, et plus généralement de l'ensemble de l'Ouganda. Cette application sur le terrain permet de renforcer le lien entre pratique et théorie, de mieux appréhender le potentiel du marché existant, d'améliorer ainsi la qualité de l'enseignement et de le rendre plus pertinent.

Conscient que l'architecte seul ne peut parvenir à renouveler les filières de construction traditionnelle, que ses hypothèses devront être validées par les ingénieurs et techniciens, et qu'il lui faudra trouver les artisans et ouvriers qualifiés qui sauront réaliser, dans les règles de l'art, les édifices qu'il aura conçus, le projet a su mettre en place dès le départ un partenariat d'organisations et d'institutions complémentaires, à savoir :

- RPWRD, avec sa connaissance des populations locales et sa capacité à intervenir auprès des professionnels en activité pour se faire l'écho des populations et permettre à court terme de disposer d'artisans qualifiés ;
- Deux écoles professionnelles et techniques – le Khymahunga Technical Institute (KTI) et l'Ugandan Technical College (UTC) – permettant de disposer à moyen terme de chefs de chantier et de conducteurs de travaux capables de gérer des chantiers de moyenne à grande envergure ;
- L'implication des enseignants et étudiants de l'Université de Makerere, afin d'avoir à terme en Ouganda une élite capable de faire évoluer le paysage architectural vers des concepts répondant mieux aux besoins et spécificités de l'ensemble de la population.

Le projet a été mis en place selon une méthode itérative en quatre temps prenant de l'ampleur au fur et à mesure de son évolution dans le temps :

1. Étude et analyse du secteur de la construction et de son environnement ;
2. Conception d'un projet, de stratégies et de plans d'actions adaptés au contexte ;
3. Mise en exécution du projet ;
4. Évaluation et analyse des résultats obtenus pour redéfinir et concevoir le programme d'activité suivant.

Les résultats du projet ont confirmé la validité et l'efficacité de cette méthode basée sur le transfert et l'introduction, puis appropriation de savoirs complémentaires dans un contexte donné.

La première étape a concerné l'étude des conditions locales d'habitat :

- la construction en torchis représente 90 % de l'habitat ;
- la technologie de l'adobe est relativement récente dans la région ;
- la brique cuite est le matériau préféré de l'ensemble de la population.

L'analyse a porté sur l'intelligence et les limites de ces modèles d'habitat traditionnels et modernes et sur les potentiels existants au niveau local en termes de matériaux disponibles, de compétences, de capacités d'enseignement et d'apprentissage.

Les problèmes relatifs à chaque type de matériau et procédés de construction ont été évalués.

Torchis :

- la stabilité de la structure est assurée par les poteaux en bois plantés dans la terre. À l'interface entre partie enterrée et partie non enterrée, ces poteaux sont soumis à des cycles d'humidité et de séchage qui entraînent leur pourrissement rapide et donc la perte de stabilité de l'ouvrage. L'ensemble de la structure doit être renouvelé tous les 10 ans environ, ce qui contribue à la déforestation du pays ;
- les populations cherchent à protéger leurs maisons en utilisant des matériaux modernes, mais par manque de connaissances et de conseils appropriés, elles gaspillent souvent leurs ressources en vain, en

appliquant par exemple des enduits en ciment sur les constructions en terre, solutions inadaptées et coûteuses qui entraînent des détériorations après seulement quelques années.

Brique cuite :

- la cuisson de la brique est faite de façon traditionnelle en consommant énormément de bois (16 m³ pour la construction d'une salle de classe aux normes) ;
- la qualité de ces briques n'est pas garantie ;
- le coût des bâtiments réalisés avec ces briques est souvent trop élevé pour permettre aux collectivités locales d'en assumer seules la prise en charge.

À partir de ces constats et sur la base de références d'architectures modernes et contemporaines, de nouveaux modèles ciblés sur les différents publics ont été conçus. Ces modèles prennent en compte une réflexion sur les modes d'organisation sociale, les capacités techniques et financières, et les principes constructifs permettant d'adapter les formes et les espaces afin de répondre aux objectifs suivants :

- répondre aux besoins contemporains ;
- optimiser l'emploi de matériaux localement disponibles pour garantir l'accessibilité économique et la durabilité environnementale ;
- mettre l'accent sur la création de qualifications et d'emplois locaux.

Les résultats attendus du projet étaient les suivants :

- accessibilité à l'habitat ;
- protection de l'environnement ;
- appui à la mise en place de centres d'excellences qui initient des projets similaires ;
- enseignement effectif des cultures constructives locales.

Un des handicaps (mais aussi un témoignage fort de leur intelligence) qui empêche de faire le meilleur usage des cultures constructives locales est leur diversité, ces savoirs étant toujours contextuels. Il n'est donc pas possible de les enseigner en donnant des recettes que les professionnels devront par la suite appliquer, sans parfois comprendre leur fondement, ceci avec tous les effets non désirés que ce type d'approche peut parfois engendrer. L'enseignement de ces approches consiste à expliquer aux futurs professionnels, selon leur niveau de

qualification, les caractéristiques des matériaux et produits dérivés, de vérifier et de contrôler les processus de production et les caractéristiques des produits obtenus, de faire comprendre aux futurs professionnels que chacune des parties d'un bâtiment subit des contraintes spécifiques et variées, et que chacune de ces parties peut donc devoir être traitée de façon spécifique.

Cela permet en fin de compte de mettre à la disposition des professionnels un catalogue de réponses techniques qui seront assemblées de façon judicieuse. L'usage de ces architectures ne doit pas se limiter à répondre seulement aux besoins des plus pauvres. Le choix final de ces assemblages est laissé au client, qui, informé des spécificités de chacune des solutions proposées, pourra prendre sa décision en connaissance de cause. Cependant, comme pour toute nouveauté, et même si leur différence avec l'existant est minime, les clients et bénéficiaires potentiels doivent pouvoir constater *de visu* la véracité des avantages qui leur sont théoriquement attribués. Le projet a donc mis en place des stratégies de démonstration, de sensibilisation et d'information des différents publics. Les activités développées ont créé autant d'occasions d'échanges avec les détenteurs des savoirs locaux et de formation sur des supports concrets.

Le projet a permis de proposer une réponse conforme aux standards de l'Ouganda en termes d'exigence de qualité, de durabilité et d'entretien des bâtiments publics (figs. 4-6). Les résultats les plus remarquables sont :



FIGURE 4 Prototype de construction contemporaine en torchis à Bushenyi, Ouganda, 2005. Photo : Olivier Moles. © CRATerre



FIGURE 5 Prototype de construction contemporaine en adobe, Bushenyi, Ouganda, 2005. Photo : Olivier Moles. © CRATerre



FIGURE 6 Prototype de construction contemporaine en blocs de terre comprimée, Bushenyi, Ouganda, 2005. Photo : Olivier Moles. © CRATerre

L'avantage économique (tableau 1)

- une réduction des coûts au m² passant de 50 à 58 € contre environ 70 € pour les solutions conventionnelles ;
- un entretien beaucoup plus accessible aux plans techniques et économiques du fait de l'emploi de matériaux locaux.

L'avantage environnemental

- une réduction de l'emploi de la brique cuite et une économie d'énergie sur la production représentant 13 m³ de bois épargné pour la construction d'une salle de classe.

L'avantage social

- un rapport monétaire directement investi au plan local de 26 à 27 % contre 11 à 20 % pour les solutions conventionnelles ;
- grâce à la variété des architectures proposées et des méthodes de construction développées, les différentes couches sociales de la population de Bushenyi trouvent des solutions pour la construction de leur habitat (urbain et rural) ;
- le rêve d'accessibilité à une maison en briques cuites est dépassé ; les artisans formés et sensibilisés sont fiers des maisons en adobe qu'ils se construisent ;

Tableau 1 Étude comparative des résultats obtenus pour un investissement de 1 million d'euros dans la construction d'infrastructures publiques (blocs de deux salles de classes) en Ouganda (district de Bushenyi)

Comparaison pour un bloc de deux salles de classe	Modèle conventionnel en brique cuite et toiture en tôle	Modèle proposé en blocs de terre comprimée stabilisée et toiture en tôle	Modèle proposé en adobe et toiture en tôle
Nombre de blocs de salles de classes qui peuvent être construits (Coût par m ² habitable)	152 (69 €/m ²)	180(58 €/m ²)	192 (54 €/m ²)
Durée de vie	> 50ans ; en fonction de l'entretien	> 50ans ; en fonction de l'entretien	> 50ans ; en fonction de l'entretien
Entretien et maintenance des murs	Nécessite un appui financier extérieur	Nécessite un appui technique et financier extérieur	Gérable par les communautés locales
Montant investi dans la main d'œuvre	80 000 €	205 100 €	253 700 €
Montant investi dans l'économie locale	110 800 €	263 100 €	353 700 €
Bois de cuisson consommé	4 864 m ³	730 m ³	2 334 m ³

- grâce à la qualité des réalisations et à la clarté des justifications liées à l'intérêt de ces approches (non basées sur le tout économique ; les intérêts sociaux, culturels et environnementaux sont traités au même niveau). Les bailleurs de fonds nationaux, bilatéraux (Ambassade d'Allemagne, de France et autres) et multilatéraux (Union Européenne) valident et utilisent ces solutions techniques dans le cadre de la réalisation d'infrastructures qu'ils financent en Ouganda, et favorisent la diffusion du concept hors des frontières du projet ;

La pérennité de l'action engagée

C'est une réponse aux besoins à court terme.

- les équipes de l'ONG RPWRD contribuent à la formation des professionnels, maçons et charpentiers ;
- des actions de formation de formateurs sont régulièrement engagées ;

C'est une réponse par anticipation à des besoins à moyen terme.

- l'introduction, à titre expérimental, des technologies dans les programmes des écoles techniques KTI et l'UTC ;

C'est une réponse par anticipation à des besoins à long terme.

- le Département d'Architecture de l'Université de Makerere a développé deux nouveaux enseignements sur « les architectures de terre » et sur « l'habitat économique ». Ces modules sont validés par les examens de fin de troisième année ;
- des matériels pédagogiques ont été conçus en partenariat avec les enseignants des institutions de formation et une attention particulière a été portée aux moyens propres et aux méthodes pédagogiques de chaque institution. Ces matériels ont été testés et améliorés durant la première phase de développement du projet.

Ce projet a permis de mieux appréhender certaines réalités de l'enseignement technique dispensé en Ouganda, et plus généralement en Afrique :

- les référentiels sont souvent inadaptés au marché local ;
- les méthodes pédagogiques sont axées sur la mémoire de l'élève et n'intègrent que peu de pratique ;

- les programmes existants ne condamnent pas l'enseignement des cultures constructives locales, mêmes si ces dernières sont souvent négligées.

La faisabilité de la remise en valeur de l'enseignement des cultures constructives locales dans l'enseignement existant :

- c'est possible et peu coûteux. La matière première est abondante et bon marché. Les savoirs sont encore vivants ;
- cela facilite la mise en place d'une pédagogie active. Les formations pratiques sont plus simples à mettre en place du fait qu'elles ne nécessitent pas d'achat d'intrants chers.

Comment rendre ce type d'enseignement effectif ?

Il est indispensable que le contrôle des acquis de ces enseignements figure dans les programmes des examens nécessaires à l'obtention des diplômes d'État. Cela est relativement simple à mettre en place pour les universités qui ont une grande autonomie dans le domaine des enseignements qu'elles développent. Cela l'est beaucoup moins au niveau des établissements d'enseignement technique, dont les programmes et les examens sont définis à l'échelle nationale. Pour atteindre ce résultat, il faut sensibiliser les élites chargées de la définition de ces politiques d'enseignement.

Ce projet a aussi permis de faire le constat que l'introduction des cultures constructives dans l'enseignement permet de mieux répondre aux marchés existants et futurs, qu'elle facilite la reconnaissance des cultures constructives de l'élève et de l'enseignant (en effet, ils habitent eux-mêmes souvent la terre), qu'elle permet le développement d'une pédagogie plus active (en partenariat avec le marché de la construction), sans surcharger le programme, mais au contraire en allégeant les cours théoriques.

Pourtant, le marché ne pourra réellement se développer que lorsque ces approches architecturales seront suffisamment intégrées dans le secteur local de la construction. Ces niveaux critiques de réalisation restent encore à atteindre dans beaucoup de pays.

Chaque nouveau projet doit donc permettre de nouvelles expérimentations, liées à la recherche et prolongées par une importante activité de publication scientifique et technique assurant la diffusion des savoirs au sein de la communauté internationale.

Le *ksar* d'Assa : Mémoire des lieux et compétence d'édifier dans le Maroc présaharien

Salima Naji et Lahoucine Rah

Résumé : Fondée au XII^e siècle sur un piton rocheux qui domine une source pérenne exploitée par une oasis importante, Assa, la cité de terre et de pierre, s'étend sur plusieurs hectares. En 2006, l'Agence de développement du Sud lance un programme de restauration autour du vieux *ksar*, témoin culturel et historique des liens unissant le Maroc au Sahel, dans l'espoir de doter la ville d'un ensemble patrimonial restauré capable à la fois de former des maîtres artisans qualifiés et d'attirer les flux touristiques. C'est ainsi que sont mises au point une méthode participative et une formation touchant toute la société civile.

Abstract: Founded in the twelfth century on a rocky peak overlooking a permanent spring used by an important oasis, Assa, the city of earth and stone, encompasses several hectares. In 2006 the Agency for the Development of the South launched a program to restore an old *ksar*, the cultural and historical evidence of the ties linking Morocco to the Sahel, in the hope of providing the town with a restored heritage site able both to train master craftsmen and to attract tourists. To this end, a participative and educational program for civil society as a whole was devised.

Dans la continuité de l'œuvre exemplaire de Hassan Fathy, le projet de réhabilitation du *ksar* d'Assa, mis en œuvre par l'Agence pour le développement des provinces du Sud, s'est appuyé sur l'implication forte de la population locale, en employant et en formant la main d'œuvre, mais surtout en proposant de vrais soutiens pour la création, sur place, d'activités génératrices de revenus ou d'emplois. L'idée forte était de concevoir une restauration qui ne soit pas une coquille vide mais le lieu d'un développement local intégré, répondant à la culture des lieux et aux besoins de la population. Le Programme Ksar Assa¹ prend une dimension totale qui asso-

cie en effet la réhabilitation comme origine et comme support à une réflexion globale sur l'usage du patrimoine dans les pays du Sud. Une méthodologie de mise en réseau articulant la cinquantaine d'associations locales, les institutions étatiques et des partenaires extérieurs, est élaborée autour de l'action concrète de restauration du site (fig. 1).

Fondée au XII^e siècle de notre ère², sur un piton rocheux qui domine une source pérenne exploitée par une belle oasis (fig. 2), Assa, port saharien où s'approvisionnaient jadis les caravanes, est avant tout une cité sainte qui s'étend sur plus de sept hectares autour d'une *zawiya* (mosquée et medersa intégrée au tombeau d'un saint). En grande partie abandonné pendant la décennie 1980 au profit de la ville nouvelle sur la rive opposée, le *ksar*³ sombre lentement dans la ruine bien qu'une dizaine de maisons continue d'être habitées. Mais, parce que c'est un lieu religieux important, tous les vendredis les lignages anciens s'y rendent, pour une visite au tombeau de leur aïeul, pour des agapes régulières, prouvant l'intérêt de la population pour le lieu. Aussi, en 1990, 1998, et 2002, des restaurations de monuments religieux sont réclamées par la population. Malheureusement exécutées avec un grand mépris de la qualité du bâti ancien et de la culture des lieux, réputés archaïques, trois mosquées sont rasées pour être remplacées par des édifices en ciment de béton qui reprennent l'habitat informel des villes arabes comme référence à la modernité.

Pourtant, ce *ksar*, architecture de collecte, fruit d'une lente accumulation de constructions, donne une leçon d'architecture et confronte à la spécificité du travail d'architecte aujourd'hui face à tout patrimoine collectif. Les architectures rurales du grand sud marocain sont pour nous, des corps constitués, des corps entiers difficilement sectionnables,

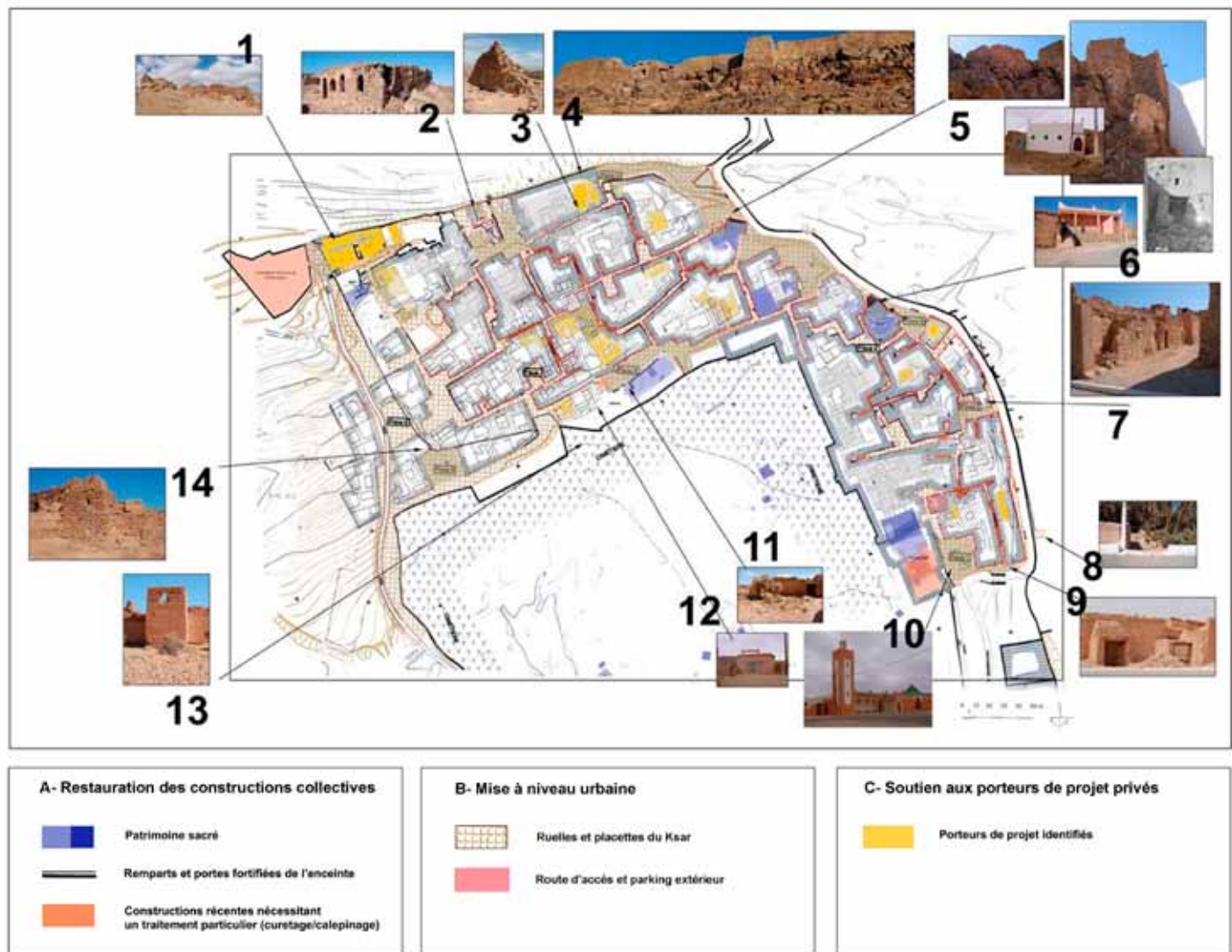


FIGURE 1 État des lieux avant intervention et pré-inventaire. A : restauration des parties collectives (patrimoine sacré, remparts, curetage ou calepinage). B : mise à niveau urbaine. C : porteurs de projets privés identifiés pour la première phase. Plan de situation © S. Naji, architecte en chef du projet

FIGURE 2 Vue panoramique sur la palmeraie et la ville nouvelle depuis le haut du Ksar avant la restauration. Assa, la cité aux « 366 saints », s'étend sur plus de sept hectares autour d'une *zawiya* (mosquée et medersa intégrée au tombeau d'un saint) et d'un cimetière immense. Photo © S. Naji

« architectures sans architectes » issues de leur environnement proche qu'elles épousent et dont elles sont le miroir. Les matériaux sont souvent uniquement locaux dans un souci d'économie et d'adaptation au milieu. Ainsi, les premières maisons proches de l'oued sont construites en pisé sur une base en galet, puis progressivement, à mesure qu'on pénètre dans le *ksar*, les techniques se font mixtes en privilégiant les briques de terre avant de laisser place à la pierre de schiste sur le promontoire. Le matériau guide la forme et le bâti. Matériaux, gestes et pratiques révèlent l'élaboration lente d'une « compétence d'édifier », transmise de génération en génération. Nous empruntons cette notion complexe à Françoise Choay qui l'a définie de façon à ce qu'elle ne soit pas confondue avec les « techniques de construction utilisées pour la production de notre cadre de vie actuel » (Choay 1992). La compétence d'édifier est, selon elle, un « langage propre à l'homme », un art d'édifier qui s'apprend sur la durée et qui concerne le corps entier dans l'espace et le temps. Elle est cette science de la conception et cette sensibilité qui permettent ensemble de bien construire un édifice ; elle est également ce qui a légitimé de savoir les regarder selon leur essence. Cette compétence d'édifier qui témoigne d'une indispensable maîtrise des matériaux et de leur mise en œuvre, est nécessaire à toute volonté de préserver un édifice historique.

Or, actuellement au Maroc, même lorsque les maîtres constructeurs (*maalmines*) connaissent les modes constructifs, ils ne suivent pas toujours les règles de l'art. Les mutations contemporaines ont transformé leur approche, ont déplacé les hommes, ont brouillé les repères. La perte de confiance dans le patrimoine bâti ancien s'est inévitablement accompagnée d'une perte des compétences. Ce que beaucoup auraient été capables de conduire seuls jadis, est devenu une source de difficultés. Du côté des décideurs, l'ignorance des mises en œuvre locales, des protocoles à respecter, des études préalables, peuvent conduire également à des erreurs qui sont, à terme, funestes aux bâtiments. Le respect des procédés constructifs originels, la nécessaire prudence, la retenue ou l'expérimentation contrôlée, qui accompagnent toute restauration, sont souvent incompatibles avec le besoin de résultats visibles et rapides, voire avec la mise en scène spectaculaire d'un édifice restauré. Tout ceci participe des fondements de toute approche de restauration ou de réhabilitation, mais ils deviennent, dans la réalité du chantier, le lieu d'un affrontement permanent.

Car ce qui ressort de toute observation sur l'évolution de l'usage des matériaux traditionnels dans le Sud marocain sur ces quatre dernières décennies, est le non-respect des règles de l'art joint à une utilisation croissante du ciment. Après

l'Indépendance, les *maalmines* relâchent leur effort : pourquoi construire de manière très résistante maintenant que le pays est pacifié ? Les procédés exigeants mis au point sur la durée sont peu à peu négligés. Les règles de l'art apparaissent comme des détails insignifiants ; non respectées, elles vont pourtant compromettre la pérennité des bâtiments. Le matériau traditionnel perd alors sa qualité première de solidité et, de ce fait, la confiance qu'on lui prêtait autrefois. Parallèlement à ces pertes dont on ne perçut pas d'abord l'importance, s'est ajoutée, comme en Europe la croyance en un produit miracle, nouveau, capable sans entretien de durer des siècles : le ciment. Il s'est immiscé dans les procédés traditionnels. Les *maalmines* faisant des allers et retours constants entre leur campagne et les villes ont voulu améliorer le traditionnel sans toujours parvenir à des résultats concluants. Les frontières entre les procédés se sont brouillées encore davantage. Mais surtout s'est ajoutée cette idée que les procédés anciens étaient des archaïsmes, symboles de misère et de ruine. Il devenait par conséquent ensuite évident que les formes construites traditionnelles allaient être pareillement déconsidérées.

Or, pour créer les conditions de pérennisation des édifices anciens, il faut créer un lieu de préservation véritable des métiers et des compétences. Les actions à conduire pour sauver ces édifices ne sont pas celles des seuls techniciens du bâtiment ou de la logistique culturelle, les volontés doivent venir des communautés elles-mêmes pour ne pas désincarner l'édifice en un objet architectural coupé de son environnement, de son histoire, des pratiques. Ces compétences « originelles » s'apprenant jadis sur la durée, furent souvent disqualifiées par les modes de construction de la « modernité » : un maître constructeur du Sud se trouvant placé ainsi entre ces deux modes constructifs antithétiques ne sait comment se positionner.

La première étape du projet d'Assa fut donc de recréer le rapport au chantier et à la compétence d'édifier. Des *maalmines* originaires des régions environnantes sont guidés par l'architecte dans une démarche archéologique de redécouverte des formes et des procédés constructifs proprement locaux (figs. 3-5). Sur le chantier, les anciens sont invités à accompagner le travail mis en œuvre pour reconstruire un lieu proche (la restitution à partir de ruines souvent très avancées est difficile). Des jeunes, originaires d'Assa, sont engagés sur le chantier et sont formés progressivement aux techniques pour recréer une main d'œuvre qualifiée indispensable à toute action de réhabilitation. Parallèlement, la démarche s'inscrit dans un partenariat avec l'Office pour la formation professionnelle (OFPPT), pour donner aux maçons ayant reçu



FIGURE 3 Restitution de l'ancien rempart, double paroi en pierre et en pisé. Mise en œuvre du pisé d'Assa : damage dans la banche sur assise de pierres. Photo © S. Naji

cet apprentissage spécifique un statut particulier reconnu nationalement. Le chantier redevient un lieu de transmission d'une culture matérielle, mais aussi immatérielle, dont la chaîne avait été rompue. Les doyens reprennent leur place de relais là où ils étaient marginalisés dans la ville moderne.

Ainsi, pour une architecture collective comme un *ksar*, la remise en mouvement du collectif sous de nouvelles formes

permet la redynamisation du lieu. Ce chantier est aussi un moment de mobilisation de la société civile autour de son patrimoine par de nouveaux usages⁴.

Un lieu ruiné matériellement n'est pas systématiquement un lieu totalement abandonné sur le plan des idées. En effet, si de nombreuses architectures collectives du monde rural comme les *ksours* (village fortifié), les *agadirs* (grenier col-



FIGURE 4 Compétence d'édifier, retrouver les gestes. La charpente très simple est constituée de stipes de palmier de section rectangulaire ou triangulaire, très rapprochées. Ces solives portent perpendiculairement au mur, le voligeage est constitué de tiges de palmes. Un lattis serré de branches de laurier ou de palmes sèches est ensuite recouvert de palmes entières fraîchement cueillies, apportées et déposées sur cette structure, de sorte que le mortier final, répandu au-dessus ne passe à travers. Une fois les interstices ainsi comblés, on peut répandre le mortier de couverture, préalablement malaxée au pied. Photos © S. Naji

FIGURE 5 Compétence d'édifier : le corps à l'œuvre pour terminer les couvertures. Photos © S. Naji



lectif), les *kasbahs* (demeure seigneuriale fortifiée), s'effritent un peu plus chaque jour au Maroc (Mouline et Hensens 1991) parce que le groupe responsable (tribus, lignages, sociétaires, familles) n'arrive plus à mobiliser ses forces vives pour assurer l'entretien matériel du lieu (Naji 2001), ce n'est pas pour autant qu'elles ont été symboliquement vidées de leur dimension identitaire et patrimoniale. Bien au contraire, ces architectures-matrices restent souvent des lieux de souvenirs et de fierté d'un temps héroïque. Le lieu est associé à une culture matérielle aujourd'hui délaissée mais non oubliée : ils deviennent des « lieux de mémoire » (Nora 1984). Cette mémoire est une donnée essentielle pour tout projet futur de réhabilitation. À Assa, le développement d'une société civile nouvelle sous forme de tissu associatif s'est donc naturellement inscrit dans la continuité des institutions traditionnelles des *jama'as*, les conseils des *inflas* ou les *Ayt Raba'yn*, instances supra-locales qui représentaient de façon égalitaire les principaux lignages du *ksar* d'Assa. Par conséquent, ces institutions traditionnelles ont été réactivées par rapport aux institutions nouvelles que représentent les associations. Les décisions importantes sont prises régulièrement en assemblées générales.

La dimension muséale est apparue immédiatement comme l'une des revendications principales des habitants du *ksar* (fig. 6). Pour autant, le musée ne doit pas être démultiplié. Il doit être un espace ouvert associé à des lieux de convivialité faisant de lui un lieu non pas de conservation de la culture,

mais de mise en mouvement de cette culture. Par exemple, à la demande de l'association Ihchach qui possède un site important en amont du *ksar*, un café a été aménagé dans l'un des belvédères du *ksar* pour que la famille puisse autofinancer d'autres projets (musée familial garant de la mémoire du groupe, associé à un théâtre de plein air pour accueillir les représentations musicales de groupes de danse). C'est alors que le *ksar* redevient un lieu de vie, de nouvelle création et de transmission, comme le prouvent différents festivals organisés dès mai 2007⁵. Ainsi, les espaces restaurés sont avant tout tournés vers la population locale et sa vaste diaspora désireuse de connaître ses origines. Le tourisme vient se greffer au mouvement sans en être l'unique moteur.

À côté des autres activités, l'accueil touristique est en effet apparu comme extrêmement convoité par les particuliers désireux de créer des gîtes ou des restaurants. Ces projets sont soutenus pour conserver une qualité architecturale attendue par le public et avant tout fondée sur le vernaculaire. L'architecte conseille sur le choix des formes, la disposition des pièces, les revêtements des murs pour que le propriétaire puisse faire une synthèse entre la tradition architecturale, qui est un attendu du public, et les besoins de nouveaux aménagements nécessaires aux nouvelles activités. Il est proposé divers niveaux de standing qui rendent toujours hommage à la culture des lieux. Ces activités d'accueil sont indispensables à la pérennité de la restauration des parties collectives. En effet,



FIGURE 6 La dimension muséale du projet : certaines familles s'intéressent soudain à leur passé en désirant, notamment, mettre en valeur leur fonds d'archives en un musée historique d'Assa. La reconstruction de cette histoire se fait autour d'un projet qui remplit ce besoin de reconstruction de la mémoire dans un échange intergénérationnel autour d'anecdotes qui mêlent traditions orales du groupe et récits familiaux des sept lignages fondateurs. Photo © S. Naji

l'usage régulier – source de bénéfices financiers, matériels et culturels – permet la mise en place d'une société civile investie et plus à même de prendre en charge ou d'accompagner les pouvoirs publics dans l'entretien des parties collectives. Enfin, le lieu va accueillir progressivement d'autres activités économiques qui donnent une vie au *ksar* : des projets de coopératives de produits locaux, une médiathèque et un cyber-café, et aussi, en partenariat avec les ministères concernés, un site d'accueil pour les pèlerins intégré dans l'une des plus belles maisons du *ksar*.

La société civile, lassée des discours et des projets de papier, s'est approprié le projet dès la mise en place du chantier. La mise en mouvement d'un collectif complexe s'est faite non sans tensions, les conflits témoignant d'une réelle volonté de participation autour d'actions fortes. Une fois les conflits dépassés par le dialogue et l'écoute, ces actions dénouent les difficultés et permettent de construire un projet solide et pérenne. L'architecte et l'Agence du Sud ont ainsi élaboré sur le terrain un plan d'action respectueux, au service d'une société complexe, visant à éviter les déséquilibres, notamment sociaux. En conclusion, nous pouvons affirmer qu'à travers le projet du *ksar* d'Assa, l'architecture devient un véritable élément dynamisant de toute une culture locale héritière des grandes cités présahariennes. La restauration des murs permet une réappropriation des lieux en créant une revalorisation du passé par des pratiques qui recréent une identité garante de l'avenir.

Notes

- 1 Programme lancé en décembre 2005 par l'Agence pour le développement économique et social des provinces du Sud, Primature, Rabat. Après une phase d'étude, un chantier de réhabilitation des parties collectives du *ksar* est ouvert, fin février 2006, pour mobiliser la population autour d'une action concrète. À partir de mai 2007, des actions de soutien aux porteurs privés de projets locaux sont engagées. En décembre 2007, le projet est présenté sur place à Sa Majesté Mohamed VI.
- 2 La *Zawiya* aurait été fondée par Sidi Issa ben Salah, mort en 500 de l'Hégire (1107) ; l'histoire retient encore la figure d'un saint guerrier, Sidi Y'azza U Ihda le conquérant, patron d'Assa, enterré en 727 de l'Hégire (1327). Depuis le XIV^e siècle, en effet, l'humble *Zawiya* devenue prestigieuse a essaimé dans toute la région. Par ailleurs, bien avant l'avènement de l'islam, les gravures rupestres et les légendes locales attestent d'une implantation humaine très ancienne sur le site.
- 3 *Ksar* (prononciation locale *gsar*) : mot d'origine arabe [*qsar*, pl. *qsour*] désignant un ensemble fortifié caractéristique, regroupant des habitations implantées en bordure des palmeraies. Entourés d'une enceinte fortifiée, munie de tours d'angle, ces établissements de formes diverses selon les configurations naturelles des sites, appartiennent au patrimoine artistique et technologique reconnu du Maroc saharien où ils fonctionnent généralement avec une palmeraie.
- 4 Fruit de l'expérience des interventions préalablement conduites sur des greniers collectifs de l'Anti-Atlas menées avec nos fonds personnels de 2003 à 2006 : grenier d'Innoumar, grenier d'Ighrem, grenier d'Aguellouy.
- 5 Ces festivals portés par des collectifs d'associations locales avec la Province comme partenaire logistique, illustrent le dynamisme de la société civile (programmation de concerts, danses chantées, d'épreuves sportives pour les enfants).

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Sustaining an Ancient Tradition: The World Monuments Fund and the Conservation of Earthen Architecture

Gaetano Palumbo, Norma Barbacci, and Mark Weber

Abstract: *The World Monuments Fund (WMF) is a private, nonprofit organization that supports conservation projects worldwide and is actively engaged in the preservation of earthen architectural heritage. This paper presents some recent large-scale projects and discusses the opportunity WMF sees in interpreting the values and issues of conserving earthen architecture to a wider donor audience. We propose a solution of developing relatively small groups of donors interested in traditional community-based conservation projects as a means to promote community cohesion and economic and environmental sustainability.*

Résumé : *Le World Monuments Fund (WMF), organisation privée à but non lucratif apportant son soutien à des projets de conservation dans le monde entier, est activement engagé dans la préservation du patrimoine bâti en terre. Cette communication présente certains projets récents de grande envergure et montre comment ils permettent au WMF d'interpréter les valeurs et les problématiques de la conservation du bâti en terre pour un large public de bailleurs de fonds. Nous proposons une solution : créer des groupes relativement restreints de donateurs qui s'intéressent à des projets de conservation traditionnels fondés sur la communauté, favorisant ainsi la cohésion communautaire et la durabilité économique et environnementale.*

As a private organization dedicated to the conservation of immovable heritage worldwide for nearly forty years, the World Monuments Fund's (WMF's) involvement with the conservation of earthen architecture is relatively recent. Over the first twenty years of the fund's existence, its programs focused on stone architecture, mainly because of

the geographic choice of project sites. WMF was first introduced to the special issues of earthen architecture in the early 1990s when it began a partnership with Cornerstones, which was at the time a program of the New Mexico Community Foundation and is now an independent conservation organization. Cornerstones was seeking to address the plight of deteriorating adobe churches throughout New Mexico by providing traditional Hispanic communities, which were losing their social viability as well as their buildings, with the capacity to work together to repair these buildings and in doing so strengthen the foundations of their communities. WMF brought financial support and international recognition to the program, but it also introduced Cornerstones staff to international training models, such as the Spanish government's Escuela Taller program, which Cornerstones later adapted successfully in a range of Hispanic and Native American communities in New Mexico.¹

With the advent of the World Monuments Watch™ program in 1996, the need for greater advocacy to protect the conservation of earthen buildings has been highlighted. Many earthen buildings throughout the world came to WMF's attention through the Watch list. A common element among them is often their capacity to embody the spirit and technology of traditional community-based construction. This architectural form requires continuous maintenance; therefore, the conservation of earthen structures presents an opportunity for community cohesion. Many communities that have historically used mud-brick construction are losing these traditions through social change and outward migration of their young people. To preserve earthen architecture, a new generation must be reintroduced to traditional practices of building construction and repair, and new sources of

economic activity, often involving tourism development, must be created to sustain youthful populations in these communities. Independently, new technologies must be developed to address the impact of climate change on vulnerable earthen structures built in regions that are experiencing drastic environmental change. Finding the resources to focus on the special issues of urban and rural architecture can be challenging. Many endangered earthen sites are located in remote and sparsely populated areas where the communities are poor. Preservation-centered organizations and individuals need to develop compelling arguments as to how the conservation of earthen and other traditional buildings can help sustain these communities and enhance their quality of life. Moreover, since many mud-brick structures are relatively simple and modest in size, efforts are needed to raise public awareness of their unique qualities and the important role they play in creating opportunities that provide economic benefit and ensure cultural continuity.

This paper provides a rapid panorama of WMF activities. We hope it will show how we and our partners are committed to the conservation of cultural heritage worldwide. We also discuss some of our strategies for financing earthen architecture conservation projects.

The World Monuments Fund and Earthen Architecture Conservation

Over the past decade WMF has conducted twenty-three projects on earthen sites in thirteen countries—only a small portion of the architectural conservation projects the organization has supported worldwide. The case studies presented here illustrate our approach to supporting the conservation of earthen architecture. A critical aspect in our decision making about which projects to support is the ability of the site managers to ensure continuous maintenance after the conservation work has been completed. This is done to avoid interventions based solely on remedial or short-term goals.

Merv, Turkmenistan

The oasis of Merv is strategically sited in the Karakum desert and formed an essential military headquarters and staging post on major east-west trade routes. Founded in the sixth century B.C.E., Merv grew to become the largest city-state in southwestern Central Asia, serving as a regional capital and the capital of the Seljuk Empire (eleventh–twelfth centuries). Its unusual urban development and cosmopolitan population make it of exceptional archaeological interest: it consists of

adjacent ancient, medieval, and postmedieval cities, each with well-preserved military fortifications that provide a unique architectural overview. An outstanding series of monuments, both religious and secular, has also survived, including the twelfth-century Mausoleum of Sultan Sanjar, one of the most important buildings of its age, and other Seljuk and Timurid mausolea. Even more remarkable are the vernacular buildings constructed of mud brick. These include uniquely Central Asian buildings, *koshks*, *kepter khanas*, palaces, pavilions, and icehouses (Herrmann 1999) (fig. 1).

WMF has supported conservation and training in Merv for over four years, partnering with University College London in the implementation of a conservation program that includes condition assessment and documentation of the buildings; experimental and remedial conservation, including controlled reburial; application of sacrificial layers to the exposed walls; reinforcement and consolidation of eroded wall bases; and site monitoring and maintenance (Williams 2004) (fig. 2). As a result of this project, the benefit and importance of preventive conservation have been amply demonstrated and incorporated into their long-term conservation program. The work conducted at Merv has encouraged site directors from other sites in Turkmenistan to adopt similar methods and practices. Also, other organizations, such as the World Heritage Center and CRATerre, have assisted in implementing a national training program, which is ongoing.



FIGURE 1 The greater and lesser Kyz Kala in Merv, Turkmenistan. Note the repairs at the base of the walls. Photo: Gaetano Palumbo. © World Monuments Fund



FIGURE 2 Kepter Kana in Merv, Turkmenistan. Corner repair using the traditional building technique of fired bricks at the wall base. Photo: Gaetano Palumbo. © World Monuments Fund

In the case of Merv, we have discouraged using a conservation approach that focuses activities on a single monument and instead have supported local efforts to build capacity in evaluating and determining risk factors and mitigating those risks at the larger site level. The positive impact of this project on conservation practice in Turkmenistan encouraged our donor to provide another grant, which allowed more training and more activities to be conducted on-site. UNESCO and CRATerre are now supporting further activities at the national level.

Basgo Gompa, Ladakh, India

In the mid-fifteenth century, high in the Himalayan kingdom of Ladakh, King Grags-pa-'bum ruled from the fortress of Basgo, known to the Tibetan inhabitants as the "Divine Peak of Great Stability." Within the walls of Basgo Gompa the king and his descendants built three temples to honor the Maitreya, the Fifth Buddha. The Maitreyan temples are constructed of mud-brick masonry and rammed earth. The buildings, which appear austere from the outside, are elaborately decorated within. All the temples contain rich and colorful murals depicting the life of Buddha. Chamba Lhakhang is the largest and most historically and artistically significant of the three temples. It contains a gilded earthen image of the Maitreya and intact sixteenth-century murals.

The conservation project conducted by the Namgyal Institute for Research on Ladakhi Art and Culture (NIRLAC)

addressed the poor condition of the retaining walls supporting the overall complex and the foundation of the temples and conserved the Chamba Lhakhang Temple roof, which was identified during the planning phase as a major priority. In a second phase of work, wall cracks were consolidated, columns were restored, and the wall paintings received emergency conservation. World Monuments Fund has been actively involved in the project and provided technical expertise at critical milestones.

In Merv, WMF encouraged preventive conservation and capacity building for the local staff of the Ministry of Culture; in Basgo Gompa, conservation activities and training were accomplished with local people and emphasized community-based heritage preservation. This stimulated a sustainable development initiative that was then carried out by the Basgo Welfare Committee. The success of the Basgo project was due in part to the close link between the project and the local community, which was also encouraged by development opportunities generated by national and international institutions interested in this site.

Larabanga, Ghana

The village of Larabanga is located in the West Gonja district of northern Ghana. The buildings are made of earth and have an architectural style well adapted to the environment, characterized by small units and flat roofs, clustered around large courtyards. The mosque is characterized by the use of wooden beams driven horizontally between the pyramidal buttresses around the external wall of the structure. The origins of the village, and perhaps the mosque that dominates it, can be traced to the seventeenth century. The mosque, which was in poor condition from the use of incompatible repair materials and general lack of maintenance, had already lost its minaret and mihrab by the time WMF was approached to sponsor its restoration. The site was restored under the supervision of CRATerre and the Ghana Museums and Monuments Board. This work was carried out entirely by the local community, which helped renew their relationship with their mosque. At the same time a tourism and handicraft project (which sells guidebooks and postcards, among other things) was developed to benefit the local community and generate funds for annual maintenance of the building, which is carried out as a community project (Olympio et al. 2004).

Bandiagara, Mali

The escarpment of Bandiagara has been inhabited for thousands of years. In addition to the cliff-face earthen and stone

structures where the Dogon people live, there are numerous archaeological sites, including rock dwellings along the face of the escarpment where the remains of earlier civilizations are found. The eleventh century witnessed the arrival of the Tellem people, who occupied the escarpment prior to the arrival of the Dogon—the region's current inhabitants—in the fifteenth century.

Initially, the Dogon, like their predecessors, settled in easily defended sites along the escarpment and in a few rocky outcroppings on the plateau. In time, however, hundreds of Dogon villages sprang up along the base of the cliff, each with numerous stone, earth, and thatch buildings. Ancient cave dwellings and granaries of previous civilizations were subsequently appropriated for use as communal shrines and burial chambers (fig. 3).

Toward the end of the nineteenth century, the Dogon expanded their range, establishing villages on the Seno Plain, which afforded more space and easier living conditions. Today Dogon Country is a 400,000-hectare protected area that includes not only the escarpment but also substantial portions of the Dogon Plateau and Seno Plain, comprising 267 villages.

CRATerre nominated the Bandiagara Escarpment to World Monument Fund's 2004 100 Most Endangered Sites list. With the help of various organizations and in cooperation with the Mission Culturelle de Bandiagara, this organization



FIGURE 3 Bandiagara, Mali. One of the hundreds of sites characterizing the cultural landscape of Dogon Country. Photo: Gaetano Palumbo. © World Monuments Fund

has been instrumental in drafting a management plan for the area, as well as developing a training program to revive artisan skills necessary to undertake individual restoration projects. WMF then agreed to underwrite further development of the management plan for the area, which was recently completed. Beyond safeguarding and conserving traditional buildings, the management plan calls for the regulation of any new construction following newly established and strict building guidelines. The plan also encourages the creation of craft initiatives and sustainable tourism projects as a means to avoid abrupt changes in the social and physical structure of this cultural landscape (Cissé et al. 2006).

WMF continues to support this project through the restoration of Arou temple. Restoration of this shrine was recommended in the management plan as a way to conserve significant remains of this cultural tradition and to bring inhabitants back to previously abandoned areas, reversing the trend toward abandonment that has characterized the edges of the plateau in recent years (Cissé 2005). Through this restoration project the local community is reclaiming their cultural heritage and is directly responsible for safeguarding and sustaining both the tangible and the intangible elements of their cultural traditions.

Huaca de la Luna, Trujillo, Peru

Huaca de la Luna, or Temple of the Moon, at the Moche complex at Trujillo, Peru, is one of the most significant pre-Columbian sites in South America (see also Morales Gamarra in part 4 of this volume). It was built of millions of adobe blocks between the first and eighth centuries C.E. Huaca de la Luna underwent at least six construction phases spanning nearly six hundred years; as a result, it rises almost 32 meters above the surrounding plain. Its enormous platforms are connected to four plazas located at various levels, and there are numerous covered-in patios and enclosures connected by corridors and ramps. Some of the enclosures were roofed and embellished with murals or friezes painted in striking colors.

After the fall of the Moche civilization, the huacas were partially occupied by Chimu settlements until the fifteenth century, when the region fell under the control of the Inca. In the sixteenth century, as a result of the Spanish conquest, these ceremonial sites were abandoned. Today, after four centuries of neglect, exposure to the elements (especially wind erosion and the El Niño phenomenon), and vandalism, some of the adobe structures have significantly deteriorated and the uppermost platforms and their architectural surface elements have been lost.

Extensive fieldwork at Huaca de la Luna started in 1991 with the financial support of the Ford Foundation, and in 1992 the Backus Foundation, a private corporate foundation in Peru, partnered with UNESCO, the Corporación Andina de Fomento, the municipality of Trujillo, and the National University of Trujillo to provide financial support to the site. Initially sitework focused on archaeological excavation and conservation, and in 1995 the exposed areas were opened to the public. In 2002 WMF joined the Huaca de la Luna program and through its Wilson Challenge Program provided matching funds to support a four-year initiative to conserve the site and develop a social agenda through cultural tourism. The project was organized into three major components: archaeological research, conservation of the monument, and management of the site. In addition, the project has provided training opportunities: in 2003 it supported an international four-week conservation course on polychrome earthen architecture. A second conservation course on polychrome earthen architecture took place at the end of 2007.

In the past few years, as a result of a balanced excavation, conservation, and interpretation strategy, there has been an exponential increase in local and international tourism to the site. Each season, after excavation and conservation work are complete, new areas are opened to the public, supported by substantive interpretive materials developed at the conclusion of major exploratory phases. Huaca de la Luna is considered a model for integrated archaeology, conservation, and sustainable tourism development and as a result has received international recognition. Recently, Huaca de la Luna was named one of the ten best-managed sites in Iberian America by the secretary of tourism of Spain.

It is important to highlight that Huaca de la Luna is the only Peruvian project supported by an ongoing and stable financial commitment from the private sector. This continuous support has enabled long-term planning, the formation of a multidisciplinary team to manage and implement the plan, extensive archaeological and conservation fieldwork, scholarly presentation and interpretation of much of the archaeological remains, and assiduous monitoring and maintenance of both excavated and unexcavated areas of the site.

Conclusion

We have briefly mentioned the difficulties faced by our organization in gaining support for the conservation of earthen architecture. Because of the nature of the interventions, doubts may be raised among our donors regarding the permanence of

the conservation interventions; the technical aspect of conservation, which may include the addition of modern materials, albeit traditionally manufactured; and the importance we give to the relationship with the communities living in or near these sites.

Fortunately, we have good examples, such as those presented here, to support our answers. From a technical point of view, we do not believe there are modern materials or methods better suited for preserving these sites than yearly maintenance with traditional resources. As for using new adobe bricks or renewing the architectural finishes on buildings, we think that this type of stabilization often takes precedence over conserving older building fabric, especially considering the extensive decay earthen materials suffer in harsh environmental conditions.

With regard to questions of architectural value and project methodology, we have expanded our understanding and classification of values to include balancing the social, spiritual, and scientific significance of a site. We encourage conservation projects to adopt methodologies that ensure that *all* of a site's diverse values are taken into account when planning for its continued preservation. We have demonstrated that training local people in combination with proper long-term planning is a key element in making conservation treatments both durable and sustainable.

To expand support of earthen heritage preservation, we need to be more explicit about our community-based approach to preservation and provide more examples of success stories, both from World Monuments Fund-sponsored projects and from others worldwide (such as the conservation project in Tarim, Yemen, a site named in our biennial 100 Most Endangered Sites list; we have chosen the site for a Best Project award). WMF participated in a monitoring mission to Peru following the disastrous earthquake of August 2007. The mission included experts from the Getty Conservation Institute and various Peruvian institutions such as the Instituto Nacional de Cultura and the Universidad Peruana de Ciencias Aplicadas. It is vital that international conservation and advocacy organizations such as WMF provide rapid response to emergency situations. Participation and involvement in these kinds of initiatives demonstrate our commitment to international cultural heritage preservation and provide useful information when the time comes to approach donors for their support.

There is great potential for enhanced international participation in the conservation of earthen architecture, especially if the significance and values of the cultural heritage are directly linked to sustainable development and if extensive

local involvement and training are realized in tandem with long-term monitoring and maintenance. These viable and collaborative approaches to site conservation are strongly endorsed by organizations such as the World Monuments Fund.

Acknowledgments

We would like to thank Bonnie Burnham, WMF president, for reading, commenting on, and suggesting improvements to various drafts of this paper.

Note

- 1 Cornerstones continues to be immensely successful in encouraging former inhabitants of remote communities to return to their home villages and participate in cooperative work to preserve the churches and other shared buildings that lie at the

heart of community life. The program became a national and international model for inspiring community commitment to the preservation of endangered structures.

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PART EIGHT

**Standards and Guidelines
for New and Existing
Structures**

**Normes et principes
directeurs pour structures
nouvelles et existantes**

A General Procedure for the Structural Condition Assessment of Historic Earthen Masonry Structures through Structural Identification and Monitoring

Yasemin Didem Aktaş and Ahmet Türer

Abstract: *This paper introduces a general procedure for an integrated condition assessment of historic earthen masonry structures, including both material characterization and structural identification through condition monitoring. The proposed procedure mainly includes (1) visual inspection methods; (2) material characterization; (3) finite element modeling, analysis, validation, and simulation; and (4) structural condition monitoring to arrive at a condition assessment. Such an approach would provide a more thorough understanding of the current state of the structure as well as the ongoing changes in terms of their spatial distribution, progressive nature, type, and future consequences. The methods suggested in this context are mainly nondestructive.*

Résumé : *Cette communication vise à présenter une procédure générale pour réaliser une évaluation intégrée de l'état de conservation des structures historiques de terre en maçonnerie, comprenant à la fois la caractérisation matérielle et l'identification structurale, par le suivi. La procédure proposée comprend 1) des méthodes d'inspection visuelle ; 2) la caractérisation des matériaux ; 3) la modélisation par éléments finis, l'analyse, la validation et la simulation ; 4) le suivi de l'état structural pour aboutir à une évaluation de l'état de conservation. Cette approche permet une évaluation plus détaillée de l'état actuel de la structure ainsi que des changements en cours avec leur distribution spatiale, leur progression, leur type et les conséquences futures. Les méthodes proposées sont pour la plupart non destructrices.*

Most historic structures, including those made of earthen masonry, have an inherent stability provided by thick walls and limited heights. Their stability has been proven by the fact

that they survive today. However, earthquakes and environmental agents (precipitation, freeze/thaw cycling, temperature fluctuations, mechanical abrasion due to wind effect, etc.) cause cumulative structural and material changes that require a correct diagnosis and analysis of the current condition of the structure. Condition assessment is needed before repairs and any restoration or preservation interventions can be carried out. Following the repair and strengthening work, a second round of condition assessment is needed to evaluate the effectiveness of the interventions (Binda and Anzani 1997). However, the condition assessment of historic earthen structures has certain difficulties that assessment of modern structures does not have. The most important of those, as has been discussed by a number of scholars (Binda et al. 2004; Lourenço 2002, 2004; Beckmann and Bowles 2004), can be briefly listed as follows:

1. There are no standards for the condition assessment of historic earthen structures. Existing design and evaluation codes cannot be used directly because the walls are thicker than those foreseen in the codes. In any case, it is easier to adapt the existing codes for earthen masonry structures, which are more consistent in composition, than it is for other types of buildings, for example, rubble stone masonry (Binda et al. 2004).
2. The characterization of construction materials (physically, mechanically, and compositionally) is difficult, expensive, and sometimes too destructive. In addition, although the physical properties of each individual building material (e.g., earth, plaster) can be successfully obtained, it is still a problem to deter-

mine the combined material properties of composite masonry walls. Therefore, testing the masonry wall as a whole might be a better idea. However, the mechanical parameters that can be obtained in this manner are limited since the tests should be performed in situ using nondestructive techniques (NDTs) as well as some slightly destructive techniques (SDT). Removing part of a masonry wall to test it in the laboratory is not possible, not only due to conservation principles, but also because removing a part of the structure can create significant differences in the boundary conditions.

3. The nondestructive techniques used for the mechanical characterization of materials commonly lack conversion factors or relationships that can be used to obtain absolute values; they mostly allow relative/comparative evaluation (e.g., ultrasonic pulse velocity).
4. Historic earthen masonry is a heterogeneous material in terms of local properties and global distribution of material properties. Therefore, it is difficult to obtain representative values for the whole structure by taking samples from just a few locations; on the other hand, taking many samples from a historic structure is not recommended.
5. Samples taken from historic structures are not usually of a standard test size and shape. Therefore, the standard mechanical tests are not applicable or they require the use of possibly imprecise conversion factors.
6. Since the *original* material properties of a historic structure are not well known, it is usually not possible to evaluate the level of the material damage caused by environmental conditions over time on an *absolute* basis, except in cases in which the original material is available from nearby quarries or other resources.
7. Records on the history of structural modifications (e.g., opening windows, adding adjacent sections), structural damage (e.g., seismic), repairs, or restoration work carried out on the structure may not always be available.

Because of all these difficulties, a systematic approach is needed for the condition assessment of earthen masonry structures. A classification of problems and symptoms, as well as a list of diagnostic tools needed, should be prepared. The

aim of this paper is to introduce a general framework for the condition assessment of historic earthen masonry structures. The procedure introduced comprises four steps: visual inspection, material characterization, finite element modeling, and structural monitoring, which consists of short-term measurements and long-term monitoring (figs. 1, 2).

Visual Inspection

Visual inspection is the most direct method of assessing the condition of historic structures. By visual inspection, one can begin to understand (a) material deterioration mechanisms and their potential causes (e.g., drainage problems, rising damp, biodeterioration, wet/dry and freeze/thaw cycling, previous interventions using incompatible materials such as concrete); (b) relative level of deterioration and its distribution within the structure; (c) some basic features of the structure, such as construction materials and structural technology (and if cracks or partially collapsed sections are visible, also sectional properties); (d) plan or elevation irregularities and structural anomalies (sags, deflections, tilts, settlement, and cracks in structural elements, overall deviations, which give an idea of structural movement); (e) structural changes and adaptations performed throughout the life of a structure that can be perceived visually (an added floor, a divided room, etc.), as well as the traces of previous repairs and restorations. In addition to these, visual inspection can be used for an in situ environmental survey to determine (f) local material resources (original material properties); (g) topographic features (to assess the condition of the foundation); and (h) similar structures in the vicinity to get an idea of local construction methods and use of materials.

Visual inspection obviously cannot be performed to detect subsurface problems or to obtain quantitative data. However, it is one of the best ways to evaluate a building's structural condition firsthand. Since visual inspection is subjective in nature and may differ based on the experience of the inspector, the information gathered, as well as the methods used to collect it, must always be well documented.

Manual methods of measurement and documentation (such as triangulation by means of measuring tape) are often time-consuming and may contain cumulative errors; therefore, the level of accuracy is low. Where possible, additional and more sophisticated documentation tools such as a total station, rectified photography, and photogrammetry (to produce documents/models of various details) should be used. Crack patterns should be documented in detail to help

determine the direction and extent of the structure's overall movement, if any. Such measurements are frequently used for short- and long-term structural monitoring.

Material Characterization

Material characterization can be performed in two ways: in situ material investigation and laboratory studies. For example, elastic modulus can be found indirectly by ultrasonic pulse velocity or by flat-jack testing as the stress-strain relationship is measured. Flat-jack testing can also be used for measuring Poisson's ratio. Although flat-jack testing is controversial because it is quasi-nondestructive, it yields very valuable information from a mechanical point of view. In addition, the distribution and level of material deterioration can be determined in situ by a variety of NDT methods such as infrared thermography. Laboratory testing, on the other hand, can be used to determine physical (bulk density, effective porosity, water absorption capacity, water vapor permeability, etc.), chemical/compositional (pozzolanicity, etc.), and mechanical (point load strength, modulus of elasticity, etc.) features of the materials investigated.

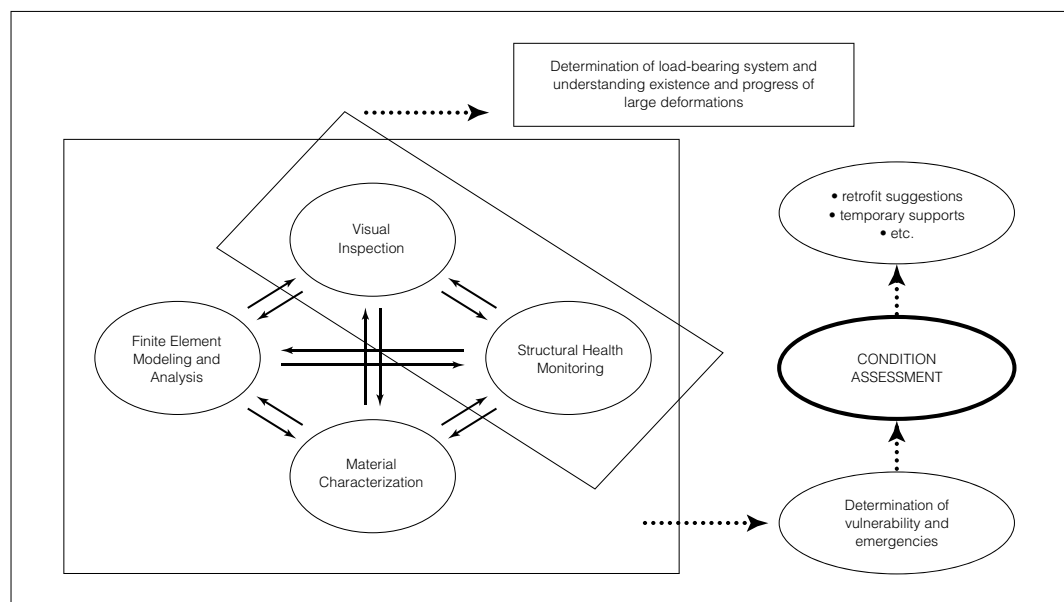
Future repair and use of restoration materials should always be based on the results of the physical and compositional characterization of the original materials carried out in the laboratory. Compatibility of original and repair materials should be investigated. The actual but slow effect of environmental conditions on the materials can also be simulated in an

accelerated manner in the laboratory (accelerated freeze and thaw/wetting and drying tests).

Finite Element Analysis

Finite element analysis (FEA), composed of five stages (modeling, analysis, updating, validation, and simulation), is the step in which the investigator reproduces the structure's properties and response. FEA can be conducted under normal service conditions as well as critical conditions where demand and stress on the structure are in the non-linear range, such as in an earthquake. In this case, material and geometric nonlinearities (e.g., cracking and contact surfaces) should be considered. Modeling would include preliminary, nominal, and calibrated analytical models. The preliminary model reflects the approximate geometry and material characteristics of a structure and is used to provide information on the structural system and its behavior. The nominal model uses correct dimensions measured during in situ investigations, preferably by photogrammetric means, or taken from available documents. Finally, the calibrated model closely reflects the actual structural behavior/response and is used for structural identification (St-Id), mostly using short-term test results. The results of static loading and dynamic measurement (mode shapes, modal frequencies) are checked against the analytical model and the structural parameters (e.g., effective elastic modulus, Poisson's ratio, density, support-boundary conditions, and some geometrical/

FIGURE 1 Evaluation scheme.



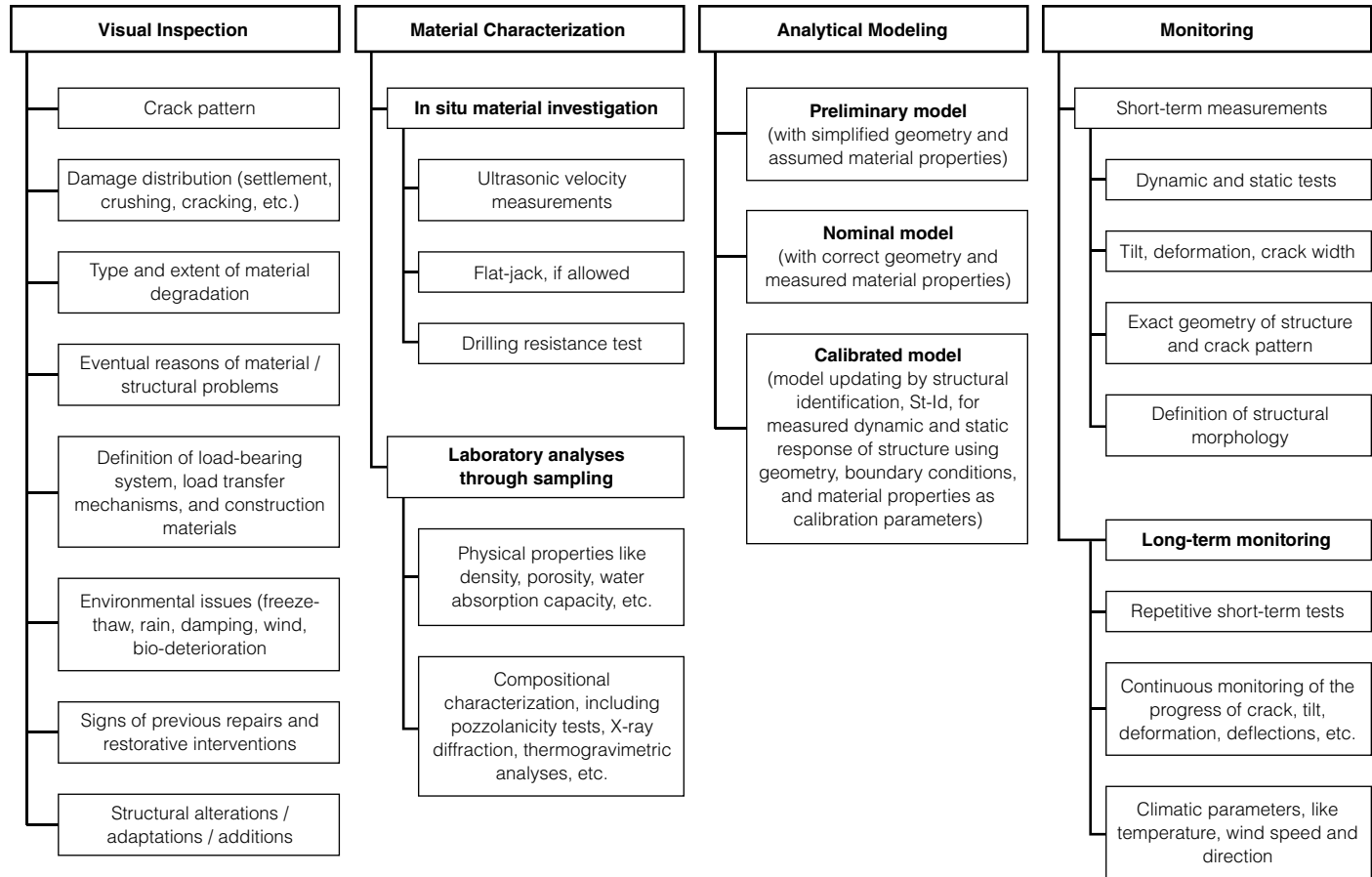


FIGURE 2 Methodology.

morphological features like the bonding between the leaves of the wall structure, if any) and are iteratively modified until the simulated and measured responses closely match. The level of consistency between the experimentally and analytically obtained dynamic parameters should be evaluated by means of one of the existing methods for this purpose. The most commonly used are Modal Assurance Criterion and Modal Vector Orthogonality. In the simulation, advanced modeling issues, such as the determination of analysis type (linear vs. nonlinear), material model, element type (solid vs. shell), and modeling type (smeared or macromodeling vs. micromodeling), and how to simulate crack growth and contact type (in case it is needed) should be reconsidered. All these choices are a function of the level of loading, the level of refinement needed, available time, the extent to which the structure will be modeled, human resources, and available equipment.

Structural Monitoring

Short-Term Measurements

Short-term measurements, in the context of this paper, include all tests carried out once or a few times within a short period of time, that is, measurements not presenting continuity. These kinds of measurements include parameters defining structural morphology, type and positioning of load-bearing members, member size and dimensions, the crack width, differential settlement, tilt, and section loss, if any. Georadar, acoustic emission, infrared thermography, and magnetic methods are the most widely used techniques. In addition, local compressive stress can be found by means of flat-jack testing without the need for modulus of elasticity or Poisson's coefficient. Other measurements are dynamic tests conducted for either ambient vibration or forced vibration excitation. The use of a variety of accelerometers appropriate for the case can be defined as other

short-term measurement instruments. The structural parameters obtained with these measurements are structural stiffness-flexibility and mode shapes, frequencies, and damping ratios. Finally, static tests can be performed by means of crack meters and displacement measurers. The loading in static tests must remain within the linear range of the system.

All the parameters obtained at the end of these measurements should be used to update the original finite element model.

Long-Term Monitoring

Long-term monitoring is used for the measurement of parameters changing over time. By using appropriate long-term monitoring tools, one can perform (a) environmental/climatic measurements such as temperature fluctuations, relative humidity, and wind speed and direction, as well as those related to (b) structural movements and tracking the progress of crack width, tilts, sags, and so on. Through these measurements the nature of the observed changes can be distinguished (e.g., whether or not the crack width progress is cyclic, if there is a correlation between daily/seasonal temperature changes and crack width variation). Other short-term measurements such as dynamic and static tests carried out in a quasi-continuous manner should also be evaluated as a form of long-term monitoring; however, the continuous measurement of dynamic characteristics of a structure generates a very large amount of data that is not stored as raw data. In the case of repetitive loading, such as vehicles passing over a historic bridge, statistical methods are used to generate histograms (such as WIMS for bridges).

It is important to note that the characteristics of the chosen sensors should be appropriate for the application, and the number and locations of sensors should be determined carefully in order to make the best use of the results. In addition, the nondestructive techniques proposed for these four interrelated steps should always be supported with a complementary method, since NDTs normally give indirect results (Lourenço 2004). The need for calibration is another important point that should be kept in mind when using NDTs. Calibration of the instruments and postprocessing of the data require expertise, resulting in an increase in the evaluation costs.

If historic sources of information such as photographs or written records are available, they should be used to determine the building chronology, including its alterations, adaptations, additions, previous repairs and restoration, and seismic and functional history.

Conclusion

There is a need for a systematized framework for condition assessment of historic masonry structures with an emphasis on earthen masonry. Assessment of historic structures is different from that of modern structures due to the lack of standards and the need for a distinct methodological approach to determining their condition. We propose that the structural condition assessment can be achieved in four interrelated steps: (1) visual inspection; (2) material characterization; (3) finite element modeling, analysis, updating, validation, and simulation; and (4) monitoring. Each of these steps should be included in an ideal condition assessment; visual inspection or material studies alone conducted independently are not usually sufficient. The limitations and weaknesses of each step should also be well understood; for example, finite element analysis has limited use unless it is based on careful observations, material and field tests, and monitoring studies. Structural condition monitoring, which is a newly developed engineering field, is seldom if ever conducted on historic buildings. Monitoring data generally provides invaluable information on the progress of observed damage and responses to environmental changes and is one of the most important contributions to finite element analysis and decision making with regard to the extent and type of restoration and repair of historic structures.

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Toward a Comprehensive Taxonomy of Earthen Architecture

Edward Crocker and Gustavo Araoz

Abstract: *Most practitioners in the field of earthen architecture probably believe that they understand and can define earthen architecture. Until they try. The vagaries of the term became clear to many members of the ICOMOS Scientific Committee on Earthen Architectural Heritage (formerly the Specialized Committee on Earthen Architectural Heritage) during a broad-based e-mail exchange in fall 2006. It was then widely acknowledged that we have a very clear understanding of the various methods of production that lead to earthen buildings but that we do not seem to have articulated the structural typologies that result when the materials are assembled. This paper proposes a solution to the problem.*

Résumé : *La plupart des praticiens en matière d'architecture de terre pensent sans doute qu'ils comprennent et sont capables de définir « l'architecture de terre », jusqu'à ce qu'ils tentent de le faire. De nombreux membres du Comité scientifique internationale du patrimoine de l'architecture en terre de l'ICOMOS (autrefois le Comité spécialisé de l'ICOMOS sur le patrimoine architectural bâti en terre) ont réalisé combien ce terme était difficile à cerner lors d'un large échange de courriels à l'automne 2006. Nous avons alors reconnu que si nous avions très bien compris les différentes méthodes de production aboutissant aux constructions en terre, nous n'avions par contre pas clairement présenté les typologies structurales résultant de l'assemblage des matériaux. Cette communication propose une solution à ce problème.*

Most practitioners in the field of earthen architecture, whether in new construction or conservation, probably believe that they understand and can define the term *earthen architecture*. Until they try. The vagaries of the term became clear to many members of the ICOMOS Scientific Committee on Earthen Architectural Heritage during a broad-based e-mail exchange in fall 2006. It was then widely acknowledged that we seem to have a very clear understanding of, and have cogently articulated, the various methods of production that lead to earthen buildings. These range from defensive earthwork trenches to sun-dried bricks, puddled mud, and extruded soil blocks. What we don't seem to have articulated well are the structural typologies that result when the materials are assembled.

The e-mail exchange highlighted some differences of opinion; for example, is a non-load-bearing curtain wall built of earth earthen architecture? And is there a point at which stone laid up in mud mortar ceases being earthen and is typologically cast as something else? The exchange contained bits of esoteric knowledge and, occasionally, a sense of the absurd. The authors note, with some disappointment, that though other ICOMOS Scientific Committees (Vernacular Architecture, Archaeological Heritage, Structures and Wood) were invited to participate in the formulation of the taxonomy, we had no substantive responses.

This discussion is intended not to be conclusive but rather to advance discussion of the taxonomy of earthen architecture.

The entire string of e-mails that originally inspired the dialogue has been organized chronologically but is of such a length that it cannot be included in this paper. It is available at www.crockerltd.net/taxonomy_discussion.htm.

What Is Taxonomy, and Why Do We Need One?

A taxonomy is a classification of related objects into an order that allows us to (1) facilitate the retrieval of information, (2) distinguish between varieties of similar things, and (3) help explain the basis of variation among typologically associated items. Taxonomies vary depending on the use they are created to serve. Thus identifying the intended use must precede the establishment of any good taxonomy. In the simplest human taxonomies, there is a given name and a name that links each human to a patrilineal or matrilineal line and/or clan. Such a taxonomy is insufficient in the world polity, which requires many additional classifications, all depending on the intent, such as country of citizenship, race, religious affiliation, sex, age, or profession/trade. The many classifiers used to group humans in ways that they can be studied statistically for different purposes is proof that intended use must precede the development of any taxonomy.

Taxonomy, in other words, allows us to place objects in rational order while simultaneously footnoting their distinguishing characteristics. Good taxonomy is what enables naturalists to point at critical issues and identify species that are endangered or disappearing.

Various taxonomies have been loosely developed to classify the built environment for a variety of purposes, but none has proven universally satisfactory in terms of broad applicability. For instance, there are building taxonomies based on the use for which the buildings were constructed, such as religious, residential, civic, commercial, industrial, or agricultural. Under each of these overarching headings, there are subheadings, such as churches, chapels, shrines, cathedrals, basilicas, monasteries, or convents for religious buildings within the Christian faith. These taxonomies are commonly used for inventories, surveys, and registers.

Buildings have also been classified according to their structural systems and construction methods (lintel-arch, wood framed, steel framed, vaulted; plus stacked masonry, form based). Building forms and embellishment, together with the establishment of acceptable time spans, are used to develop a taxonomy or classification of historic architectural styles.

The field of urban morphology constantly develops another type of taxonomy based not on intended building use but on the physical form of the buildings (e.g., volume, shape, lot location, relation to other buildings). Such taxonomies are useful only in the narrow context or the urban environment in which they exist and are applied as a tool to protect the character of historic urban districts.

In the case of earthen architecture, and of historic structures in general, a good taxonomy with universal or at least multiple applications would similarly help identify uniqueness, patterns, best representatives, and so on—all important not only for establishing significance but also for establishing treatment and protection priorities.

On the world heritage level, in order for us to be able to assess outstanding universal value, we need to know the global context, taxonomies, and geographic spreads. One of the big challenges in evaluating nominations to the World Heritage List lies in our inability to say with unwavering certainty that a nominated site is the only one of its kind, the best of its kind, or perhaps even the most representative of its kind. A good taxonomy, which does not exist in this field, is very likely to accelerate the inscription of earthen architectural sites on the World Heritage List as well as inform conservation approaches and site management and identify the threat of “extinction” of a typology.

What Kind of Taxonomy Would Be Useful, and How Do We Derive It?

A review of taxonomic approaches indicates that there are hundreds, perhaps thousands, of taxonomies for everything from snails to software architecture. Without doubt, the most well-known taxonomies are those advanced by Carolus Linnaeus (1707–78) in his *Systema Naturae* (1735), in which he outlined the hierarchical classification of the natural world, dividing it into the animal kingdom, plant kingdom, and mineral kingdom. The usefulness and popularity of his system led eventually to thirteen editions, each greatly expanded, from eleven pages in the first to three thousand in the thirteenth. Linnaean taxonomy successively refines and specifies according to kingdom, phylum, class, order, genus, and species. Thus a domestic dog would be identified as Animalia, Chordata, Mammalia, Carnivora, *Canis*, and *familiaris*. It is an elegant and successful methodology that works well for animals, works less well for plants, and falls apart entirely with minerals. It also fails to help us clarify an approach to the understanding of earthen architecture. However, Linnaeus’s contemporary and chief rival,

Baron George Leclerc Buffon (1708–88), in his *Histoire naturelle*, comes to our aid by providing a nonhierarchical system that joined each species to some others by physiology, to a different group by anatomy, and to a still different set by ecology. Nevertheless, attempting to isolate a system that could be readily adapted to the present question was somewhat frustrating to the authors who, under duress, think that it makes sense to start from scratch, despite the noble contributions of antecedents.

There are five essential steps to building a taxonomy:

1. Determine the scope of the system.
2. Ascertain the authorities whose findings will be accepted by the interested constituency.
3. Extract concepts from the authorities and other sources.
4. Organize the concepts into a usable format.
5. Validate, review, and refine the taxonomy through use.

While structuring the format, we must also keep in mind the following questions:

1. How best can we access/utilize the information?
2. How best do we apply it to treatment and protection (standards) in earthen architecture?
3. How best can we make the information useful in the world heritage forum?

Building a Taxonomy of Earthen Architecture

The review of taxonomies above makes one thing very clear: agreement about relationships does not guarantee consensus about importance. Therefore, in an effort to remain scrupulously objective, we have abstracted some of the keywords and concepts from the e-mail string and made some assumptions that we feel address the purpose of the exercise as outlined above.

Step 1: Determine the Scope

The initial impetus for deriving a taxonomy for earthen architecture came from an inquiry (Crosby) to colleagues to help create “a map of the U.S. broken down in regions that seem most appropriate for brief descriptions of the architectural types in those areas.” The idea caught hold but very rapidly expanded first to a global scale (Araoz) and subsequently to include experts in other, related heritage fields. In terms of technical inclusion, the authors are embracing the full realm of

possibilities; anything that anyone thinks should be classified as earthen architecture will be included in discussions.

Step 2: Ascertain the Authorities

The authors note that the attempt to include practitioners in other heritage fields has not yet been productive. Nevertheless, we fully expect that those practitioners will come forward as the discussions proceed. Thus, though the door is open, the present authorities are members of the ICOMOS Scientific Committee on Earthen Architectural Heritage.

Step 3: Extract Concepts from the Authorities and Other Sources

Other writers (e.g., Houben, Guillaud) have very succinctly and cogently described the various processes involved in the construction of earthen architecture. We do not seek to further refine that work, which by now has been validated over time and use. What we do seek to refine is the way in which we refer to the products derived from those processes. As an example, the literature and local knowledge are clear as to the classification of an adobe as an unfired masonry unit used in the construction of buildings. What is somewhat less clear is how function (load bearing, non-load bearing, decorative) affects the classification of the resulting building. Thus our goal is ultimately to provide a comprehensive list of buildings and structures, define them, and place them in a taxonomy that serves our stated purposes. In order to provoke discussion and perhaps help present a format, the following abstracts some of the discussions that took place in the e-mail string.

Agreement as to conforming:

- Load bearing vs. non-load bearing (relating to function). The consensus seems to be that this distinction is not one that should be used to distinguish earthen architecture from all other typologies but *should* be used to distinguish function within the kingdom.
- “Built” versus “formed” (relating to the method of construction). Here we may need to avoid the multiple meanings of the word *formed* (as in shuttering for *pisé de terre*), as opposed to *excavated*. The consensus clearly is that defensive earthworks (e.g., trenches) and other features of whatever purpose, formed by the removal of material, belong solidly in the kingdom. But do we need to note, perhaps elaborate on, the fact that such “formed” earthworks are both a process and a defined typology?

Lack of agreement as to conforming:

- Majority versus minority component. Here there is disagreement. Some (e.g., Watson) think that the kingdom should include only structures with a principal *functional* component of unfired soil, the definition of which is also subject to discussion and definition (Thomson). Others (Mold, Hare, Hurd) note that such a definition excludes fieldstone laid up in mud mortar, as well as other applications in which unfired earth is an essential but not majority component.
- Composite (with nonearthen materials) versus traditional. One observer (Crocker) is reluctant to acknowledge that asphalt-stabilized adobes laid up in portland cement, sprayed with polyurethane, and plastered with elastomeric coatings can constitute “earthen” buildings, even though the majority component is unfired soil. Another (Hurd) notes that reclaimed cinder blocks infilled with mud should be considered, essentially for cultural reasons.

Presented but not discussed:

- Treatment as a defining factor. Several observers (Crosby, Dowdy, Crocker, others) suggest or imply that the maintenance or conservation of a structure may be one of the factors that help define it as earthen. The premise appears to be that if one component (earth) among many (stone, wood, lime) is that which requires either the most or the more sophisticated treatment, then a distinction may be drawn that leads to classification.
- Erudite versus vernacular. One observer (Hurd) distinguishes between three general typologies: historic, ethnic, and aboriginal. The authors draw a distinction here that may be other than that originally intended, and that is an implied distinction between structures that are no longer in use and those that are. Archaeological sites, even reconstructed ones, might typically be thought of as requiring a different approach to conservation than, say, a historic cob tavern that is still in use. Clearly there would be some overlap as, for example, in the case of Taos Pueblo, New Mexico, or the center city of Yazd, Iran. In both cases the architecture is erudite in its singularity but vernacular in origin; the two examples are ancient in

both form and materials but have undergone regular modification to accommodate use over time. On the other hand, nonoccupied sites such as Pueblo Bonito, New Mexico; Paqime, Mexico; and the Citadel of Bam, Iran, are subject to very strict conservation principles that do not allow for change over time.

- Modern derivatives of traditional knowledge. There is general agreement that mass-produced compressed earth blocks and nonstabilized adobes produced with the assistance of machinery can be used in the construction of validly classified earthen architecture. However, do burlap bags filled with a mix of clay, sand, and lime stacked into walls and saturated qualify?

Step Four: Organize

The authors throw open the door to all interested parties to assist in compiling the structure of the taxonomy, which might include, among many more, the following keywords and phrases.

Earth as a defining characteristic. Local soils. Amended soils. Natural lime. Local tradition. Load bearing. Non-load bearing. Excavated. Earthen mixed (or composite) technologies. Archaeological. Living. Ephemeral. Monumental or “massive.” Mixed use. Residential. Communal. Agricultural. Commercial. Industrial. Defensive. Religious. Vernacular. Seismic. Defining characteristic must be integral. Defining characteristic may be purely decorative. Puddled. Formed. Rammed earth. Compressed earth block. Stabilized. Necropolis. Earth sculpture.

We have not attempted to break down regional typologies based on use and function. We see this as being part of a global effort by our colleagues to report on extant surveys, or to create, implement, and report on new surveys. Such surveys might include, among others, some of the categories listed above.

It is our challenge to the community of earthen architecture conservators, historians, engineers, architects, contractors, and all interested parties to begin assembling the body of the taxonomy. The authors and the ICOMOS Scientific Committee on the Earthen Architectural Heritage look forward to advancing the discussion.

Guides, Codes, and Standards for Rammed Earth Structures: An African Case Study

Rowland Keable

Abstract: *Standards and norms are tools for creating a climate of acceptability for new earth buildings. Putting standards into place is a process that takes time and patience. A standard for rammed earth structures has taken twenty years to write, put in place, and expand to a larger group of countries. Building on this experience can accelerate the process toward allowing lower-carbon building materials. Knowledge of climate change means there are more routes to funding for standards change.*

Résumé: *Les standards et normes permettent de créer un environnement favorisant l'acceptation des nouvelles constructions en terre. Mettre en place ces normes est un processus long et ardu. Il a fallu 20 ans pour rédiger, mettre en place et élargir à d'autres pays une norme pour les constructions en pisé. À partir de cette expérience, on devrait pouvoir accélérer le processus d'autorisation d'utilisation de matériaux de construction plus économiques en carbone. La sensibilisation au changement climatique ouvre de nouvelles possibilités de financement des changements de normes.*

Ram Cast CIC has been working as an independent earth building company in the United Kingdom since 1999. Previously we worked in many African countries on a number of earth building projects. Over time we have found that codes and standards are a major tool for building acceptance of new earth construction. Moreover, they begin to break the monopoly that production materials such as cement have enjoyed for many decades in most countries.

Background

Throughout the 1980s Ram Cast applied to the British Department for International Development (DfID) for construction projects in Africa, to work on schools, clinics, and housing and finally to write a guideline for the technology, to set a benchmark for future government funding.

In 1990 we assembled a team and began thinking about what such a guideline could and could not achieve. It is impossible to write a construction guideline for the continent of Africa and remain strictly prescriptive. Because its geography, geology, society, and economy are so varied, perhaps more than anywhere else, the work tended to center on safety and basic testing rather than on detailed specifications. We ended up with the Code of Practice (COP),¹ recognizing that it was not an adopted standard but framed in that way.

The COP was set out with three basic elements: a guide, a standard (or deemed to satisfy the requirements of one), and a test for each of a number of issues, such as materials, water, formwork, density, and stability. The COP was formatted such that the narrative was on the left and the illustration on the right. In this way guide, standard, and test were each given both a written and a visual representation.

When we finished the work we were given access to a publisher through our funder, and in 1996 the COP was published. With additional funding we were able to send two copies to each minister of housing and secretary of state for housing in Africa at that time.

Standardization

In 1995 I moved to Zimbabwe to try to build a technical base there. Zimbabwe has a history of rammed earth building in the twentieth century, one that is not widely known but leaves a considerable residue of housing stock in all the major towns and cities in the country. With that came the knowledge that there existed suitable soils and a well-developed mortgage or bond market that regularly refinanced these buildings.

I had formed a strategic alliance with the newly formed Scientific and Industrial Research and Development Council (SIRDC) by the time the COP was published. SIRDC agreed we would take the COP to the Standards Association of Zimbabwe (SAZ), a nongovernmental and nonprofit organization, to write a standard.

Timing helped this process. The new director general, Maureen Mutasa, was just taking up her post, and she immediately saw the utility of addressing construction issues through standards. According to her, the field of construction regulation needed a paradigm shift. Standards and regulations had long been in the control of big business and developed into a “product only” mentality.

Cement Monopolies

Cement is now responsible for approximately 10 percent of global carbon dioxide emissions, which are linked to its high energy intensity and release of fixed carbon. Cement is by far the biggest and most influential construction product in Zimbabwe. In addition to being a high-energy, high-emissions product, it has set the standard for a range of building products in a fairly random manner over previous decades. For instance, the crushing strength of any brick to be used in a regulated construction project must achieve 7 N/mm². This arbitrary figure was imposed by the cement industry’s lobbying because it is the crushing strength of cement. This is in the context of a construction industry in which two-story housing is an expensive rarity. We have built two-story buildings with material that crushes at 0.8 N/mm², so clearly it is not the strength of the individual brick that should determine the suitability of a building’s design.

Because of the enormous amount of energy required to turn limestone into clinker, cement has always been out of the reach of the majority of populations in most of sub-Saharan Africa, and in fact far beyond. And yet in all these countries cement enjoys monopolies of regulation, finance, insurance,

training, and research. For this reason the majority of urban Africans have two choices, to try to rent or buy a home constructed of a high-energy regulated material, often obscenely above their means, or to trust to an unregulated informal sector that is within their means. Because the second of these two choices means living in properties without official approval, the buildings can be destroyed at any time. Faced with this situation, most people do not then expend a great deal of time, energy, or money on their homes; slums are the result.

These monopolies are worth dwelling on because they apply more or less everywhere. In the United Kingdom, for instance, there are planning permission and building regulations. Planning permission looks at wider planning issues and is silent on the use of earth beyond its vernacular status or visual impact. Lately planning authorities have become more favorable to the use of earth for other reasons, mainly to do with transport of materials to and from building sites and waste disposal. Building regulations, on the other hand, require a fully engineered design underwritten by the structural engineers’ professional insurance. Without a standard or norm, this ad hoc approach always limits the scope of the material. Compare this with concrete, for which standards apply: the engineer submits a design that is checked by the building regulator, and no special insurance is required. Because of this engineers are freer to design with concrete, rather than earth, which their insurance must fully underwrite.

Legislation and By-Laws

In Zimbabwe the situation is much the same. The Modern Building By-Law allows use of a very limited group of wall building materials. Anything else has to be approved by the city council. This policy was originally intended as a crude tool of petty apartheid, to prevent—by the imposition of stringent by-laws and prohibitive cost—black Zimbabweans from building in a city area. Independence has not brought changes, and as the legislative route to change was effectively blocked, the standards route was the only one open.

The by-law allows the use of any nationally certified material, meaning that city regulators do not have total veto power over new earthen structures. So standards can effect some change at the level of government regulation, thereby freeing up insurance, that is, private funds. It can also help in the sphere of loans. For example, at present in the United Kingdom there is only one mortgage lender that will provide a loan on an earthen building as part of its mission statement.

The knock on effects of regulation, finance, and insurance goes on. Architects and engineers are not taught about nonregulated materials, do not routinely test them, and do not build test structures with them. Government rarely funds research into these materials, and clearly the cement industry is content to finance cement research. An enormous professional and research gap therefore has opened up and has widened for seventy or eighty years.

In the United Kingdom there are many examples of multistory earthen housing, none of which could be built under the current regulatory regime. They were built more than one hundred years ago without the aid of testing, computer analysis, or any of the technology available today. Yet, unlike with new earthen construction, mortgage companies do not question their value.

Process

Given the background described above, it was especially encouraging to have strong support from SAZ. The SAZ process is quite rigorous. A technical committee is established with representation from academia, industry, and, in the case of construction standards, professional bodies. A prepared text is then worked through line by line, with specific testing through the organization as and where deemed necessary by the committee. In this case it was two years before the first draft could be circulated among industry and academic participants more generally. After comments were received and approved, there was a period of broader public consultation.

The resulting Standard Code of Practice for Rammed Earth Structures was approved and published in 2001.² Although SAZ is a nonprofit NGO, its standards, once passed, take force in law. In the case of Zimbabwe, the standard meant that for the first time people could build with earth in an urban area without special dispensation. This was effectively the first change to the legally binding Model Building By-Law since independence in 1980. For most other countries in the region, building with earth is prohibited in urban areas by building codes written during or after the colonial era.

Regional Harmonization

By 2001 I had returned to the United Kingdom and established a company building with rammed earth. I made a connection to Peter Walker at Bath University, and we agreed to apply for research funding for a U.K. guideline. With his experi-

ence writing the Australian guidelines and with the Zimbabwe standard published, we were in a strong position and did indeed secure the funding we sought. Again the process took some time; a combination of literature review, test structures, built project review, and writing meant the document was ready by mid-2004. As part of the process a steering committee recommended us to a publisher; and the *Rammed Earth Design and Construction Guideline* was published in 2005.³

As we had used the standard to gain funding for the rammed earth guideline for the United Kingdom, the guideline then gave the African standards approach fresh impetus. I asked Maureen Mutasa at SAZ if we could broaden the reach of the standard. She readily agreed, moving to harmonize the standard across the regions of both the Common Market for Eastern and Southern Africa (COMESA), which has twenty members, and the Southern African Development Community, which has fourteen members. Once harmonized across the region, the standard takes immediate force in law under protocols agreed to by the two blocs.

I was asked to present the case to SADC's annual SADCSTAN standards meeting. This unprecedented honor highlighted a number of interesting developments. First was the regional recognition that building standards are out of step with people's ability to pay for standard, regulated materials. This has been an open secret for decades for anyone working in the field of construction in sub-Saharan Africa, and the reason I became interested in earthen building in the first place. Also the recognition that standards could be used to change law is something novel for many of the regional bodies, which are largely tied to government departments that have long-standing vested interests in the status quo. Also, now was the chance to harmonize a standard generated from within the region and not introduced from the North, as so many of the standards under consideration are. Not only would the Rammed Earth Standard be a locally generated norm, with fourteen countries of the SADC agreeing to it, but the chance to take it to the International Standards Organization (ISO) for international harmonization suddenly looked like a real possibility.

The SADCSTAN meeting was well attended by other regional bodies: COMESA, the East African Community (EAC), the African Regional Standards Authority (ARSO), the Economic Community of West African States (ECOWAS), and the Standards Organization of Nigeria (SON), among others. Their delegates voiced an interest in the earthen building standard because SADC had done so.

Conclusion

To begin the long job of building acceptance for earthen structures in Africa, standards and regulation issues have to be addressed. This means both writing and adopting guidelines and norms for earthen building but also redrafting norms written for materials such as cement that have come to apply to all other materials. This is a process that takes time. It is a process that is not well understood and that is changing rapidly in the African context. Regional agreements mean single country codes can now be harmonized by many countries and enjoy immediate force in law. When the standards are generated in the region rather than parachuted in from elsewhere, there may be a particular interest and willingness to accept them.

For us, this process has been a largely unfunded labor of love. The significance of standards for earthen building needs to be better understood by funders, and those working in this

field can bring about this understanding. The emphasis needs to shift from research to standards dissemination.

Because building with earth is still proscribed in towns and cities, millions of people for whom cement is unaffordable have no choice but to live in shacks. So we must strive to put the legal tools in place to allow people to build affordable, decent schools, clinics, commercial buildings, and homes for the first time.

Notes

- 1 J. Keable, *Rammed Earth: A Code of Practice* (London: IT Publications, 1996).
- 2 *Zimbabwe Standard Code of Practice for Rammed Earth Structures* (Harare: Standards Association of Zimbabwe, 2001).
- 3 P. Walker, J. Keable, et al., *Rammed Earth Design and Construction Guideline* (Watford, U.K.: IHSBre Publications, 2005).

Development of Earth Construction Standards: What Is Next from New Zealand?

Hugh Morris and Jason Ingham

Abstract: *In 1998 three comprehensive earth building standards were produced in New Zealand to meet the specific regulatory framework and building culture in this seismically active country. The standards provide a useful reference for other countries. Improvements to the New Zealand Standards for Earth Buildings are proposed with reliable earth building material and structural properties. Local and international research is required, with large numbers of test samples, to determine rigorous results with known statistical reliability. A new analytical procedure, revised design philosophy, and improved document format are recommended based on burnt brick and concrete masonry research and masonry design standards.*

Résumé: *En 1998, trois normes générales sur la construction en terre ont été publiées en Nouvelle-Zélande pour satisfaire aux exigences particulières du cadre réglementaire et de la culture de la construction de ce pays présentant des risques sismiques. Ces normes constituent une référence utile pour d'autres pays. Il est proposé d'améliorer ces Normes néo-zélandaises pour les bâtiments en terre en utilisant des matériaux de construction en terre fiables présentant des qualités structurales. Il va falloir effectuer une recherche au niveau local et international, avec l'aide de nombreux échantillons, pour aboutir à des résultats rigoureux à la fiabilité statistique reconnue. Il est recommandé d'adopter une nouvelle procédure analytique, une philosophie affinée en matière de conception et un format de documents plus adapté, comme cela a été fait pour la recherche sur la brique cuite et la maçonnerie en béton, et pour les normes de conception de la maçonnerie.*

Ten years ago three earth building standards were published in New Zealand, a country with moderately high seismicity.

These standards have enabled around forty earth houses to be built annually, and with a national population of 4.5 million and increasing environmental awareness we expect interest in earth building in New Zealand to increase. These standards serve in a regulated construction context and are cited in the New Zealand Building Code.

It is normal practice for standards to be reviewed and updated, but there is a need for significant growth in scientifically rigorous local and international research if the New Zealand earth building standards are to stand alongside other modern material design standards in the long term. This paper outlines needs and opportunities for earth standards and some recommendations based on developments in burnt brick and concrete masonry.

Building Standards for Housing in New Zealand

New Zealand has a performance-based building code that allows for a range of alternative building construction solutions. The New Zealand Building Code (Department of Building and Housing 2004) defines the expectations of building performance. However, for ease of approval, the vast majority of small to medium-sized buildings are designed and constructed to meet prescriptive compliance documents. New Zealand has also been through fifteen years of deregulation when builders have not needed certification. The resulting reduced skill levels and inadequate understanding of best practice in the workforce was compensated for by the highly prescriptive outcomes.

The "NZS 3604:1999 Timber Framed Buildings" standard (Standards New Zealand 1999) is the most widely used standard in New Zealand that every builder, architect, and

architectural designer will own. Timber is used for over 90 percent of houses and some light commercial construction. NZS 3604 is a 400-page document that is extremely detailed and prescriptive. It requires that wind and earthquake loads be evaluated in two orthogonal directions and that the load-resisting bracing walls be selected to provide the resistance in those two directions based on tables of data. It describes exactly how many nails are needed for every floor joist, the size, joist and solid blocking spacing, and all the other details for designing and building a house. This covers a varied range of houses, so specific engineering input is needed only for unusual structures. This standard established the benchmark against which other nonengineered construction standards are measured.

Earth Building Standards in New Zealand

In 1998 Standards New Zealand published a comprehensive suite of three earth building standards (Standards New Zealand 1998a, 1998b, 1998c) for structural engineers and architectural designers and builders. These standards are described in more detail elsewhere (Morris and Walker 2000; Morris 2005).

Both the engineering design and the materials and workmanship standards are used by engineers. Home builders and architectural designers would use the more prescriptive “Earth Buildings Not Requiring Specific [Engineering] Design” standard as well as the materials and workmanship standard as shown in figure 1.

“NZS 4299:1998 Earth Buildings Not Requiring Specific Design” follows the approach used in NZS 3604 for timber and requires that wind and earthquake loads be evaluated and that the appropriate load-resisting walls be selected to provide the in-plane strength. This standard is over one hundred pages long and provides very prescriptive details, such as the specific configuration for concrete or timber bond beams and timber roof diaphragm materials, thickness, and the number and sizes

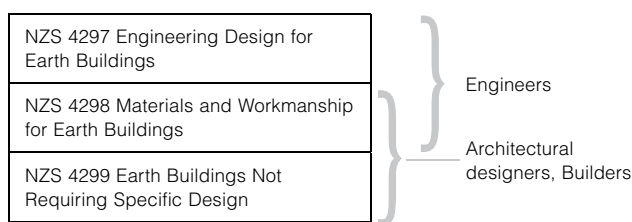


FIGURE 1 The New Zealand Earth Building Standards and intended users.

of nails and their spacing. Wall reinforcing details are specified depending on seismic area with vertical steel reinforcement at the end of panels. The reinforcement is the full wall height and is moderately post-tensioned to provide extra axial load to mobilize the shear capacity of the wall material.

The NZS 4299 standard is very prescriptive and detailed when compared with most international standards, as this was required to obtain approved document status from the Department of Building and Housing. This makes a major difference in the time and expense to obtain a territorial authority (local council) building consent. As noted earlier, the format follows the approach of NZS 3604 for timber, so the document's structure and methodology are familiar to engineers, architects, builders, and building officials.

Materials and Material Properties

“NZS 4298 Materials and Workmanship for Earth Buildings” defines material properties and workmanship specifications that need to be achieved. They define a low nominal-strength standard material quality that is assumed with minimal testing. For higher-than-nominal material strengths, a significant number of tests are required to determine the characteristic values. The on-site tests described in the materials and workmanship standard were developed to be low cost, but they are time-consuming. They still add a significant expense to an average house when compared with other construction materials.

For earth materials to become widely used, simple soil identification and characterization methods are needed that will reference directly to structural material strength characteristics once the materials are mixed and dried or compacted. While there are a range of qualitative approaches in use, reliable structural engineering properties such as tensile strength, compressive strength, Modulus of Rupture, and Modulus of Elasticity are needed. This is a long-term task that will require international collaboration by earth building researchers. To make progress on this, standardized testing systems and a set of agreed-on soil reference properties are needed to give comparability of results.

To develop a proper understanding of statistical reliability to determine coefficients of variation and underlying statistical distributions, databases of material tests are needed. A clear understanding of the statistical variation for each performance property is needed for a wide range of materials. This will require that tests with hundreds of specimens be undertaken to determine the appropriate lower 5 percent char-

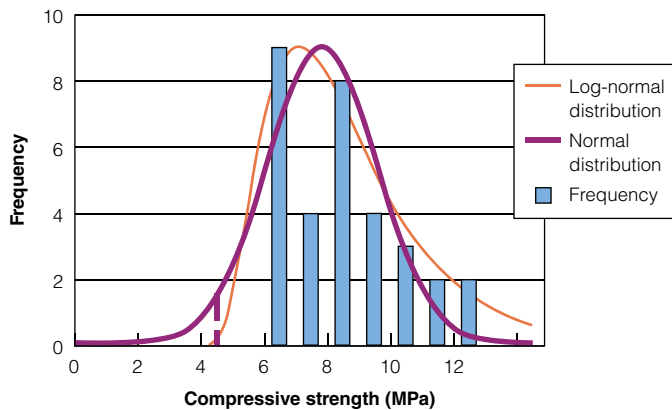


FIGURE 2 Histogram of compression test results overlaid with normal distribution, log normal, and nominal 5 percent value.

acteristic strengths for the various material properties. Over a number of years international databases of materials and an understanding of population characteristics can be built with this information.

The statistics are demonstrated by research conducted at the University of Auckland (Cheah 2007; Cheah, Ingham, and Morgan 2008) on a cement-stabilized rammed earth wall incorporating natural fibers. Thirty-three specimens were cut from a single wall panel and gave an average compressive strength of 7.6 MPa and a coefficient of variation of 24 percent. Applying a normal distribution to this data gives a 5 percent value of 4.6 MPa, as shown in figure 2. Assuming that there are no specific physical factors influencing the results, it is clear that this simple statistical approach is significantly overconservative. If there were adequate statistical data, the proper distribution could be established (maybe log-normal?) and a realistic 5 percent characteristic strength could be derived.

Engineering Design

“NZS 4297:1998 Engineering Design for Earth Buildings” outlines the analytical methodologies for an engineer to design an earth building. This standard was used to derive the design tables in NZS 4299. The basis of this was outlined by Morris (2009) but is in need of revision and further development, especially for out-of-plane analysis.

The out-of-plane energy method is based on a stability approach developed for unreinforced masonry by the New Zealand Society for Earthquake Engineering (1995) that assumed that walls span vertically between a beam at roof

or upper-floor level and the foundation. This is a simplistic approach and does not account for the very thick walls used in earth construction, where lateral and end wall support will be more significant. While it assumes bond beams or their equivalent, it does not account for the end of wall tiedown or horizontal reinforcing that the New Zealand earth building standard requires.

In Australia Griffith and Lawrence have contributed to a virtual work methodology in an amendment to “AS 3700-2001 Masonry Structures” (Standards Australia 2001, 2004, 2007; Willis, Lawrence, and Griffith 2006) that calculates the input energy and then internal energy along the cracks as the panel deflects. This considers vertical and horizontal mortar joint interfaces in both flexure and torsion and failure through the brick itself to determine out-of-plane wall strength. Further development from this work aimed as seismic design is in progress by Griffith on the flexural strength of unreinforced masonry and is expected to provide a more appropriate design methodology.

Further Recommendations Based on Developments in the Masonry Design Standard

Burnt brick and concrete masonry are also governed by seismic design considerations, except for low seismic and extreme wind locations, and design is usually governed by the ultimate limit state. Considerable work by a large number of researchers over the past four decades means that seismic design of concrete and masonry buildings is comparatively well understood. Extending the recommendations now incorporated in these standards maximizes the use of existing knowledge.

Design Document Format

New Zealand Standard “NZS4230:2004 The Design of Reinforced Concrete Masonry Structures” (Standards New Zealand 2004b) is a recent engineering design standard that follows a different layout from the conventional standards, as shown in table 1. In a future revision of the earth standard changing the format so that it is similar to the masonry standard would improve the ease of use of the document.

New Zealand material design standards are now being formatted on the basis of component design rather than action design. This arranges subject material into component sections such as structural walls, beams, and columns rather than the existing flexural, axial, and shear actions. This makes it

Table 1 Design standard document structure

Existing Format (action based)	Proposed Format (component based)
<ul style="list-style-type: none"> • Performance criteria —durability, strength, shrinkage, thermal, fire • General construction and design requirements • Strength and serviceability • Flexure with or without axial load • Shear • Reinforcement—details, anchorage, and development • Foundations 	<ul style="list-style-type: none"> • Limit state design and material properties • Design for durability • Design for fire resistance • Reinforcement • Structural walls • Beams • Columns • Structural component design • Secondary elements

more accessible to engineering designers, who will have all the criteria associated with the design of one component in one location.

Seismic Design Philosophy

Without well-established data it is necessary to assume elastic response when applying the earthquake provisions of “AS/NZS 1170.5 The New Zealand Structural Actions Standards” (Standards New Zealand 2004a). This brings about two penalties with the structural performance factor, as well as not gaining the benefits of the actual structure ductility. Testing is going to be undertaken; this is expected to give a ductility of 2, which will reduce the seismic design loads by 50 percent.

There is little rigorously validated data available on the seismic response of earth buildings. This understanding is needed if the lower loads are to be permitted because of well-understood building performance.

Reinforcement Detailing

Because of the seismic context, all New Zealand earth buildings need reinforcement. At present the vertical reinforcement is steel, and the bulk of other reinforcement is steel or geogrid. Research is needed to determine the bond characteristics between the steel reinforcement and the earth materials, bend radii need to be determined for bent steel reinforcement, and suitable spacing needs to be specified to take into account con-

struction equipment such as compacting rammers in rammed earth. It is assumed that wall penetrations and openings will be strengthened by reinforcement, and consequently the effectiveness of this reinforcement for crack control around wall openings needs to be verified.

Conclusion

Standards need to be appropriate for their context. In New Zealand we have one of the lowest levels of corruption, and there is a high expectation that laws and regulations will be enforced. The New Zealand standards will not be appropriate in many parts of the world, but in the longer term the prescriptive detail that we have in our standards and more rigorous development will become necessary to meet expectations when compared with standards for concrete, steel, and timber.

For the standards to meet the needs of the twenty-first century, we make the following recommendations:

- Earth materials properties need to be well defined, and their statistical reliability must be understood.
- Improved seismic design approaches for out-of-plane performance.
- Verified seismic design philosophies to allow advantage to be taken of ductility.
- Engineering standards change to a component design format for ease of use.
- Reinforcement detailing needs to be tested and verified.

Acknowledgments

We wish to thank the committee of eight engineers, architects, and earth builders who put in ten years of effort to develop the New Zealand Standards and the Australian participants who assisted in part of the standard writing process.

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PART NINE

Training Formation

Knowledge Transfer and Networking in Earth Architecture

Mariana Correia and Célia Neves

Abstract: *This paper analyzes the latest developments in training and technology transfer in Latin America, as well as cooperation and scientific dissemination developed through distinctive networks. The first part presents the current situation in Latin America concerning training in earth architecture, which provides not only an increase in new job opportunities but also the development of knowledge. The second part addresses the cooperation that exists between interdisciplinary and international networking. This paper contributes to the establishment of synergies and consistent strategies for cooperation, invaluable for profound, interdisciplinary, and integrated knowledge of earthen architecture.*

Résumé : *Cet article analyse les derniers développements en matière de formation et de transfert de technologie dans le domaine de l'architecture de terre en Amérique latine, ainsi que la coopération et la diffusion scientifique mises en place grâce à certains réseaux uniques. La première partie de l'exposé présente la situation effective de la formation en Amérique Latine, avec ses conséquences positives de nouvelles possibilités d'emplois et de développement du savoir. La seconde partie traite de la coopération au sein de réseaux interdisciplinaires et internationaux. Cet article participe à l'effort de création de synergies et de stratégies durables de coopération, indispensables à une connaissance approfondie, interdisciplinaire et globale de l'architecture de terre.*

Knowledge Transfer

During the late twentieth century and the beginning of the twenty-first, the use of earth for building has seen a revival, making a significant impact on the value of architecture, sus-

tainability, and ecological construction. To better respond to this awakening interest, professionals and researchers have initiated activities to educate the public. Their contribution is significant and comes from all over the world and from a wide range of interdisciplinary experience. Their contribution is possible because of their persistence, creativity, and dedication to gathering and sharing information.

Thanks to these dedicated researchers and professionals, several research centers and associations have been created. The best known is the Center for the Research and Application of Earth Architecture, CRAterre, based at the School of Architecture, Grenoble, France (<http://terre.grenoble.archi.fr>). Its contribution is fundamental to the field: it provides opportunities for research, technical cooperation, dissemination of information, and promotion of earthen architecture. Other entities have also dedicated themselves to the transfer of knowledge through the creation of annual workshops, for example, Foundation Navapalos in Spain and FUNDASAL in El Salvador.

In Colombia a very interesting program for transferring technology, “Ecosostenibilidad y Técnicas de Construcción con Tierra” (Ecosustainability and Techniques of Construction with Earth), was created in 2004 by Fedevivienda. It is a program of informal education, open to the public, based on two hundred hours of theoretical learning and two hundred hours of practice in construction systems (Garzón 2006). As a result, in 2007 the Escuela Colombiana de Ingeniería Julio Garavito, together with Fedevivienda, created a course titled “Técnicas de Construcción Sostenible” (Sustainable Construction Techniques).

The transfer of knowledge can be done by formal and informal methods. Most formal transfer is concentrated in

universities and research centers. The informal approach is seen in employment, training centers, and professional associations. Recently there has been increasing use of Internet-based instruction, especially in earth construction and sustainability.

Brief Historical Background: Latin America

Since the mid-twentieth century there has been a concentrated effort on the part of specialists to improve and promote the use of earth as a building material (Neves 1995). During the 1950s the Colombia InterAmerican Centre for Housing and Planning (CINVA) organized a research program on earth construction that developed a simple model for a manual press, commonly known as the CINVA-RAM. CINVA also published *Suelo-Cemento: Su aplicación en la edificación* (Colombia 1963), which is a classic on the subject.

In the 1970s the Pontificia Universidad Católica del Peru (PUCP) launched an intense research program on seismic behavior in adobe construction that resulted in the development of appropriate construction techniques, in particular, for wall reinforcement (fig. 1). In 1977 the Instituto Nacional de Investigación y Normalización de la Vivienda (ININVI) accepted adobe as a construction material for seismic-resistant projects; in 1985 the Peruvian Ministry for Housing and Construction approved and published the Adobe Standard. This publication (revised in 2000) is considered an excellent reference for specialists working in this area (Perú 2000). The standard is continually revised and improved. ININVI also published a series of didactic manuals, and the bibliographic data were transferred to the Centro de Investigación, Documentación y Asesoría Poblacional (CIDAP).

In Brazil studies on earth construction conducted during the 1970s and 1980s were directed toward the use of stabilized soil. A majority of the studies focused on soil-cement, soil-lime, and waste carbide-soil (industrial residue from the production of acetylene). To date, thirteen soil-cement technical standards have been published.

The great majority of the earth construction techniques applied in Brazil are basically compressed earth bricks (CEBs), but monolithic panels molded in place are also used. During the 1990s a movement to use debris from the fabrication of bricks and CEBs began (fig. 2).

In Paraguay during the 1980s the Centro de Tecnología Apropriada (CTA) developed a program to improve wattle-and-daub construction techniques used in rural housing. The goal was to eliminate the kissing bug (*Trypanosoma cruzi*), which lives in dwellings and is responsible for the transmis-



FIGURE 1 Seismic retrofitting tests performed during SismoAdobe 2005, held at PUCP, Lima, Peru, in May 2005. Photo: Mariana Correia



FIGURE 2 CEB construction in Carrapateira, Algarve. Visit during the IV SIACOT, held in Monsaraz, Portugal, in October 2005. Photo: Mariana Correia

sion of human American trypanosomiasis, or Chagas disease. Unfortunately, the research and the technological transfer did not continue.

In Argentina in 2002 the National University of Tucumán, Faculty of Architecture and Urbanism, established the Centro Regional de Investigaciones sobre Arquitectura



FIGURE 3 Annual reunion of Proterra members during Construtierra 2006, held in Colombia, in February 2006. Photo: Mariana Correia

de Tierra Cruda (CRIATiC). This center coordinates research projects on earthen architecture and construction with the transfer of knowledge through the extrauniversity extension and other training programs.

It is important to note that through the development of standards and regulations, knowledge transfer occurs. There has been a movement in Latin American countries to develop and publish technical standards for the construction of earth buildings. In addition to the Peruvian norm, in Colombia a technical norm concerning soil-cement blocks for interior and exterior walls (ICONTEC 2005) was published. There are also commissions working in Spain, Nicaragua, and Mexico for the elaboration of national norms.

Iberian American Research Project: Proterra

Proterra was created in October 2001 as a four-year project under the aegis of the Iberian-American Program of Science and Technology for Development (CYTED) (fig. 3). Its purpose was to encourage the use of earth as a construction material through explanatory projects, publications, courses, and other events. The results of this investigation included several publications, numerous events, and the association of over one hundred specialists in architecture and earthen construction from Portugal, Spain, and Latin America. Among its activities were the following:

- SIACOT (Iberian American Seminars on Earthen Construction) (fig. 4);
- conferences, regional seminars, courses, and workshops (fig. 5);
- traveling exhibition of didactic panels with information and examples of earthen architecture and construction; and
- digital and print publications.



FIGURE 4 IV SIACOT, held in the Convent of Orada, Monsaraz, Portugal, in October 2005. Photo: Mariana Correia



FIGURE 5 Workshop during Construtierra 2006, held in Colombia, in February 2006. Photo: Jacob Merten

Networking

Networking encourages people to work in areas of common interest both formally and informally. Sharing information and data provides a chance for professional colleagues to exchange ideas and research and to work together to accomplish a common goal. Networking can be developed through an Internet forum, a portal, a Web site, seminars, workshops, newsletters, and systematic exchange but also through associations, research centers, and so on.

National Networks

In Portugal the Associação Centro da Terra (www.centroda.terra.org) was established in 2003. The association is dedicated to the study, documentation, and diffusion of earthen construction and architecture in Portugal. The publication of the bilingual book *Earth Architecture in Portugal* (Fernandes and Correia 2005) contains contributions from more than fifty authors.

In Italy the Associazione Nazionale Città della Terra Cruda is very active and has competed for European and regional funding for the conservation of the urban fabric of the different municipalities in Italy. It is a unique case of a European earthen architecture municipal association that has had very positive results (www.terra-cruda.org).

Other national organizations are also made up of interdisciplinary groups of professionals, such as the German earth building association Dachverband Lehm e.V. (www.dachverband-lehm.de), the Tecnitierra-Colombia network, and the TerraBrasil-Brazil network, among many others throughout the world (www.uni-terra.org/associations).

Thematic Networks

a) Interdisciplinary. The rising interest in earthen architecture research studies has resulted in stronger institutional cooperation. Consequently several informal networks have been created between different disciplines. The March 2006 conference in Oporto, Portugal (Correia and Oliveira Jorge 2006), sponsored by Escola Superior Gallaecia and the University of Porto, focused on earthen architecture, anthropology, and archaeology and was fundamental to strengthening the exchange of knowledge. In October 2007, to develop interest in earthen architecture materials and their behavior, the University of Aveiro was invited by Escola Superior Gallaecia to host the 5th Seminar on Earthen Architecture in Portugal (ATP) (Neves et al. 2007). Other interdisciplinary exchanges have occurred in international seminars and working sessions (Achenza et al. 2006).

b) By technique. There are several informal networks around the world associated with earth construction. One of them is the cob group created in California by Deatech Research, Inc. (www.deatech.com/natural/coblist/). In addition, the organizers of the biannual French meeting Rencontres Transdisciplinaires have contributed significantly to the study of specific construction techniques in different disciplines.

c) By subject. Several different themes can bring people together. For example, an international association for the protection and conservation of the heritage of Hassan Fathy was recently created. One of their priorities is safeguarding the New Gourni in Egypt (<http://fathyheritage.over-blog.com>).

European Networks

Two European Union–financed earthen architecture projects were successfully concluded under the Cultura 2000 program. The first project (2004–6) was Houses and Cities Built with Earth and the second was Terra Incognita (2006–8). Both produced scientific publications. Through the exchange and visits of students, researchers, and professionals from European universities there is now collaboration among these universities as well as national associations and independent professionals.

Iberian American Networks

a) Arqui-terra list. Arqui-terra is an Iberian American electronic mailing list of Spanish origin. In addition to a discussion forum on earth construction, they have a Web site where images, previous discussions, or documents that are specific to architecture and earthen construction can be accessed. There are over a thousand enrolled participants from the five continents (www.eListas.net/lista/arqui-terra).

b) Proterra. In February 2006 the Proterra Iberian American Network was launched. Since then Proterra has supported the V SIACOT (Mendoza, Argentina), the VI SIACOT (Tampico, Mexico), TerraBrasil 2006 (Ouro Preto, Brazil) (fig. 6), and the 5° ATP (Aveiro, Portugal). They have also supported the technical commission for the elaboration of “earthen norms” in Nicaragua and participated in several publications produced in Portugal, Mexico, Brazil, and Argentina. At present Proterra coordinates discussions on testing procedures and parameters for product qualifications, such as adobe, CEBs, and masonry, among others, in addition to its activities of dissemination and training. Apart from this, Proterra also encourages the creation of regional networks. A newsletter is distributed three times a year (more information at <http://redproterra.org/>).



FIGURE 6 Workshop during TerraBrasil 2006, held in Ouro Preto, Minas Gerais, Brazil, in November 2006. Photo: Mariana Correia

International University Networks

a) *UNESCO Chair on Earthen Architecture.* With the support of UNESCO and in the scope of the Terra Project, Consortium Terra was developed by a network of several universities around the world. The UNESCO Chair on Earthen Architecture, Building Cultures, and Sustainable Development is managed by CRATerre. It networks with earthen architecture programs in universities and targets the creation of an active education and research axis. In 2006 the network was reactivated through the UNESCO Chair Internet platform (www.craterre.archi.fr/chaireUNESCO.php and www.craterre-unesco@archi.fr).

b) *Universiterra.* Universiterra is an Italian network of universities dedicated to earthen architecture research. It is based on the regular exchange of researchers who present their work at several of the organized regional earthen architecture conferences (Bollini 2002).

c) *Uni-Terra.* It has been proposed that an international Internet platform (www.uni-terra.org) be created for academic exchange on earthen architecture, in which universities can participate and communicate their ongoing activities. The general goal of the project is to give students information concerning teaching modules or curricula about building with earth in various universities around the world.

Earthen Architecture Initiative

The Earthen Architecture Initiative (EAI) of the Getty Conservation Institute (GCI) “seeks to further the conservation of earthen architecture through international activities and institutional partnerships” (www.getty.edu/conservation/field_projects/earthen/). In April 2006 the GCI hosted the Getty Seismic Adobe Project 2006 Colloquium in Los Angeles, at which professionals from around the world presented their research. Key themes in adequately answering the challenge of preserving common cultural heritage and safeguarding human life in the world’s seismically active regions were discussed. The meeting evolved into a discussion group made up of professionals associated with seismic retrofitting of earthen structures.

Mediterranean Network

Cagliari University, Escola Superior Gallaecia, and CRATerre-ENSAG are organizing the first Mediterranean conference on earthen architecture, *Mediterra 2009* (<http://people.unica.it/mediterra>), in March 2009. The main objectives are to convene specialists from all the Mediterranean countries and to develop a Mediterranean network for research, education, and development of regional strategies.

International Scientific Committee on Earthen Architectural Heritage

The ICOMOS International Scientific Committee on Earthen Architectural Heritage (ISCEAH) was reactivated in 2005. Its goals are to increase the activity and participation of members of the committee, to share experiences, and to contribute to the development of best practices and methods for protection and conservation of the world’s earthen architectural heritage, including architecture, archaeology, and cultural landscapes (<http://isceah.icomos.org/>).

Conclusion

There has recently been a significant increase in institutional cooperation that has encouraged the exchange of knowledge and helped earthen architectural conservation and research projects to develop in a more systematic, scientific, and professional way. The increase in financed international research projects has allowed Europe and Latin America to progress in their knowledge of the field and to grow in terms of the demand and quality of the work. Technological advances in earthen

architecture and innovations in disseminating the knowledge gained have helped demystify earth as a construction material and have helped modern societies accept it as a conventional building material for new construction. This is an example of how the earthen architecture networks discussed in this paper have become a principal instrument for communication, independent of their objectives, number of users, and geographic parameters. To attract interest and keep this interest active, it is important that these established networks have precise objectives and clear strategies, as well as achievable goals.

It should be stated that it is of utmost importance to establish synergies and strategies to transfer knowledge, whether through education, diffusion, or networking. This will make it possible to reach and engage a wider audience and to integrate and disseminate local knowledge and experience, which is at the core of sustainable conservation practice. It is now a reality that several institutions have doubled their efforts to engage in research on earthen architecture and scientific dissemination of the knowledge gained.

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« Grains de bâtisseurs® » : Un nouvel outil pédagogique pour l'enseignement de l'architecture de terre

Hugo Houben, Patrice Doat, Laetitia Fontaine, Romain Anger, Wilfredo Carazas Aedo, Christian Olagnon et Henri Van Damme

Résumé : En 1999, le projet Terra a procédé à une évaluation de ses dix ans d'activités pédagogiques et a fait ressortir la nécessité de repenser l'enseignement de l'Architecture de Terre en fonction de nouveaux termes de référence qui ont été identifiés. CRATerre-ENSAG a apporté une réponse à ce défi par la mise au point, entre 2003 et 2007, d'une méthode pédagogique phénoménologique qui permet d'acquérir, en complément au savoir pratique et savoir théorique, un savoir intuitif basé sur la connaissance profonde de l'essence fondamentale intrinsèque de la matière terre. L'outil pédagogique porte le nom de « Grains de bâtisseurs® ».

Abstract: In 1999 the Terra project undertook an evaluation of its ten years of teaching activities, which pointed to the need to rethink the teaching of earthen architecture according to newly identified terms of reference. CRATerre-ENSAG responded to the challenge between 2003 and 2007 by devising a phenomenological educational method making it possible to acquire, in addition to practical skills and theoretical knowledge, an intuitive knowledge based on a thorough understanding of the intrinsic fundamental essence of earth. The pedagogical tool is known as « Grains de bâtisseurs® ».

Le besoin d'une approche pédagogique nouvelle pour l'architecture de terre

Depuis sa création en 1979, il y aura bientôt 30 ans, CRATerre-ENSAG considère l'enseignement de l'architecture de terre comme un point essentiel de son mandat avec l'option fondamentale d'enseigner à la fois la pratique et la théorie, le comment et le pourquoi. Les éléments pratiques proviennent de la capitalisation de l'expérience acquise continuellement lors d'innombrables interventions sur le terrain. Les éléments

théoriques sont basés sur l'étude bibliographique, la veille technologique et les résultats de nombreux travaux de recherche menés en permanence.

Ce mode d'enseignement, devenu classique et également pratiqué par beaucoup d'autres institutions et opérateurs, a été très satisfaisant pendant près de 20 ans. Cependant, en 1999, lors du cours Pat 99 du Projet Terra (ICCROM, CRATerre-ENSAG, GCI, INC) il s'est avéré que les limites de l'approche pratique/théorie, savoir-faire/savoir pourquoi, étaient atteintes. Il devenait donc nécessaire de repenser entièrement l'enseignement de l'architecture de terre pour concevoir une nouvelle pédagogie répondant aux besoins suivants identifiés à la suite d'un travail de réflexion :

- maintenir les acquis en matière d'enseignement pratique et théorique ;
- fusionner l'enseignement de la construction et de la conservation ;
- encourager la multidisciplinarité ;
- appliquer à différents niveaux de compréhension ;
- garantir la capacité de transfert des apprenants ;
- échapper au carcan technologique existant ;
- couvrir tous les stades du cycle de vie ;
- intégrer les principes du développement durable ;
- convenir à une très large gamme de contextes culturels.

La démarche générant une réponse pédagogique innovante

La construction en terre a toujours été perçue comme la transposition d'un matériau volumineux et massif horizontal en

matériau volumineux et massif vertical. La philosophie pédagogique de la construction en terre s'est évidemment basée sur cet axiome pour l'appliquer aussi bien à la partie pratique qu'à la partie théorique. Il est logique de penser que pour donner une réponse aux termes de référence nouvellement développés, un point de vue différent devait être adopté.

Le choix de notre point de vue particulier a été influencé par nombre de facteurs, dont la percée spectaculaire effectuée depuis quelques années en termes de compréhension des mécanismes fondamentaux régissant la cohésion du matériau terre. Ces nouvelles connaissances sont basées sur les résultats d'un vaste programme de recherche lancé par le Projet Terra et collectivement conduit par CRATerre-ENSAG, l'ICCROM et le GCI, avec l'aide de dix laboratoires de recherches du CNRS dont le LTHE (Grenoble), l'INSA (Lyon), l'ESPCI (Paris) et l'HYDRASA (Poitiers), et achevé en janvier 2005.

Un deuxième facteur d'influence est l'évolution de la philosophie de l'approche « échelle nano / échelle macro » qui gagne la communauté scientifique de façon continue depuis dix ans.

Un troisième facteur d'influence est constitué par l'éclosion dans le monde scientifique depuis quelques années d'une nouvelle discipline nommée « science de la matière en grains » dont le prix Nobel, Pierre-Gilles de Gennes (ESPCI), était un des principaux acteurs depuis 1990.

Et un quatrième facteur d'influence est l'apparition de la phénoménologie dans le domaine de la vulgarisation scientifique.

La nouvelle approche : La matière en grains

Un des points de départ de notre perception de la nécessité de revisiter l'enseignement de l'architecture de terre était dicté par la constatation que les connaissances de base enseignées lors des cours de conservation étaient en fait issues du domaine de la construction nouvelle. Or, les constructeurs sont formés pour identifier le matériau terre, le transformer en produits optimaux, utiliser des techniques de mise en œuvre spécifiques et appliquer des systèmes constructifs appropriés. À chaque stade, ils ont l'occasion de faire un choix entre plusieurs options. Pour des constructeurs, le vecteur du cycle de vie va du berceau à la tombe. Les conservateurs, par contre, se trouvent devant une structure existante, souvent à l'état de ruine ou dans un certain état de dégradation, qui a été construite avec une technique donnée qui ne correspond pas nécessairement à une des techniques optimisées pratiquées aujourd'hui. Ils doivent souvent identifier la composition du matériau originel et, s'il faut travailler avec celui-ci pour la

restauration de cette structure, ils doivent identifier sa provenance géologique. Pour les conservateurs, le vecteur du cycle de vie va donc de la tombe au berceau.

Les constructeurs comme les conservateurs ont leurs technologies spécifiques concernant les différents stades du cycle de vie, mais qu'est-ce qui est à la base de la pratique et de la théorie de ces technologies spécifiques ? Quelles sont les connaissances de base qu'ils partagent ? Si on doit admettre qu'à chaque stade du cycle de vie, la construction et la conservation ont leurs spécificités propres, il y a cependant un stade rigoureusement identique pour les deux, c'est le stade de la matière. Il était donc logique d'en conclure que l'innovation pédagogique souhaitée devait avoir la matière comme point de sortie. Mais la matière appréhendée de quelle façon ?

La réponse à cette question est venue un peu par hasard, déclenchée par une frustration provoquée par une remarque formulée des années auparavant, lors d'une des séances d'analyse critique du déroulement du cours Pat 99. Jeanne Marie Teutonico (GCI) et Alejandro Alva (ICCROM) avaient fait remarquer qu'en ce qui concernait le cours sur la granulométrie, il aurait été souhaitable de non seulement enseigner la pratique et la théorie mais également d'expliquer le pourquoi de la nécessité d'établir la courbe granulométrique.

Dans un premier temps, une remarque pareille est évidemment frustrante dans la mesure où l'interprétation des paramètres de la courbe permet de préconiser les mesures nécessaires pour optimiser une intervention donnée et se justifie ainsi d'elle-même. Par contre, il y a, en effet, une réponse très simple à donner à la question du pourquoi : c'est d'établir la courbe granulométrique pour faire l'inventaire de ce qu'on a, c'est-à-dire pour faire l'inventaire quantitatif des grains.

Dans le diagramme granulométrique, la quantité de grains a toujours été exprimée en poids ou en volume : cela correspond à l'approche classique « matériau massique » de la terre. Mais il nous avait échappé qu'on pouvait aussi l'exprimer en nombre et cela mène vers une approche atypique de la terre que l'on considère dans ce cas comme une « matière divisée ». En fait, on peut se demander combien de grains il y a dans 1 m³ de terre. La réponse est époustouflante : 600 millions de milliards de grains. Si on devait les compter un par un à raison de un grain par seconde, il nous faudrait 20 milliards d'années, alors que notre univers n'existe que depuis 15 milliards d'années. Si on juxtaposait ces grains, cela ferait un ruban de 600 millions de km, soit deux fois la distance aller-retour au soleil. En partant du premier grain, la lumière mettrait 32 minutes avant d'atteindre le dernier.

Le matériau terre est bien un matériau ultra divisé et désordonné, constitué par des millions de milliards de grains

minéraux qui déterminent son essence fondamentale et sa nature intrinsèque. Il est donc tout à fait légitime de se poser quelques questions les concernant :

- qui sont-ils ?
- d'où viennent-ils ?
- de quoi sont-ils faits ?
- quelle est leur nature ?
- comment se comportent-ils ?
- comment sont-ils organisés ?
- comment tiennent-ils ensemble ?

La terre est donc une « matière en grains » et par conséquent assujettie aux règles et lois de la science de la matière en grains qu'il nous faut apprendre à connaître et maîtriser.

Avec ces observations, constatations et conclusions, le cadre était dressé pour une approche pédagogique radicalement différente.

« Grains de bâtisseurs® » : Un nouvel outil pédagogique pour l'architecture de terre

Une réponse concrète aux termes de référence susmentionnés a pu être élaborée en intégrant les quatre facteurs d'influence évoqués plus haut. L'outil pédagogique correspondant a reçu le nom de « Grains de bâtisseurs® – La matière en grains, de la géologie à l'architecture ».

« Grains de bâtisseurs® » est un atelier scientifique de plus de cent cinquante expériences interactives, permettant d'acquérir, par un cheminement qui va de la géologie à l'architecture, et sans faire appel à des connaissances physiques, chimiques et mathématiques avancées, une culture scientifique et technique générale de la matière en grains pour ce qui concerne son utilisation dans les domaines de la construction et de la conservation de bâtiments et plus spécifiquement pour l'architecture de terre. « Grains de bâtisseurs® » est divisé en trois thèmes :

- les grains secs ;
- les grains humides ;
- les argiles et colloïdes.

Cet atelier peut se décliner en plusieurs versions impliquant sa taille et sa durée dépendant de la spécificité de la demande et du lieu de son installation.

En ce qui concerne nos propres besoins, l'atelier est déployé dans sa version intégrale qui se développe sur envi-

ron 400 m² (fig. 1) et l'atelier scientifique est associé en aval à l'atelier technique qui se développe en même temps sur environ 800 m² (fig. 2). Les expériences sont en libre-service individuel et elles peuvent également être pratiquées collectivement, mais dans tous les cas la présence d'un(e) médiateur(trice) scientifique est obligatoire. De nouvelles expériences sont développées constamment au fur et à mesure de l'évolution des connaissances qui sont produites par les programmes de recherche en cours et des nouveaux besoins pédagogiques identifiés. En amont, l'atelier « Grains de bâtisseurs® » est précédé par un ensemble intégré d'exercices analytiques théoriques (fig. 3) et pratiques (fig. 4) impliquant les cinq sens et



FIGURE 1 L'atelier scientifique « Grains de bâtisseurs® » pour lequel plus de cent cinquante expériences ont été développées et qui se déploie sur 400 m². © CRATerre-ENSAG



FIGURE 2 L'atelier technique de 800 m² qui accompagne l'atelier scientifique « Grains de bâtisseurs® ». © CRATerre-ENSAG

visant à découvrir le caractère triphasique de la matière terre. Les conséquences de ce caractère triphasique sont reprises dans l'atelier scientifique et l'atelier technique.

La nature des expériences

Les expériences sont pour la plupart contre-intuitives. Une expérience contre-intuitive est une expérience qui produit un résultat inverse ou très différent de celui auquel on s'at-



FIGURE 3 Exercice de classification des composants et élaboration d'un modèle théorique de la nature triphasique de la matière terre. © CRATerre-ENSAG



FIGURE 4 Exercice de synthèse des variations paramétriques des interactions triphasiques de la matière terre. © CRATerre-ENSAG

tend intuitivement, ou dont l'interprétation va à l'encontre de l'évidence ou du sens commun. Les expériences contre-intuitives sont particulièrement efficaces en pédagogie. Elles permettent à la fois d'émerveiller, de perturber les concepts de l'apprenant et de le motiver pour en savoir davantage. Elles permettent surtout, à force de multiplication, d'ajuster au fur et à mesure notre intuition à la réalité des expériences, jusqu'à ce que les expériences contre-intuitives ne soient plus perçues comme contre-intuitives et que notre intuition parvienne à parfaitement prévoir le déroulement des phénomènes qui caractérisent la spécificité des expériences. C'est alors seulement qu'on peut considérer que la nature intrinsèque de la matière en grains a été assimilée.

Les expériences sont des transformateurs scalaires. Elles sont conçues pour porter à notre échelle spatio-temporelle humaine – le mètre et la minute –, des phénomènes qui se passent à l'échelle du nanomètre et du dix millième de seconde, ou au contraire, se passent au niveau de régions entières sur des millions d'années. Les apprenants sont donc tour à tour invités à changer d'échelle, à la fois au niveau spatial (de l'infiniment petit à l'infiniment grand) et temporel (temps quantique et temps géologique). C'est donc une autre vision du monde qui nous entoure qui est en jeu.

La nature pédagogique de « Grains de bâtisseurs[®] »

« Grains de bâtisseurs[®] » est une méthode pédagogique phénoménologique¹ qui permet de développer un savoir intuitif, basé sur une connaissance profonde de l'essence fondamentale et de la nature intrinsèque de la matière terre, procurée par la manipulation des expériences. Cette approche permet d'arriver mentalement « dans un autre monde », prêt à s'unir à ce qu'on y contemple. Devenir « un » avec les grains, devenir « un » avec la terre. Et emmener, en quittant ce monde, les choses qu'on y a découvertes pour les appliquer au monde réel. Ce savoir intuitif est complémentaire à l'acquisition du savoir-faire pratique et du savoir pourquoi théorique.

La nature pédagogique de « Grains de bâtisseurs[®] » est allostérique². Selon le modèle allostérique, s'approprier un nouveau savoir, c'est tout autant évacuer des savoirs peu adéquats, qu'en élaborer d'autres. Ce processus relève à la fois d'une réorganisation des informations préexistantes et d'une régulation, en interaction avec des données nouvelles. Apprendre est le résultat d'un processus de transformations, de transformations de questions, d'idées initiales, de façons de raisonner habituelles.

Conclusions

Le concept de « Grains de bâtisseurs® » s'est avéré très flexible puisqu'il peut être utilisé non seulement pour l'enseignement, pour lequel il a été conçu, mais aussi se révéler un outil très performant pour la recherche, et un merveilleux instrument de vulgarisation.

Pendant les quatre dernières années, l'atelier scientifique « Grains de bâtisseurs® » a été pratiqué par plus de 11 000 personnes de tous les âges, origines, cultures et niveaux de compétence. Forts de cette expérience, nous pouvons confirmer que « Grains de bâtisseurs® » respecte le cahier des charges mentionné plus haut puisque nous avons pu constater qu'il est :

- complémentaire à la pratique pédagogique existante ;
- applicable à toutes les situations professionnelles ;
- ouvert en termes de communication avec d'autres disciplines ;
- adapté à l'enseignement supérieur, mais aussi à d'autres niveaux ;
- capable de permettre aux apprenants de faire face à des situations inconnues ;
- stimulant pour le développement de techniques innovantes ;
- stimulant pour la réflexion holistique ;
- mobilisateur pour utiliser la matière de façon intelligente ;
- universellement efficace sur le plan pédagogique.

La demande pour « Grains de bâtisseurs® » est telle que nous avons dû développer une version « conférence expérimentale » adaptée aux amphithéâtres de plusieurs centaines d'auditeurs. « Grains de bâtisseurs® » a également attiré l'attention de la Cité des Sciences et de l'Industrie de la Villette, temple de la vulgarisation scientifique, qui produit actuellement une version exposition de « Grains de bâtisseurs® » destinée à itinérer en France et ailleurs. Il est estimé que cette exposition permettra de faire découvrir l'intelligence de l'architecture de terre à environ 1 000 000 visiteurs entre 2009 et 2012.

Un livre est prévu pour mai 2009, et entre-temps une brochure introductive a été publiée. Elle est téléchargeable sur notre site <http://www.craterre.archi.fr>.

« Grains de bâtisseurs® » est un programme collectif des laboratoires CRATerre-ENSAG (Grenoble), PPMD - ESPCI (Paris), MATEIS - INSA (Lyon) et de la Galerie EUREKA-CCSTI (Chambéry). Il est soutenu financièrement par la Région Rhône-Alpes.

Notes

- 1 Phénoménologie : étude des phénomènes qui régissent le comportement.
- 2 Allosphérique : d'après le fonctionnement de certaines protéines dites « allostériques ». Ces molécules enzymatiques, fondamentales pour la vie, changent de forme, et donc de fonction, suivant les conditions de l'environnement dans lequel elles se trouvent.

International Collaborations to Preserve Earthen Architectural Heritage

Antonio Guerrero Arzaga, Luis Fernando Guerrero Baca, and Francisco Uviña Contreras

Abstract: *Since 1995 the international initiatives known as SICRAT and TICRAT (Seminario/Taller Internacional de Conservación y Restauración de Arquitectura de Terra) have been outstanding sources of support to many large and small communities. These workshops and seminars have successfully organized professionals from the United States and Mexico to disseminate information on traditional earthen architecture technologies in communities in these countries. This commonality has established a friendly and cooperative exchange of ideas and goals. This paper summarizes the many years of collaboration to preserve earthen architecture in both countries and in particular the past workshops and their successes. It focuses on how this well-established endeavor and model can be transferred to other sites and communities around the world that have similar needs.*

Résumé : *Depuis 1995, les initiatives internationales SICRAT et TICRAT ont apporté un soutien précieux à de nombreuses communautés, grandes et petites. SICRAT et TICRAT sont les acronymes en espagnol de Seminario y Taller Internacional de Conservación y Restauración de Arquitectura de Tierra. Ces séminaires et ateliers pour la conservation et la restauration de l'architecture de terre ont rassemblé des professionnels des États-Unis et du Mexique pour diffuser des informations sur les technologies traditionnelles de l'architecture de terre dans des communautés de ces deux pays. Ces éléments communs ont conduit à une collaboration et à un échange fructueux d'idées et d'objectifs. Cette communication résume les nombreuses années de collaboration pour préserver le bâti en terre des deux pays. Nous insisterons sur la manière dont cette initiative et ce modèle pourraient être transférés à d'autres sites et communautés du monde qui auraient les mêmes besoins.*

Earthen architecture has been present for several millennia in human settlements located in the vast geographic region of the present border area of Mexico and the United States. The fact that these earthen construction techniques are still used and have remained essentially unaltered over time is convincing proof of the capacity to resolve the problems of adaptation and development of culture in a hostile environment. However, in spite of its vague origin and its survival in many traditional sites, earthen architecture has been disappearing, because of either disuse or the substitution of new construction systems. Another contributing factor has been the discrediting of earthen building material as an underdeveloped and poor-quality technology.

With regard to this gradual disappearance of our material and intangible resources, in the mid-1990s a group of academicians and professionals from governmental and nongovernmental institutions from the states in northern Mexico and the U.S. Southwest took on a series of tasks to establish an organization called the Seminario Internacional de Conservación y Restauración de Arquitectura de Tierra (SICRAT; International Seminar for the Conservation and Restoration of Earthen Architecture).

Among the major contributors and partners are the National Institute of Anthropology and History (INAH) and ICOMOS in Mexico and the National Park Service and Cornerstones Community Partnerships in the United States. The component of the patrimony in both countries that faces the greatest threat of extinction is earthen architecture, in part because of the loss of knowledge and the use of industrial materials such as concrete in Mexico and the cost factor in the United States.

The rapid destruction of this irreplaceable technology has created a rapid increase in networking among institutions, including institutions of higher learning, which are regularly invited to participate, as a means to promote the use of earthen technologies in both material and design. Since their inception, approximately thirty seminars and workshops have been organized in the U.S. Southwest and in northern Mexico. Over the years they have contributed substantially to education in the technology and use of earth as a valuable and viable building material, especially in rural communities where these practices were common historically. During the workshops not only is the use of earth as a building material a point of discussion, but so too are the traditional technologies of roof construction and finishes, basal interventions, lime and mud plasters, and lime paints, as well as tourism, urban design, and the economic advantage of conserving the earthen patrimony.

This paper's main objective is to present the fundamentals and the mission of this organization, as well as some of the work that has developed during this past year. It is only through the knowledge of our earth-built patrimony and the collective participation of the community that it will be possible to value and preserve the shared inherited cultural wealth and transmit it to future generations.

SICRAT Activities

SICRAT was created in the 1990s as a joint venture of the National Institute of Anthropology and History (INAH) in Mexico and the National Park Service (NPS) in the United States. Initially the idea of research with regard to the characterization of the earthen architecture of the border states was sought, as well as the exchange of experiences in the application of preservation strategies. The seminar work consisted of roundtable discussions with specialists, supported by site visits, where firsthand technical solutions were sought to problems faced by this earthen heritage.

Soon after the activities started, the nonprofit organization Cornerstones Community Partnerships was incorporated into the seminar. Cornerstones had several years of experience in the conservation of earthen vernacular architecture and is financially supported by private donations. Cornerstones is also tightly linked to community and volunteer participation.

The objectives and methods of the seminar were slowly transformed. The specialized gatherings were opened to a larger audience and developed into practical hands-on work directly related to local communities. To date, seminars have been held in communities in Arizona, New Mexico, and



FIGURE 1 The lack of interest in salvaging the historic adobe architecture in Historic Durango is evident in this ruined adobe building. Photo: Francisco Uviña, 2003

Texas in the United States and Sonora, Chihuahua, Coahuila, Zacatecas, Aguascalientes, and Durango in Mexico.

Recent Workshops

The following is a brief description of the previous three meetings of the seminar and workshop to explain the work structure that has developed. During June 8–10, 2006, the workshop took place in two distinct sites in the town of Bernalillo, New Mexico, and was organized by Cornerstones Community Partnerships, the town of Bernalillo, and New Mexico State Monuments. The event was of great importance as one of the sites, Coronado State Monument, was celebrating its seventy-fifth anniversary. This archaeological site belonged to the Tiwa pueblo of Kuaua. It is now named for the Spanish explorer Francisco de Coronado, who, with 300 soldiers and 800 Indian allies from New Spain, arrived in the pueblo in search of the Seven Cities of Gold. At the archaeological site a small adobe structure was repaired and a traditional earth roof applied.

The other site in the town was a small adobe building that was in need of serious repairs. The small structure is known as the well house, where a pump was housed to provide water to a large convent across the main street of the town. Although not a large-scale structure, it was the perfect site for adobe repairs and demonstrations, especially in the use of traditional lime plasters and paints.

Lectures were presented that ranged from the care and maintenance of archaeological earthen sites, such as the World Heritage Site of Paquime in Mexico, to the application of tradi-



FIGURE 2 The application of cementitious plaster over wire lathe in Santa Fe, New Mexico, showing the lack of use of traditional plasters. Photo: Luis Fernando Guerrero Baca, 2006



FIGURE 3 Morning lectures during the workshop in Bernalillo, New Mexico. Photo: Francisco Uviña, 2006

tional lime and earthen plasters. The afternoons were used for hands-on work at both sites. Adobe repairs, earthen roof applications, traditional mud plasters, and lime plasters were demonstrated during the practical fieldwork. The local community, INAH Mexico, university students, the Sandoval Historical Society, and professionals participated in this workshop.

In October 2006, in the town of Guerrero, Chihuahua, another TICRAT was held, organized by INAH. Guerrero has a unique history; it is best known as the birthplace of the Mexican Revolution and is considered one of the best apple-growing regions in the world. The site was an adobe house in desperate need of repair, especially to the roof and walls. The lectures in the mornings were held at the police department, which could accommodate more than one hundred attendees. The lectures ranged from the causes of deterioration in earthen structures to lime plasters to the composition of local stone and chemistry. A site visit to a local limestone quarry and kiln and to the stone quarry where the “cantera” stone used for architectural details was extracted took place. An important lecture was given by representatives of the state of Chihuahua showing recent urban design improvements with the idea of improving and promoting tourism in this region.

The site work at the adobe house ranged from basal repairs, mud plasters, and lime plasters to traditional earthen

roofs and alum waterproofing of the lime-plastered roofs, an old technology still practiced in Mexico. Lime-based paints were also applied when the lime plasters were completed.

Among the participants were U.S. organizations and institutions such as the University of Arizona, Cornerstones



FIGURE 4 Work on a small building at the Coronado State Monument and the application of mud plaster. Photo: Francisco Uviña, 2006



FIGURE 5 Architecture students applying the traditional lime paint, Ciudad Guerrero, Chihuahua, Mexico. Photo: Francisco Uviña, 2006

Community Partnerships, and the National Park Service and large numbers of architecture students from the Tecnológico de Chihuahua, as well as local community members, surpassing all expectations. The three days were filled with lectures, hands-on work, and site visits. The site where the reception was held was perhaps the most historically significant; it is a large ranch house that held the first adobe apple storage refrigerator in the state of Chihuahua, where all the old equipment still remains.

The most recent workshop in the state of Chihuahua, in October 2007, was another success. The site where the hands-on activities took place was a small house located near the historic Hacienda of El Sauz. The typical morning lectures ranged from “The Participation of Communities in the Conservation of Earthen Architectural Heritage” to “Lime Plaster Application” and “Restoration of Mission Projects in Chihuahua.” The site visits during the workshop included the restoration project of the Hacienda El Sauz and the historic mission Church of Santa Ana de Chinarras.

Conclusion

Placing a value on the earthen heritage presents notable difficulties. Due to its abundance, historically it has not received the attention that it deserves. This fact relates to the simplicity of its construction. It is thought that it does not make sense to preserve for posterity something that can be easily substituted,



FIGURE 6 Hands-on activities during the workshop in El Sauz, Chihuahua, Mexico. Photo: Luis Fernando Guerrero Baca, 2007



FIGURE 7 Students applying the traditional lime paint in the interiors, El Sauz, Chihuahua, Mexico. Photo: Luis Fernando Guerrero Baca, 2007

that is “disposable.” This point of view has led to the destruction of countless examples of architecture whose value, as evidence of the past, has been lost forever.

In order to guarantee the survival of this heritage, it will be necessary to travel a path with three routes: conservation of the existing patrimony, preservation of traditional knowledge,

and incorporation of both into contemporary life. Each of these routes has its own logic and a specific field of action, but they should all be traveled simultaneously as they are interrelated.

The first route involves the safeguarding of historic earthen structures. This includes the identification of our patrimony, its documentation, its cataloguing and recording, its legal protection, its conservation, its maintenance, the development of policies and protection programs, and, if necessary, intervention and restoration.

The second route relates to the preservation of traditions. Historic earthen architecture has always required community participation at its conception, during its execution, and for periodic maintenance. The materials of these structures cannot be safeguarded if the intangible heritage that constitutes the wisdom and knowledge of ancient ways of construction and care is not simultaneously preserved. As a result of a gradual change in cultural patterns this knowledge has been altered and lost in many communities.

The third route arises from the research of other fields of study, such as ecology and industrial and environmental engineering. The necessity to save energy during the transformation of natural products into construction materials and bioclimatic design have generated valuable data that can allow the coexistence of new sustainable technologies that use earthen materials to build with. The new technologies, simple or sophisticated, can be incorporated into traditional culture with the aim of improving quality of life. The interconnection between bioclimatic and vernacular architecture will surely give valuable results in both disciplines. In this manner, the perspective of conservation radically increases its scope within these three parameters: the protection of historic buildings, the safeguarding and teaching of the intangible heritage that constitutes the traditional wisdom of the construction, and the generation of comfortable spaces that have the least possible impact on our natural resources.

The architecture of the future should embrace the search for solutions based on criteria of sustainability that take as a point of departure the preservation of historic and traditional structures. The conservation of historic buildings allows a millenary tradition to live on, serving as testimony to the technology of development, as well as a fountain of knowledge for future generations, thus increasing the possibility of taking maximum advantage of our existing resources. The rational reuse of older structures, independent of their antiquity, avoids new construction, with a consequent saving of energy and expensive materials.

The events and processes that have been discussed here are gradual steps that put forward the value of the recovery and dissemination of earthen construction technologies. It is necessary to continue the search for viable alternatives that will permit the continued development of communities, for they are the inheritors of this cultural resource.

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General Conclusions and Recommendations

Jeanne Marie Teutonico

At each conference session, rapporteurs recorded significant points and recommendations that emerged from the presentations and discussions related to each theme. These were collated and edited to arrive at the general conclusions and recommendations of the conference, which are summarized below.

- Mali contains some of the world's most extraordinary earthen heritage as well as a vital and continuing earth building tradition. This should be recognized at an international and national level for the tremendous value it represents to the world community.
- The study of earthen architecture has become (or is fast becoming) a discipline in its own right with an explicit terminology, a defined body of knowledge, and its own pedagogy.
- Earthen architecture embodies a tremendous amount of local knowledge and intuitive engineering that can provide useful and important indications for its continued care as well as for new building.
- Conservation efforts must strive to integrate both tangible and intangible aspects of heritage and respect the social structure in which building practices are embedded.
- Conservation initiatives must involve the local community. This is essential if efforts are to be sustainable and the heritage is to be valued and cared for in the long run.
- There are many forms and sources of knowledge. Traditional knowledge, scientific research, and professional practice all have a role to play in both the conservation and new design of earth buildings.
- Conservation and development are not antithetical but are part of a continuum. Earthen architecture is not simply a vestige of the past, but a viable component of contemporary life. This is especially true as issues of social and environmental sustainability gain increasing importance in a fragile world.
- Earthen architecture in urban centers entails particular challenges that must be addressed through integrated planning efforts and specific policy development.
- Monitoring and maintenance are essential to the survival of the earthen heritage, wherever it occurs and whoever is responsible for its care.
- Better and more creative dissemination mechanisms need to be devised to ensure that technical innovations and the results of recent research of all kinds reach those who need it.
- Similarly, traditional systems for the transmission of local knowledge should be respected and preserved.
- Training should integrate theory and practice and respect various forms of teaching and learning.
- Attention should be paid not only to the preservation of traditional building skills and practices but also to the way that such skills are learned and passed down.
- Both local efforts and international collaboration are essential to ensure that the world's extraordinary earthen heritage and the know-how that created it will survive for generations to come.

Conclusions et recommandations générales

Jeanne Marie Teutonico

Lors de chaque session de la conférence, les rapporteurs ont consigné les points essentiels et les plus importantes recommandations des présentations et discussions sur chaque thème. Ceux-ci ont été rassemblés et mis au point pour aboutir aux conclusions et recommandations générales de la conférence résumées ci-dessous.

- Le Mali offre l'un des plus extraordinaires patrimoines en terre du monde, ainsi que la permanence d'une tradition du travail de la terre. Il conviendrait de le reconnaître au niveau international, national et local en raison de l'immense valeur que cela représente pour la communauté mondiale.
- L'étude de l'architecture de terre est devenue (ou devient rapidement) une discipline à part entière, avec sa terminologie spécifique, son savoir bien défini et sa propre pédagogie.
- L'architecture de terre réunit une quantité remarquable de savoirs et d'ingénierie intuitive qui donnent d'utiles indications pour en assurer l'entretien permanent et pour envisager de nouvelles constructions.
- Les efforts de conservation doivent viser à intégrer les aspects matériels et immatériels de ce patrimoine, et à respecter la structure sociale dans laquelle s'inscrivent les pratiques de construction.
- Les initiatives de conservation doivent impliquer la population locale. Cela est essentiel pour assurer la durabilité de ces efforts et la valorisation et l'entretien à long terme de ce patrimoine.
- Il existe différentes formes et sources de savoirs. Le savoir traditionnel, la recherche scientifique et la pratique professionnelle ont tous un rôle à jouer dans la conservation comme dans la conception de constructions en terre.
- La conservation et le développement ne sont pas antinomiques mais appartiennent à un même processus continu. L'architecture de terre n'est pas seulement un vestige du passé ; c'est une composante vivante de la vie contemporaine. Cela est particulièrement vrai dans notre monde actuel fragile où la notion de durabilité en matière d'environnement et de social prend de plus en plus d'importance.
- L'architecture de terre dans les centres urbains implique certaines remises en question qu'il convient de résoudre par des efforts intégrés de planification et des politiques de développement appropriées.
- Le suivi et l'entretien sont essentiels pour le maintien du patrimoine en terre, où qu'il soit et quels que soient les responsables de son entretien.
- Il conviendrait de mettre en place des mécanismes de diffusion plus performants et plus innovants pour faire connaître les innovations techniques et les résultats de la recherche à ceux qui en ont besoin.
- Il est également important de respecter et de préserver les systèmes traditionnels de transmission des savoirs locaux.
- La formation devrait intégrer théorie et pratique et prendre en compte les diverses formes d'enseignement et d'apprentissage.

- Il convient de veiller non seulement à la préservation des techniques et pratiques de construction traditionnelles, mais aussi au mode d'apprentissage et de transmission de ces connaissances.
- Il faut s'efforcer – au plan local, ainsi que par des collaborations internationales – d'assurer le maintien de

l'extraordinaire patrimoine architectural en terre du monde, ainsi que des savoirs qu'il représente, pour les générations à venir.

Contributors

Maria de Lourdes Abad Rodas is an architect. She graduated from the State University of Cuenca, Faculty of Architecture and Urban Planning, in 1984. She attended the Second Pan-American Course on the Conservation and Management of Architectonic Historical-Archaeological Earthen Heritage in 1999 at the National Institute of Culture of Peru, organized by the Grenoble School of Architecture's International Centre for Earthen Construction (CRATerre-EAG), ICCROM, and the Getty Conservation Institute (GCI).

Yehdih O. M. Abdelhaye est maître-assistant à la Faculté des sciences de Nouakchott. Docteur de l'Université d'Orléans, il a travaillé sur les propriétés d'écoulement, d'adhésion et de rupture des milieux pâteux.

Abubaker A. Aboufayed graduated in 1990 from the department of architecture and urban planning in the College of Engineering, Al Fateh University, in Tripoli, Libya. Currently he is chief of the supervision division in the university's technical department. He has been active in architectural design and conservation.

Abdulgader Abufayed is a professor of environmental engineering at Al Fateh University, Tripoli, Libya. He received a B.S. in civil engineering in 1974, an M.S. in environmental engineering in 1976, and a Ph.D. in environmental engineering in 1984. He was the chief technical adviser and manager of the Project for the Rehabilitation of the Old City of Ghadames, Libya. He is an environmental engineering and heritage conservation consultant.

Maddalena Achenza is an architect and researcher at the University of Cagliari, Faculty of Architecture, where she has been coordinating the activities of Labterra since 1997. She is the technical coordinator of the Earthen Towns National Association, and the Italian member of the ICOMOS International Scientific Committee on Earthen Architectural Heritage. She is the author of several publications and articles on the topic of earthen and sustainable architecture.

Wilfredo Carazas Aedo est architecte, spécialiste de l'habitat et du patrimoine axé sur la problématique sismique. Depuis 1985, il réalise des projets d'architecture et de construction au Pérou. En 1994, il a rejoint le laboratoire CRATerre-ENSAG en tant que chercheur associé avec une forte implication dans la formation. Il est consultant pour des organismes internationaux en Amérique latine, Afrique et Asie centrale. Il est auteur de monographies, manuels et guides parasismiques.

Léonard Ahonon est administrateur d'actions culturelles depuis plus de 24 ans. Il est actuellement gestionnaire du site des Palais royaux d'Abomey. Il a participé à la création de l'Agence pour la conservation du patrimoine culturel, à la restauration du palais Honmê de Porto-Novo, du musée ethnographique Alexandre Sènou Adandé, du musée d'histoire de Ouidah, et des palais royaux d'Abomey. Il a contribué à l'élaboration de la loi 2007-20 portant sur la protection du patrimoine culturel et du patrimoine naturel en République du Bénin.

Yasemin Didem Aktaş is a structural engineering graduate from the Middle East Technical University. She earned her M.S. degree in archaeometry in 2006 from the same university.

After a one-year research period in Rome on archaeological restoration, she is currently a doctoral student in the restoration department. Her main fields of study are modeling of historic structures, monitoring, and structural condition assessment.

Romain Anger est ingénieur, diplômé du DSA « Architectures de Terre » du laboratoire CRA Terre-ENSAG. Il poursuit simultanément au laboratoire CRA Terre-ENSAG et au laboratoire MATEIS à l'INSA de Lyon des activités de recherche liées à l'étude des relations entre microstructures et propriétés macroscopiques du matériau terre, tout en étant également très impliqué dans les programmes de formation et de vulgarisation (« Grains de bâtisseurs »).

Gustavo Araoz is a preservation architect specializing in the management and conservation of the historic built environment and the executive director of US/ICOMOS. He has a B.Arch. from the Catholic University of America and an M.A. in Latin American studies from Georgetown University and has completed the international certificate program in architectural conservation from the Instituto Nacional de Antropología e Historia, Mexico.

Antonio Guerrero Arzaga, an architect, graduated from the National School of Architecture of the Autonomous University in Mexico City in 1977. He has worked with the National Institute of Anthropology and History (INAH) since 1987. He is the cofounder of SICRAT and TICRAT, International Seminar/Workshop for the Conservation and Restoration of Earthen Architecture.

Erica Avrami is a Ph.D. candidate at Rutgers University, where her research focuses on sustainability planning and conservation. She received her undergraduate and master's degrees in architecture and historic preservation, respectively, from Columbia University. As a former project specialist at the Getty Conservation Institute, her work involved earthen architecture, heritage planning, and the role of values in conservation.

Francesco Bandarin est architecte et urbaniste et est actuellement directeur du Centre du patrimoine mondial de l'UNESCO. Il a enseigné la conservation et la gestion du patrimoine urbain dans des universités de renommées internationales, consulté pour des organisations internationales majeures et coordonné des programmes de formation dans des villes en voie de développement. Fortement impliqué

dans la mise en application de la Convention du patrimoine mondial, il s'efforce de favoriser la mise en place de partenariats et la création d'institutions veillant à la conservation des sites du patrimoine mondial.

Norma Barbacci is currently director of programs for Latin America, Spain, and Portugal for the World Monuments Fund (WMF), where she has worked since 2001. She has a degree in architecture from Carnegie Mellon University and an M.S. in historic preservation from Columbia University, where she received a Historic Preservation Thesis award. Barbacci is a registered architect in the state of New York. Prior to joining WMF, she worked for twelve years as a preservation architect at Beyer Blinder Belle Architects and Planners.

Angelyn Bass Rivera is a principal at Conservation Associates, specializing in archaeological site management and the preservation of architectural features and finishes. Rivera worked for the National Park Service for fifteen years leading field conservation projects and worked privately performing consulting services, treatment, and field training for museums, educational organizations, and other not-for-profit organizations. She holds an M.S. in historic preservation from the University of Pennsylvania and an M.B.A. from the University of New Mexico. She is a professional associate of the American Institute for Conservation of Historic and Artistic Works (AIC).

Mahmoud Bendakir est architecte d'état, docteur de l'École pratique des hautes études, et titulaire d'un certificat d'études approfondies de l'École d'architecture de Grenoble. Depuis 1991, il dirige les travaux de restauration du site de Mari en Syrie. Au sein de l'équipe CRA Terre-ENSAG, il participe au développement de projets pour la conservation et la gestion des sites et monuments du patrimoine mondial en terre et intervient en tant qu'expert consultant auprès de l'UNESCO.

Mauro Bertagnin est professeur de technologie de l'architecture à l'université de Udine, Italie. Il est membre de CRA Terre depuis 1985 et a effectué plusieurs missions en Algérie, Maroc, Nigeria, Érythrée et Mali en tant que consultant UNESCO WHC pour la conservation de l'architecture de terre. Il enseigne en tant que professeur associé en Afrique, en Europe et aux USA (Harvard Graduate School of Design, MIT-Faculty of Architecture and Columbia University-Graduate School of Architecture, Planning and Preservation).

Allen Kenneth Birabi is a lecturer at the School of Architecture, Makerere University, Kampala, in fine arts, education, architecture, and built heritage conservation. He was a Fulbright research scholar in 2008–9. He is a member of the Uganda Artists Association, and an honorary member of the Uganda Society of Architects.

Marcial Blondet is professor of civil engineering and dean of the graduate school at the Catholic University of Peru. He obtained his Ph.D. in engineering from the University of California, Berkeley. Among his research interests are the development of low-cost solutions to mitigate the seismic risk of informal adobe masonry dwellings and the conservation of earthen monuments in seismic areas.

Alessandra Bonazza has a Ph.D. in earth sciences applied to cultural heritage and has six years of experience in inorganic materials characterization related to damage evaluation. Her recent interests include the chemistry of crusts and climate damage to building materials.

Silvia Briccoli Bati is a professor of structural mechanics at the University of Florence. She is director of the Official Laboratory of Materials and Structural Tests, where her research activity focuses on the classical themes of material and structural mechanics, in particular, theoretical and experimental research on the behavior of nonstandard materials, with reference to the preservation of historic heritage.

Peter Brimblecombe is a professor of atmospheric sciences at the University of East Anglia, with a particular interest in the effects of air pollution and climate on cultural heritage.

Nick Brooks is a Tyndall Centre Visiting Fellow. His primary interests are long-term human-environment interaction and human responses to severe and abrupt climatic and environmental change and contemporary vulnerability and adaptation to climate change in the Afro-Asiatic desert belt.

Claudia Cancino is a licensed architect and architectural conservator trained in Peru, Italy, and the United States. She was a principal professor at the School of Architecture at the Universidad Peruana de Ciencias Aplicadas in Lima and has taught several international conservation courses. She is a project specialist at the Getty Conservation Institute and manages the Earthen Architecture Initiative.

Carolina Castellanos est consultante auprès d'institutions telles que le Getty Conservation Institute, le Centre du patrimoine mondial – UNESCO, ICCROM et ICOMOS International, en matière de conservation du patrimoine culturel et plus particulièrement de gestion des sites archéologiques. Elle collabore à la préparation et au développement d'ateliers et de cours régionaux pour la gestion et la conservation de sites archéologiques.

Cecilia Cerron is a graduate student with a bachelor's degree from the Catholic University of Peru.

Chiara Cirinnà is an architect, with a Ph.D. in the technology of architecture. She is experienced in the cultural heritage sector and involved in projects at a national and European level. She coordinates projects on digital preservation, knowledge management, and semantic Web applications. She is involved in research activities with the University of Florence, on Web-based systems for scientific data collection and management.

Lassana Cissé est anthropologue et gestionnaire de site au Mali. Depuis 1994, il est le chef de la Mission Culturelle chargé de la gestion du site des Falaises de Bandiagara (pays dogon), inscrit sur la Liste du patrimoine mondial en 1989. Auteur de plusieurs publications et rapports sur le patrimoine et le tourisme, il a participé à plusieurs rencontres sur la préservation et la mise en valeur de l'architecture de terre. M. Cissé était membre du comité scientifique préparatoire de la conférence Terra 2008.

James Conlon, former director of the Visual Media Center at Columbia University, was a new-media designer and conservator focusing on pedagogical design and heritage interpretation. While at Columbia, he began to explore the potential of new media to facilitate the interpretation and conservation of the built environment and extended this project to develop teaching tools for students and educators around the globe. Sadly, James Conlon passed away in 2009. He will be greatly missed by his colleagues in the profession; his contributions to the field will long be valued.

Louise Cooke is an archaeologist and conservator who has worked on a wide variety of archaeological and conservation projects, both in the United Kingdom and abroad. She currently works freelance in addition to teaching through the

Open University. The work discussed in this paper was undertaken while she was researching her doctorate at the Institute of Archaeology, University College London, specializing in the archaeology and conservation of earthen architecture.

Mariana Correia is director and head of research at ESG/Gallaecia University, Portugal. She has a master's degree in architecture from FAUTL, Portugal, and a DPEA-Terre diploma from CRATerre, France. Correia is a Ph.D. researcher at Oxford Brookes University, U.K.; a member of ICOMOS-ISCEAH and PROTERRA; administrator of the Convent of Orada Foundation for heritage conservation; and coeditor of six books on earthen architecture.

Aníbal Costa is a professor in the civil engineering department of the University of Aveiro. His main research interests are the evaluation, rehabilitation, and strengthening of existing construction and seismic engineering.

Edward Crocker is president of Crocker Ltd. and has an extensive background in archaeology, construction, groundwater development, and the preservation of historic earthen buildings. He was founding technical director of Cornerstones Community Partnerships, a nonprofit organization that restores historic structures in rural Hispanic villages and Indian pueblos throughout the southwestern U.S. He is a graduate of the CRATerre ICCROM PAT 90 course and a fellow of US/ICOMOS.

Bhawna Dandona is a graduate in historic preservation from the University of Pennsylvania and has a bachelor's degree in architecture from India. She has undertaken research and field projects focusing on conservation in India. After completing her thesis on the repair of structural cracks, she assisted the Getty Conservation Institute's Earthen Architecture Initiative in the production of a bibliography on grouting repairs for structural cracks in earthen buildings in seismic areas.

Michel Dayre est géologue, ingénieur de l'École nationale supérieure de géologie de Nancy, docteur en mécanique des sols de l'université de Grenoble et spécialisé en génie civil, géotechnique, hydrogéologie et matériaux de construction. Enseignant, maître de conférences à l'université Joseph Fourier de Grenoble et professeur à l'École d'architecture de Grenoble, il est aujourd'hui conseiller scientifique auprès de CRATerre-ENSAG.

Manijeh Hadian Dehkordi is a conservation scientist. He received his M.A. in the conservation of cultural property from the Islamic Azad University, Tehran, in 2003 and his B.S. in chemistry from the Shahid Beheshti University, Tehran, in 1992. He is currently head of the research group on materials science and historic technologies at the Research Centre for the Conservation of Cultural Relics and has fifteen years of research experience in identification and conservation of museum objects. He has worked on the conservation of the Chogha Zanbil, Arge-Bam, and Konar Sandal historical and archaeological sites of Iran.

Mamadi Dembelé est directeur de recherche (spécialité archéologie) et directeur adjoint de l'Institut des sciences humaines du Mali. Il est titulaire d'un doctorat de 3^e cycle de l'École des hautes études en sciences sociale (EHESS) de Paris obtenu en 1986. Depuis cinq ans ses recherches portent sur deux programmes : les fouilles archéologiques sur le site de la mosquée de Kankou Moussa à Gao et les recherches de sauvetage sur les sites culturels menacés (zone de Bamako et Boucle du Baoulé).

Françoise Descamps est une architecte diplômée en conservation des monuments et sites. Après avoir travaillé sur des sites du patrimoine mondial, elle a rejoint le Getty Conservation Institute en 1997. Elle occupe la position de Senior Project Specialist, responsable des projets de conservation, préservation et gestion de sites archéologiques et de centres historiques.

Nayondjoua Djanguenane est titulaire d'une licence es-lettres et diplômé du Centre régional d'action culturelle. Il a été au Togo, directeur des musées, sites et monuments, directeur du patrimoine culturel et conseiller technique au patrimoine, puis, assistant du directeur de l'EPA au Bénin. Il travaille actuellement au ministère de la communication et de la culture du Togo. Il a conduit le dossier de nomination du Koutammakou, inscrit sur la Liste du patrimoine mondial depuis 2004.

Patrice Doat est architecte, professeur et membre fondateur du laboratoire CRATerre-ENSAG dont il a été le président pendant deux décennies. Il a initié de nombreux projets dont l'habitat social de Mayotte, où environ 18 000 logements en terre ont été construits. Il est président des Grands Ateliers, un ensemble d'équipements qui permet l'expérimentation

architecturale à l'échelle 1/1 et où « Grains de bâtisseurs® » est déployé annuellement.

Alexandre Douline est ingénieur et chercheur au CRATerre-ENSAG, à Grenoble.

Dominic M. Dowling developed the QuakeSafe Adobe reinforcement system as part of his Ph.D. research at the University of Technology, Sydney (UTS), Australia. His expertise is in developing, promoting, and implementing solutions that are sustainable and appropriate in the local context. He has been contracted by UN-Habitat, the Earthquake Engineering Research Institute (EERI), GE Money Wizard India, Aga Khan Development Network, and RiskRED, among other institutions.

Afshin Ebrahimi is a faculty member of the Conservation and Restoration of Historical and Cultural Monuments Research Center related to Iranian cultural heritage tourism and handicraft organization and manager of the Firuzabad base in Fars province. He holds an M.A. in conservation and restoration of historical artifacts from the Isfahan Art University. He has participated in the Chogha Zanbil world heritage project for more than nine years and in the Parsa-Pasargadae research foundation from 1998 until the present. He has participated in various regional educational earthen architecture workshops.

Lazare Eloundou Assomo est architecte et urbaniste. Il travaille comme spécialiste du programme au Centre du patrimoine mondial de l'UNESCO et coordonne le programme du patrimoine mondial sur l'architecture de terre. Sa vocation pour renforcer les cultures constructives africaines et en terre l'a amené à coordonner plusieurs projets de construction et de conservation en Afrique et en France et à co-gérer le programme Africa 2009 pour la conservation des sites culturels africains.

Yvan Espinoza is an undergraduate student with a bachelor's degree from the Catholic University of Peru.

Stephen J. Farneth is a principal architect in the Architectural Resources Group, San Francisco, California. He has over thirty years of experience in the design of seismic strengthening systems for historic structures, including many earthen structures throughout California. He is also actively engaged in international conservation and serves as the vice chairman of the Board of Trustees of US/ICOMOS (U.S. Committee of the International Council on Monuments and Sites).

Maria Fernandes is an architect (FA/UT Lisbon, 1986), a master in the rehabilitation of the architectonic and landscape

heritage (UÉvora, 1998), a Ph.D. student in architecture (FCT/UCoimbra), and a researcher at the Center for Archaeological Studies of Coimbra and Porto Universities (CEAUCP).

Amila Ferron is an associate project specialist at the Getty Conservation Institute working on the Earthen Architecture Initiative. She has worked previously at the University of Pennsylvania's Architectural Conservation Laboratory, managing a project at Mesa Verde National Park. She holds an Advanced Certificate in architectural conservation and an M.S. in historic preservation from the University of Pennsylvania.

Enrico Fodde, Ph.D., is a lecturer in the Department of Architecture and Civil Engineering, University of Bath. Since 2002 he has worked as consultant for the Division of Cultural Heritage (UNESCO Paris), the World Heritage Centre (UNESCO Paris), and the Abu Dhabi Authority for Culture and Heritage (UAE).

Laetitia Fontaine est ingénieur matériaux, diplômée du DSA « Architectures de Terre » du laboratoire CRATerre-ENSAG. Elle poursuit simultanément au laboratoire CRATerre-ENSAG et au laboratoire MATEIS à l'INSA de Lyon des activités de recherche liées à l'étude des relations entre microstructures et propriétés macroscopiques du matériau terre, tout en étant également très impliquée dans les programmes de formation et de vulgarisation (« Grains de bâtisseurs® »).

Renee Friedman is director of the international archaeological expedition to the important Predynastic and Early Dynastic site of Hierakonpolis, Egypt, where she has been working since 1983. She received her Ph.D. from the University of California, Berkeley, in Egyptian archaeology and is now based in the Department of Ancient Egypt and Sudan at the British Museum, London, where she is the Heagy Research Curator of Early Egypt.

Yukiyasu Fujii, Ph.D., is a researcher at the Fukada Geological Institute, Tokyo, Japan, where he conducts geological and geographical surveying by employing both fieldwork and photogrammetry techniques.

David Gandreau est archéologue et chercheur associé au laboratoire CRATerre-ENSAG. Il travaille sur les stratégies et les techniques de coordination entre fouilles archéologiques et conservation des vestiges en terre. Cette recherche de post-

diplôme en archéologie (DEA, Université Lyon II) a été engagée dans le cadre de la formation de troisième cycle à l'École nationale d'architecture de Grenoble (DPEA-terre, CRATerre). Les résultats sont mis en application depuis lors sur des projets de conservation de sites archéologiques en Iran, en Asie centrale et en Afrique.

Philippe Garnier est architecte expert au CRATerre-ENSAG depuis 1991. Il enseigne dans le post-diplôme DSA-Terre : « architecture de terre : cultures constructives et développement durable » et le Master « Architecture et cultures constructives » à l'École nationale supérieure d'architecture de Grenoble. Depuis 2001, il est responsable du programme « Etablissements Humains ». Il a développé une expertise dans le domaine des risques sismiques en relation avec l'architecture de terre, à travers des interventions à Bam, au Maroc, en Indonésie et plus récemment au Pérou.

David Gelard est docteur de l'Institut national polytechnique de Grenoble. Ses travaux de thèse ont porté sur la cohésion du matériau terre. Il est co-fondateur d'une entreprise de travaux de maintenance du patrimoine bâti.

Daniela Geyer is a freelance conservator of architectural surfaces. She graduated in 2007 from the University of Applied Sciences Potsdam with a specialization in the conservation of wall paintings. She has participated in various conservation projects in Germany and abroad, including in the U.A.E. and Hue, Vietnam, where she worked on the wall paintings in the An Dinh Palace.

Pietro M. Apollonj Ghatti est architecte et urbaniste, titulaire d'un doctorat en architecture (Université de Rome). Après un engagement dans une carrière académique, il a poursuivi son activité en profession libérale, avec un intérêt particulier pour la planification urbaine et territoriale. Son activité se déroule en Italie et à l'étranger (Cameroun, onze ans à Yaoundé, République Dominicaine). Depuis 2002, il est consultant UNESCO WHC et a effectué plusieurs missions au Mali, en liaison avec la Mission Culturelle de Tombouctou.

Olivier Grossein est doctorant au Laboratoire d'étude des transferts en hydrologie et environnement. Il est issu de l'École normale supérieure de Cachan où il a reçu une formation de Sciences de la Terre. Il s'est orienté vers l'étude et la modélisation des transferts en milieux poreux naturels.

Carlota M. Grossi is a geologist. Currently, she is a senior research associate at the University of East Anglia. Her main interests are in building stone decay and conservation, most recently focusing on damage by salts and climate change, in addition to undertaking studies of aesthetic damage and the alteration of color of buildings.

Luis Fernando Guerrero Baca has been a professor and researcher at the Metropolitan Autonomous University (UAM) in Mexico since 1987. He is a graduate of UAM-Azcapotzalco, Mexico, the master's program in architectural conservation from the National Institute of Anthropology and History (INAH), Mexico. He holds a doctorate in design, with a specialty in conservation and restoration, from UAM-Azcapotzalco.

Mary Hardy practices conservation architecture with Siegel & Strain Architects in Northern California, focusing on historic preservation and sustainable design. From 2001 to 2007 she was a senior project specialist at the Getty Conservation Institute, where she managed Project TERRA and the Earthen Architecture Initiative. She served on the executive committee of ICOMOS/ISCEAH (2005–8) and currently serves on the board of the Western Chapter of the Association for Preservation Technology (WCAPT). Hardy holds an M.Arch. degree from the University of California, Berkeley, and an M.S. in historic preservation from Columbia University. She was a member of the scientific committee for Terra 2008.

Ian Harris is a senior researcher at the Climate Research Unit. His special interests are dendroclimatology, climate scenario development, data manipulation, and visualization and programming.

Andrew Heath (B.Sc., M.S., Ph.D.) is a geotechnical engineer and has been a lecturer in the Department of Architecture and Civil Engineering at the University of Bath since 2001. His research interests include earthen structures, seismic risk assessment, constitutive modeling, and retaining structures.

Hugo Houben est ingénieur physicien et membre fondateur du laboratoire CRATerre-ENSAG. Il est spécialisé dans la construction en terre depuis 1972. Il a participé à de très nombreux projets de construction et à la mise en place de formations académiques et professionnelles. Il est co-auteur de plusieurs livres de référence. Depuis 2000, il est responsable des programmes de recherche fondamentale et appliquée.

John Hurd is the international conservation director for the Global Heritage Fund, president of the ICOMOS International Scientific Committee for Earthen Architectural Heritage (ISCEAH), and president of the ICOMOS Advisory Committee (ex-officio member of the ICOMOS International Executive Committee). He is an honorary visiting fellow in the Department of Archaeology, University of York, U.K. Hurd has been working in conservation since 1978. He has many publications and papers and lectures widely.

Jason Ingham is an associate professor in the Department of Civil and Environmental Engineering at the University of Auckland. He has worked on revising the New Zealand concrete and concrete masonry design standards. Currently he is leading major research projects investigating the seismic retrofit of unreinforced masonry buildings and fiber-reinforced rammed earth construction.

Mohammad Shariful Islam is an associate professor in the Department of Civil Engineering, Bangladesh University of Engineering and Technology (BUET). He obtained his M.Sc. degree from BUET and his Ph.D. from Saitama University. He was awarded the Dr. Rashid Gold Medal and the Sharfuddin Gold Medal by BUET. He also received an Excellent Presentation Award and a Best Paper Award from JSCE and TGS, respectively.

Carlos Iwaki is a civil engineer and obtained his professional diploma in civil engineering at the Catholic University of Peru in 2007. He worked as a research assistant on the project Repair of Historical Adobe Buildings through Injection of Mud-Based Grouts. He is currently pursuing graduate studies in Europe on the structural analysis of historical buildings.

Kazuyoshi Iwashita is a professor in the Department of Civil and Environmental Engineering, Saitama University, Japan. He obtained his M.Eng. and D.Eng. degrees from the University of Tokyo, Japan. Iwashita received the Award for Young Researchers from the Japan Society of Civil Engineers in 1992.

Richard L. Jaeschke is a freelance conservator familiar with a wide range of objects and materials. He has a degree in anthropology from the University of Wisconsin, Milwaukee, and a degree in conservation from the Institute of Archaeology at University College London and has studied toward a degree in Egyptology at the Oriental Institute, Chicago. He has worked

with many museums on a variety of archaeological and historical material but specializes in ancient Egyptian material of all kinds.

Pamela Jerome is a registered architect. She is partner-in-charge of preservation with WASA/Studio A, a New York City-based architecture and engineering firm, and an adjunct associate professor at Columbia University's Graduate School of Architecture, Planning and Preservation. Jerome is vice president of ICOMOS's International Scientific Committee on Earthen Architectural Heritage (ISCEAH) and an elected coordinator of ICOMOS's Scientific Council. Her expertise is in masonry conservation and waterproofing. She has consulted on cultural property conservation in the United States, the Mediterranean and Black Sea regions, and the Middle East.

Thierry Joffroy est architecte, spécialisé dans la construction en terre. Après avoir longuement travaillé sur des projets de développement (habitat économique, lutte contre la pauvreté), il s'est spécialisé dans la conservation du patrimoine avec un intérêt particulier pour le lien avec les aspects liés au développement. Il a travaillé avec de nombreux partenaires dans plus de 40 pays. Depuis 2003, il est le président de CRATerre, le centre international pour la construction en terre. Il était membre du comité scientifique pour Terra 2008.

Yves Jorand est enseignant chercheur au laboratoire MATEIS à l'INSA de Lyon. Ses compétences couvrent l'élaboration et la mise en forme des matériaux céramiques et granulaires, en lien avec leur microstructure et leurs propriétés physiques et mécaniques.

Om Prakash Joshi is a specialist in the sociology of art. He did his postgraduate study in sociology in 1960 and received his Ph.D. in sociology of art in 1972. His primary interest is in earthen houses and toys. He is the author of the books *Art and Aesthetics in Tribes of Gujarat* and *Tribal Architecture*.

Barthélemy Kaboré est historien et géographe. Après avoir exercé comme professeur, il a rejoint la Direction du patrimoine culturel du Burkina Faso où il s'est vu confier la gestion des sites et des monuments de l'architecture traditionnelle burkinabé. Sa connaissance du terrain et ses formations dans le cadre du programme Africa 2009 l'ont amené à se spécialiser dans l'inventaire des sites puis dans la mise en œuvre de projets de conservation et mise en valeur du patrimoine national (Kokologho, Tiébélé).

Maria Isabel Kanan is an architect at the Brazilian Institute of Cultural Heritage. She studied conservation at CRATerre, ICCROM, IoAAS, and Bournemouth University. Kanan is involved in training, research, and technical advice on lime and earth technologies. She was a guest scholar at the Getty Conservation Institute and a member of ICOMOS ISCEAH.

Mohsen G. Kashi is a civil engineer and managing director of Soil Rock & Structures Consulting Co. He has collaborated on the project to conserve the historic Citadel of Bam. Kashi has more than eight years of construction field experience in hydraulic structures and seventeen years of broad-based experience in engineering consulting, construction, teaching, and research. He holds a Ph.D. and an M.S. in civil engineering from Virginia Polytechnic Institute, Blacksburg; and a B.S. in civil engineering from Florida International University, Miami.

Rowland Keable is the director of a consultancy firm in London and has been involved in planning, building, consulting, teaching, and researching rammed earth structures since 1985. Since 1991 the firm has enabled building some of the largest rammed earth structures in western Europe in the past hundred years. The firm's work in southern Africa has improved the prospects of a fourteen-nation bloc of countries to have earth building standards for the first time. The goal of low-carbon construction is a major impetus to Keable's work.

Jean-Paul Laurent est chercheur au Centre national de la recherche scientifique et travaille au Laboratoire de thermodynamique et hydrodynamique de l'environnement. Il a notamment travaillé sur la conductivité thermique de la terre et développe actuellement des systèmes de monitoring.

Mike Lawrence (M.A., M.Sc., Ph.D., FCMA) is currently a postdoctoral research officer in the BRE Centre for Innovative Construction Materials at the University of Bath. His Ph.D. thesis work investigated techniques for mapping carbonation of air-lime mortars and plasters. His current research work includes unfired clay masonry and prefabricated straw bale construction.

Youssef Madjidzadeh is an archaeologist. He is head of the archaeological team in the Halil roud region in southeastern Iran.

Hossam Mahdy is a freelance conservation architect. He received his Ph.D. in the conservation of built heritage from the University of Glasgow, an M.Sc. in the conservation of historic buildings and towns from the University of Leuven, and a B.Sc. in architectural engineering from Ain Shams University. He is currently involved in conservation and training projects in Egypt and Yemen.

Trevor H. J. Marchand is a trained architect (McGill University), an ESRC Fellow, and a senior lecturer in anthropology at SOAS, London. His research focuses on building-craft knowledge and apprenticeship. He is the author of *Minaret Building and Apprenticeship in Yemen* (2001) and *The Masons of Djenné* (2009) and coproducer of the documentary film *Future of Mud* (2007).

Jean-Claude Margueron, est docteur ès-lettres, ancien pensionnaire de l'Institut français d'archéologie de Beyrouth, et pendant 20 ans a enseigné l'archéologie orientale à l'Université de Strasbourg, avant de devenir directeur d'études à l'École pratique des hautes études. Il a débuté sa carrière d'archéologue de terrain en 1954 en Syrie, sur le site de Mari, dont il a assumé la direction de 1979 à 2005.

Frank Matero is professor of architecture and chair of the graduate program in historic preservation at the School of Design and director and founder of the Architectural Conservation Laboratory at the University of Pennsylvania. He is also a member of the Graduate Group in the Department of Art History and research associate of the University Museum of Archaeology and Anthropology.

Saverio Mecca is an architect and professor of building production at the University of Florence. He specializes in both building process management and vernacular architecture in the Mediterranean region. Since 2007 he has been director of the Research Center on Innovation and Local and Indigenous Knowledge Systems at the University of Florence, INN-LINK-S, whose aim is to investigate local and traditional knowledge systems through an interdisciplinary approach.

Eskandar Mokhtari is currently the director of recovery of Bam's Cultural Heritage Project in Iran and has extensive experience in the conservation and restoration of historic monuments. He holds a graduate degree in archaeology and art history, an M.A. in restoration and rehabilitation of historical

buildings and fabrics, and a Ph.D. in art research. He served as the deputy director for Tehran heritage for fifteen years.

Olivier Moles est ingénieur, rattaché depuis 1995 au laboratoire CRATerre-ENSAG où il intervient en tant qu'enseignant et chercheur associé. Il a participé à initier, suivre et évaluer des projets dans plus de 30 pays, sous l'égide de différentes organisations (UNESCO, UNIDO, FAO, UNDP, UN Habitat, CDE, MISEREOR, CARITAS).

Kathya Morales is a civil engineer and obtained her professional diploma in civil engineering at the Catholic University of Peru in 2007. She worked as a research assistant on the project Repair of Historical Adobe Buildings through Injection of Mud-Based Grouts. She is currently pursuing graduate studies in Europe on the structural analysis of historical buildings.

Ricardo Morales Gamarra is the conservator and director of the Huaca de la Luna Archaeological Project and professor at the Faculty of Social Sciences in the National University of Trujillo, Peru. He holds a bachelor's degree in history and geography and a master's degree in biological sciences, specializing in environmental management, from the School of Postgraduate Studies, National University of Trujillo. He is the recipient of the certificate of Exceptional Achievement, World Monuments Fund, for implementation of the Emergency Project Los Pinchudos in 2000 (2004) and the Fourth Queen Sofia International Prize in Conservation of Cultural Heritage, Spain (2005).

Sébastien Moriset est architecte, chercheur associé au laboratoire CRATerre-ENSAG depuis 1993. Sébastien a travaillé sur 33 projets dans 26 pays d'Afrique et d'Asie centrale pour développer des stratégies de conservation, des plans de gestion et des propositions d'inscriptions de site sur la Liste du patrimoine mondial. Cette expérience de terrain est retransmise dans de nombreuses formations, en France et à l'étranger.

Hugh Morris is a senior lecturer in the Department of Civil and Environmental Engineering at the University of Auckland. He was on the committee that wrote the New Zealand Earth Building Standards and supervised a number of student research projects on adobe and rammed earth. He writes for the Earth Building Association of New Zealand and also researches timber design.

Tom Morton is principal architect with Arc, a private architectural practice specializing in earthen construction through conservation, research, and new-build projects. He is the founding secretary of Earth Building UK, a national association whose aims are to promote the conservation, understanding, and development of earth construction in the United Kingdom. His most recent publication is *Earth Masonry: Design and Construction Guidelines*.

Salima Naji est architecte DPLG (Paris-la-Villette) et docteur en anthropologie (École des hautes études en sciences sociales, Paris) et est auteur de plusieurs ouvrages de référence sur le patrimoine marocain. Elle exerce au Maroc notamment dans la réhabilitation des procédés traditionnels. Elle a reçu le prix « jeunes architectes » de la Fondation EDF (2004).

Barnabas Nawangwe is a registered architect and serves as a consulting architect in Uganda and beyond. He holds Ph.D. (Arch.) and M.Sc. (Arch.) degrees from the Kiev Engineering Institute, Ukraine, and has been responsible for various rehabilitation projects of Makerere University in the past decade. Nawangwe is also former head of the Department of Architecture and current dean of the Faculty of Technology at Makerere University, Uganda. He is past president of the Uganda Society of Architects.

Mahmoud Nejati is a civil engineer and holds a Ph.D. in earthquake engineering from Kassel University, Germany. He has had more than fourteen years of experience in the field of structural and earthquake engineering and masonry structures in Iran and Germany. He has served as the deputy for research and recovery of Bam's Cultural Heritage Project since 2006, coordinating various activities with international and national institutions.

Célia Neves is a materials and construction systems researcher, responsible for laboratory research on construction materials. For the past fifteen years she has conducted research on the use of cement-soil for building walls and has always been dedicated to the transfer of knowledge. She was the Brazilian representative of the HABITERRA thematic network and was later invited to coordinate the PROTERRA network.

N. A. Nwankwor (B.Sc., M.Sc., Ph.D.) is a university lecturer in building construction technology and a research fellow in building construction technology with a focus on technology for optimization of local building materials for quality low-cost

housing at the Department of Technology Education, Federal University of Technology, Yola, Adamawa State, Nigeria.

Ishanlosen Odiava is an architect and lecturer at the Abubakar Tafawa Balewa University, Bauchi, Nigeria. She has been involved in heritage conservation activities in her country and at the continental level and is currently carrying out doctoral studies on the conservation of African architecture at the Université de Paris I, France.

Julias Juma Ogega is a heritage researcher and educator with the Directorate of Regional Museums, Sites, and Monuments at the National Museums of Kenya (NMK). He designs and executes museum education programs for various museum audiences, especially schoolchildren. As explained in the mission statement of the NMK, these programs aim to “promote peoples’ understanding and sustainable use of natural and cultural heritage by enhancing access to museum collections, research and exhibition.”

Christian Olagnon est ingénieur et professeur à l’INSA de Lyon dont il est membre du conseil scientifique, chercheur au laboratoire MATEIS et directeur du département « Science et génie des matériaux ». Ses compétences couvrent la mécanique des matériaux fragiles et le comportement des matériaux granulaires. Il est responsable de la collaboration avec l’industrie et les universités étrangères ainsi que du suivi des programmes de coopération européenne.

Laurent Oxarango est maître de conférences à l’Université Joseph Fourier et chercheur au laboratoire LTHE. Il est spécialisé en modélisation et simulation des transferts en milieu poreux. Investi dans des actions de recherches sur les procédés industriels (filtration, procédés thermiques), il s’est orienté depuis 2006 vers l’étude des milieux poreux en lien avec le milieu naturel (construction, stockage des déchets).

Gaetano Palumbo is area representative for Africa, the Middle East, and Central Asia at the World Monuments Fund and honorary senior lecturer at the Institute of Archaeology of University College London. He has taught at University College London and worked at the Getty Conservation Institute. Palumbo holds a Ph.D. in archaeology from the University of Rome and has conducted archaeological and conservation projects in several countries.

Honório Nicholls Pereira is an architect and urban planner (EAUFGM, 1997) with a specialization in integrated territorial and urban conservation (CECI/UFPE, 2004) and conservation and restoration of monuments and historic sites (CEAB/FAUFBA, 2004). He is now obtaining his M.Arch. in the field of urban history (PPGAU/FAUFBA). He has been the director of SANETEC since 1998, where he has been working on architectural conservation projects.

Francesca Piqué is a conservator and earned a diploma in wall painting conservation and an M.S. from the Courtauld Institute of Art, University of London, after graduating in chemistry from the University of Florence. She worked at the Getty Conservation Institute for over twelve years on archaeological, mosaic, and wall painting conservation projects worldwide and continues to work as a consultant. She has published numerous articles and two books on wall painting and mosaic conservation and teaches in various institutions.

Lahoucine Rah, Lahoucine Rah, diplômé d’un DESA de droit public, est directeur régional Guelmim-Tata-Assa-Smara pour l’Agence de Développement des Provinces du Sud.

Leslie Rainer is a wall painting conservator and senior project specialist at the Getty Conservation Institute. She received an Independent Master’s Degree from Antioch University and a certificate from ICCROM’s Mural Paintings Conservation Course. She has worked with museums, regional conservation centers, and international organizations on projects in various parts of the world. She has a particular interest in the conservation of decorated surfaces on earthen architecture. She is a former chair of the US/ICOMOS Earthen Architecture Committee and led the GCI team in the organization of Terra 2008.

Bakonirina Rakotomamonjy est architecte. Après avoir exercé durant cinq années pour des cabinets privés, elle a orienté sa carrière vers des actions plus sensibles aux contextes et cultures locales en se spécialisant dans l’architecture en terre au Centre international pour la construction en terre (CRATERRE-ENSAG). Depuis 2002, elle contribue à la conservation du patrimoine culturel immobilier en Afrique sub-saharienne, à travers le programme Africa 2009, pour lequel elle coordonne et met en œuvre plusieurs projets.

Amer Rghei is professor of architecture and urban planning at Al Ain University, United Arab Emirates. He graduated in the

same field from Al-Fateh University in 1982. He received his M.S. degree from McGill University, Canada, in 1987 and his Ph.D. from the University of Waterloo, Canada, in 1992. Rghei is currently active in the fields of conservation of architectural heritage and vernacular architecture.

Luisa Rovero is an assistant professor of structural mechanics at the University of Florence, Italy. She graduated in architecture in 1991 and received a Ph.D. in the history of sciences and constructive techniques from the University of Florence. Her research activity is focused on the mechanical behavior of masonry and earthen structures and consolidation techniques for historic buildings.

Cristina Sabbioni is currently research director at the ISAC Bologna. Her primary interest is damage to cultural heritage from atmospheric pollution. She has been chairperson of the Expert Advisory Group "The City of Tomorrow and Cultural Heritage" within the fifth EU FP and is professor of environmental physics and climate and cultural heritage at the University of Bologna.

Klessigué Sanogo est professeur, directeur national du patrimoine culturel auprès du Ministère de la Culture du Mali. Il est expert de la gestion du patrimoine et de la tradition africaine. Il participé activement au programme Africa 2009 et dans l'organisation de Terra 2008.

Ali Ould Sidi est historien géographe, titulaire d'une maîtrise de l'ENS de Bamako et d'un master en géographie culturelle du Western Illinois University. Il a été chercheur au Centre Ahmed Baba de Tombouctou de 1979 à 1992 et est chef de la Mission Culturelle de Tombouctou depuis 1993, ainsi que président de la Délégation spéciale - commune urbaine de Tombouctou depuis 1994. Il est auteur de plusieurs articles sur l'histoire et le patrimoine de Tombouctou.

Dora Silveira is a Ph.D. candidate in the civil engineering department of the University of Aveiro, Portugal. Her main investigation interests are the evaluation, conservation, and rehabilitation of existing construction, especially traditional adobe buildings.

Constance S. Silver is the president of Preservar, Inc., a firm that plans and implements conservation projects for historic architecture, mural paintings, and rock art. She has graduate degrees in fine arts conservation and architectural conserva-

tion and has specialized in the conservation of mud-based murals and architectural decoration. She has published extensively in this area of research.

Stefan Simon is director of the Rathgen Research Laboratory at the National Museum in Berlin, Germany. He headed the building materials section at the Getty Conservation Institute from 2001 to 2005. He has taught conservation science at Munich Technical University since 1998 and founded the private laboratory KDC Konservierung und Denkmalpflege Consult in 1993. Trained as a chemist, he specializes in material deterioration diagnostics, microanalytics, nondestructive testing, physico-chemical analysis, and climatology.

Ashton Sinamai is a Zimbabwean archaeologist who has vast experience in heritage management in southern Africa. He has worked for the National Museums and Monuments of Zimbabwe (1994–2004) and is currently a lecturer in archaeology and heritage management at the Midlands State University. He has worked with ICCROM and Africa 2009 in heritage management projects in southern and eastern Africa. He has published several papers on both archaeology and heritage management.

Francesco Siravo is an Italian architect specializing in town planning and historic preservation. He received his degree from the University of Rome, La Sapienza, and specialized in historic preservation at the College of Europe, Bruges, and Columbia University, New York. Since 1991 he has worked for the Aga Khan Trust for Culture, with projects in Cairo, Lahore, Mopti, Mostar, Samarkand, and Zanzibar.

Mirta Eufemia Sosa est professeur et chercheur à la Faculté d'architecture et d'urbanisme de Tucumán en Argentine. Elle est diplômée du DPEA Architecture de terre délivré par CRATerre-EAG. Membre fondateur du CRIATIC, elle participe aux projets de recherche CIUNT et ANPCyT dans les thématiques relatives aux technologies pour l'habitat, le profit énergétique et le développement productif dans les secteurs ruraux de Tucumán et du nord-ouest argentin.

Mohammad Hassan Talebian is an architect. He is a member of ICOMOS Iran and of the Bam Strategic Committee. He received a Ph.D. in architecture from Tehran University and has worked for over fifteen years in cultural heritage, restoration, and management, especially at world heritage sites. At present he is the technical supervisor of Iranian cultural heritage, direc-

tor of ICHO of Fars province, Choghazanbil, and Bam earthen World Heritage Sites, as well as Persepolis and Passargadae. He is active in the restoration of Iranian earthen architecture.

Koffi Tizie Bi est chargé du suivi des travaux de restauration à la Direction du patrimoine culturel ivoirien, rattaché au Ministère de la culture et de la francophonie. Titulaire d'un diplôme d'Étude supérieures spécialisée de l'action culturelle (D.E.S.S.A.C), il a consacré son mémoire de fin d'études à la problématique de l'architecture de terre en Côte d'Ivoire. Ses domaines de compétences sont l'inventaire et la conservation des biens culturels immobiliers et l'élaboration de projets et dossiers techniques sur les sites et monuments.

E. Leroy Tolles is principal of ELT & Associates, an engineering firm that specializes in the earthquake design and retrofit of all types of earthen buildings. He received a Ph.D. in structural engineering in 1989 from Stanford University, where he conducted shake table tests on models of rural adobe houses. Subsequently he was appointed principal investigator for the multiyear, multidisciplinary Getty Seismic Adobe Project of the Getty Conservation Institute.

Ugo Tonietti is an architect and associate professor of structural mechanics at the University of Florence. His current research activity focuses on mechanical behavior of masonry structures and consolidation techniques for historical buildings, with a special interest in seismic problems of masonry constructions. As an architect, he has studied and designed structural rehabilitation projects for historical heritage.

Daniel Torrealva is a professor in the department of civil engineering at the Catholic University of Peru. He is experienced in the field of experimental seismic resistance of earthen buildings and innovative strengthening techniques. Torrealva has been a visiting scholar at the Getty Conservation Institute and is a current member of the International Scientific Committee on Earthen Architectural Heritage, with field experience in the structural restoration of historic masonry buildings.

Ahmet Türer is currently assistant professor at the METU civil engineering department, from which he received his undergraduate degree. After working in steel design and project management positions for two years, he completed M.S. and Ph.D. degrees in the civil engineering department at the University of Cincinnati, Ohio. His main research fields are SHM, nondestructive testing, condition assessment, and strengthening.

Francisco Uviña Contreras is the architectural/technical manager of Cornerstones Community Partnerships, an organization that he joined in 1994 to assist with field assessments and the documentation of historic buildings. He received a B.A. degree in architecture, minoring in art history, from the University of New Mexico and is currently completing his master's degree there. He is coauthor of Cornerstones' *Adobe Architecture Conservation Handbook*.

Henri Van Damme est professeur à l'École supérieure de physique et chimie industrielles de Paris depuis 1999. Il s'intéresse particulièrement à l'architecture de terre et aux matériaux innovants. Ses recherches portent sur les géomatériaux et les polymères et concernent principalement la construction et la conservation. Son approche est basée sur la physique de la matière dispersée et la physico-chimie des interfaces. Une partie importante de ses travaux récents concerne la cohésion de matériaux granulaires et leur interaction avec l'eau.

Chris J. van Vuuren is an associate professor in the Department of Anthropology and Archaeology and director of the African Centre for Arts, Culture, and Heritage Studies (ACACHS) at the University of South Africa. He studied at the University of Pretoria, where he obtained an M.A. and a D.Phil. in anthropology. He specializes in oral tradition studies and Ndebele architecture and ritual and is involved in the heritage industry in southern Africa. He was a member of the scientific committee for Terra 2008.

Julio Vargas Neumann is a consultant to the president of the Catholic University, Peru. Since 1970 he has been engaged in the study of earthen constructions in seismic areas. In 1985 he became vice-minister of housing of Peru. He received the National Award of Culture in Science-Technology in 1986. Since 1990 he has been a member of the Getty Seismic Adobe Project Advisory Committee.

Humberto Varum is an assistant professor in the civil engineering department at the University of Aveiro. His main research interests are the evaluation, rehabilitation, and strengthening of existing constructions and seismic engineering.

Rasool Vatandoust is currently director of the Research Centre for Conservation of Cultural Relics, an institution he founded in Tehran in 1995. He holds a graduate degree in chemistry, a diploma in conservation of cultural properties, and a Ph.D. in conservation science from the University of London. He has

established a number of conservation departments, laboratories, and academic conservation courses in Iran. Vatandoust organized the Ninth International Conference on the Study and Conservation of Earthen Architecture in Yazd in 2003. He was a member of the scientific committee for Terra 2008.

Pete Walker (B.Sc., Ph.D., MIEAust., CPEng.) is a chartered civil engineer with over twenty-five years of research experience in earthen structures, masonry construction, timber engineering, and other low-impact construction materials. He is director of the BRE Centre for Innovative Construction Materials at the University of Bath.

Kunio Watanabe (Ph.D.) is a professor at the Graduate School of Science and Engineering, Saitama University, Japan, and

director of the Geosphere Research Institute. He is director of the project Conservation of the Buddhist Monastery of Ajina Tapa (Tajikistan) and has previously worked on international conservation projects such as that of Chogha Zanbil in Iran and Otrar Tobe in Kazakhstan.

Mark Weber is currently technical director and field projects manager for the World Monuments Fund's field programs department. He is coauthor of the book *Newport Houses* (1989). Weber has an M.A. in historic preservation from Boston University's Preservation Studies Program and a B.A. in economics from the Whittemore School of Business and Economics at the University of New Hampshire.

List of Conference Participants

Affiliations are given as of the time of the conference.

Last Name	First Name	Affiliation/Occupation	Country
Abad	Maria de Lourdes	Collegio de Arquitectos	Ecuador
Abdel Azim	Abdel-Nasser Ahmed Abdel	Supreme Council of Antiquities	Egypt
Abdel Rehim	Mohamed Hussein Ahmed	Supreme Council of Antiquities	Egypt
Abdelhaye Maouloud	Mohamed Yehdih	Université de Nouakchott, Faculté des sciences	Mauritanie
Abufayed	Abdulgader	University of Tripoli	Libya
Achenza	Maddalena	Architect-Researcher, University of Cagliari	Italy
Ag Moustapha	Almaïmoune	Direction Régionale de l'Urbanisme – Gao	Mali
Agbo	Komlan	UEMOA	
Ago	C. Paul	Ministère de la Culture, de la Jeunesse, des Sports et des Loisirs	Benin
Ahmed	Afaf Mohamed Mahmoud	Supreme Council of Antiquities	Egypt
Ahonon	Léonard	Site des Palais Royaux d'Abomey	Benin
Akhmedova	Elena	Samara State University, Department of Architecture and Civil Engineering	Russia
Aktas	Yasemin Didem	Middle East Technical University	Turkey
Alassane	Hasseye	Corporation des maçons de Tombouctou	Mali
Algros	Jean-Jacques	École d'Avignon	France
Althoff	Mary	Peace Corps, Mali	Mali
Andersson	Fred	Lerbyggeforeningen i Sverige	Sweden
Andersson	Jenny	Jenny Andersson Arkitektkontor	Sweden
Angbashim	Benjamin J.	Rockville Construction Ltd.	Nigeria
Anger	Romain	CRATerre-ENSAG	France
Apollonj Ghatti	Pietro M.	UNESCO	Italy
Arnot	Alain	ICOMOS Michoacan Mexico	Mexico
Assi	Eman	University of Sherjah, Department of Architectural Engineering	West Bank
Baba Nedjar	Younes	Office de la Vallée N'Zab	Algérie
Badiou	Hasseye	Corporation des maçons de Tombouctou	Mali
Bah	Amadou Tahirou	Association Djenné Patrimoine	Mali
Bahamondez Prieto	Monica	Centro Nacional de Conservacion y Restauracion	Chile
Bakker	Karel	University of Pretoria, Department of Architecture	South Africa
Balbo	Riccardo	Politecnico di Torino, CRD-PVS	Italy
Balez	Chantal	Association: "Pays Dogon: Parlons Français Ensemble"	France
Bamba	Fatogoma	Subdivision Urbanisme Djenné	Mali
Bamba	Fountiéré	AGETIER Mali	Mali
Barantandikiye	Jean-Mélance	Ministère de l'Education Nationale et de la Culture, Direction de la Culture	Burundi
Barro	David	Cellule d'Appui à la Gestion Communale (CAGEC)	Burkina Faso
Barrow	Jake	National Park Service	USA

Last Name	First Name	Affiliation/Occupation	Country
Bass Rivera	Angelyn	Architectural conservator	USA
Bathily	Hamady G.	DRJSAC (Direction Régionale de la Jeunesse, des Sports, des Arts et de la Culture) – Sikasso	Mali
Bavay	Gerard	Chercheur indépendant	Belgium
Bedair	Ramadan Mohammed Salem	Supreme Council of Antiquities	Egypt
Belinga	Christian	CRATerre-ENSAG	Cameroun/France
Bendakir	Mahmoud	CRATerre-ENSAG	Algérie
Béré	Younou	Corporation des Maçons de Djenné	Mali
Bergman	Michael	Claybuilding Society of Sweden	Sweden
Bertagnin	Mauro	University of Udine, Department of Civil Engineering	Italy
Berthe	Bassidi	ENI	Mali
Berthe	Isaac	Mission Culturelle de Bandiagara	Mali
Berthe	Salif	FLASH	Mali
Berthé	Oumar	Subdivision Urbanisme Bandiagara	Mali
Birabi	Allan Kenneth	Makerere University, School of Architecture	Uganda
Bitibaly	Abdoulaye	ENSUP	Mali
Blondet	Marcial	Catholic University of Peru, Civil Engineering Department	Peru
Boré	Amadou	Ordre des Architectes du Mali, Président	Mali
Bosman	Gerhard	University of Free State, Unit for Earth Construction, Department of Architecture	South Africa
Bouwens	Dirk	Eartha East Anglia Region Telluric Houses Association	UK
Breitenfelder	Katja	Architecture student	Germany
Brimblecombe	Peter	University of East Anglia, School of Environmental Sciences	UK
Brunet-Jailly	Joseph	Association Djenné Patrimoine International	France
Bufflier	Claire	EPFL	Switzerland
Bugini	Roberto	Istituto CNR Conservazione e Valorizzazione Beni Culturali	Italy
Bulow	Birgitte	Architect	Denmark
Bulthuis	Johannes	Contractor	Sweden
Butoto Nsanabandi	Jean	Institut des Musées Nationaux du Rwanda	Rwanda
Cancino	Claudia	Getty Conservation Institute	USA
Carazas	Wilfredo Aedo	CRATerre-ENSAG	France
Carvalho	Antonio	Architect	Portugal
Carvalho	Eduardo	Plano B Arquitectura	Portugal
Casal	Francisco Tomas	Union de Arquitectos e Ingenieros de la Construction de Cuba	Cuba
Casquero	Nuria Modrego	Polytechnic University of Catalonia	Spain
Castellanos	Carolina	Cultural Heritage Consultant	Mexico
Cebon Lipovec	Neza	Raymond Lemaire International Centre for Conservation-Katholieke Universiteit van Leven	Belgium
Chaudhry	Charu	University of Pennsylvania	USA (India)
Chiari	Giacomo	Getty Conservation Institute	USA
Chirhalwirwa	Lievin Mwilarhe	Université Libre de Bruxelles	Belgium
Chitalia	Salima	Aga Khan Development Network	Mali
Chuyate	Marvin	Pueblo of Zuni	USA
Cisse	Abdoulaye	ESIAU	Mali
Cisse	Baba	Mission Culturelle, Tombouctou	Mali
Cissé	Baba Alpha Ismail	BEAU	Mali
Cissé	Gouro Yoro	Maire de Djenné	Mali
Cissé	H. Seydou	DRJSAC (Direction Régionale de la Jeunesse, des Sports, des Arts et de la Culture) – Kidal	Mali
Cissé	Habi	Mosquée Sankoré	Mali
Cissé	Housseini	RADEV Bandiagara	Mali
Cissé	Kader	Mosquée Djingareyber	Mali
Cissé	Lassana	Mission Culturelle de Bandiagara	Mali
Cissé	Mamadou	Rice University	Mali
Cissé	Papa Moussa	Association Djenné Patrimoine	Mali
Cody	Aaron	Student	USA

Last Name	First Name	Affiliation/Occupation	Country
Cody	Jeff	Getty Conservation Institute	USA
Conlon	James	Columbia University, Visual Media Center	USA
Conti	Anna Paola	Architect	Italy
Cooke	Louise	Open University, University College London	UK
Cooper	Deborah	Architectural Resources Group	USA
Correia	Mariana	ESG-Escola Superior Gallaecia	Portugal
Cortes Alvarez	Marcelo	CRATerre-ENSAG	France
Coulibaly	Adama	CNREX	Mali
Coulibaly	David	Direction Nationale du Patrimoine Culturel	Mali
Coulibaly	Moulaye	Direction Nationale du Patrimoine Culturel	Mali
Coulibaly	Nafogo	Institut des Sciences Humaines du Mali	Mali
Coulibaly	N'golo	Direction de l'Urbanisme et de l'Habitat	Mali
Coulibaly	Tiessama	Direction Régionale de l'Urbanisme – Sikasso	Mali
Crocker	Ed	Crocker Ltd.	USA
Cruchon	Jacky	Association Nationale des Villes et Pays d'Art et d'Histoire	France
Dabo	Aliou	FLASH	Mali
Dayre	Michel	CRATerre-ENSAG	France
De Chazelles	Claire-Anne	CNRS	France
De Filippi	Francesca	Politecnico di Torino, CRD-PVS	Italy
Dean	J. Claire	Dean+Associates Conservation Service	USA
Dembele	Ousmane	ENI	Mali
Dembélé	Adama	Mission Culturelle de Bandiagara	Mali
Dembélé	Kora	Direction Nationale de l'Action Culturelle	Mali
Dembélé	Mamadi	Institut des Sciences Humaines du Mali	Mali
Dembélé	Salif	Direction Régionale de l'Urbanisme – Kidal	Mali
Descamps	Françoise	Getty Conservation Institute	USA
Dethier	Jean	Architecte urbaniste	France
Devan	Sarah	Wiss, Janney & Elstner Associates	United States
Deyoko	Abdoulaye	ESIAU	Mali
Deyoko	Youssouf	FISA MALI	Mali
Diaby	Boubacar H.	PSIC (Programme de Soutien aux Initiatives Décentralisées du Mali)	Mali
Diakite	Bah	Ministère de la Culture, Chargé du Patrimoine	Mali
Diakité	Seydou	ALPHALOG-Ségou	Mali
Diallo	Abdouramane	Établissement Public pour le Développement Communal	Burkina Faso
Diallo	Dielika		Mali
Diallo	Issa	Ministère de la Culture	Mali
Diallo	Kaba	CFP/SK	Mali
Diallo	Mamadou	ATA	Mali
Diallo	Modibo	Mémorial Modibo Keita	Mali
Diallo	Sebastien	Architecte, BEAU	Mali
Diarra	Alfouseini	Direction Régionale de l'Urbanisme – Kayes	Mali
Diarra	Amadi	UNESCO, chargé du Programme Culture	Mali
Diarra	Souleymane	DRJSAC (Direction Régionale de la Jeunesse, des Sports, des Arts et de la Culture) – Bamako	Mali
Diaw	Tidani	DRJSAC (Direction Régionale de la Jeunesse, des Sports, des Arts et de la Culture) – Ségou	Mali
Dicko	Békaye	E.C.I.C.A	Mali
Dicko	Ismaël	UNESCO	Mali
Diop	Alpha	Atelier d'Architecture ALDI – Bioclimatic Designs	Mali
Dioubate	Saidou	Direction Nationale de la Culture	Guinée
Dissanayaka	Rasika	Senior technical officer	Sri Lanka
Djanguenane	Nayandjoua	École du Patrimoine Africain	Benin
Djissodey	Angelo	Direction de la Promotion du Patrimoine Culturel et Touristique	Togo
Djittaye	Mahamane	FLASH	Mali

Last Name	First Name	Affiliation/Occupation	Country
Dondolo	Luvuyo Mthimkhulu	Amethole District Municipality	South Africa
Dosso	Sindou	Ministère de la Culture et de la Francophonie	Côte d'Ivoire
Doukoure	Abdoulaye		Mali
Douline	Alexandre	MISEREOR	France
Doumbia	Abdou	DRJSAC (Direction Régionale de la Jeunesse, des Sports, des Arts et de la Culture) – Kayes	Mali
Doumbia	Moussa	ENI, Directeur	Mali
Ducoloner	Pierre	Cabinet d'architecture PIERRE DUCOLONER	France
Ducoloner-Rossignol	Paulette Roberte	Cabinet d'architecture PIERRE DUCOLONER	France
Duff	Michael	Happold Consulting Limited	UK
Dupont	Christelle	Association BOTMOBIL	France
Eggert	Aditya	Stagiaire DED, Mission Culturelle de Bandiagara	Mali
El Gammal	Saad Zaki Abdallah	Supreme Council of Antiquities	Egypt
El Moctar	Mohammed	Ministère de la Culture, Ministre	Mali
Elhadji Ousmane	Diané	ENI	Mali
Eloundou	Lazare	UNESCO, World Heritage Centre	France
Essesse	Amélie	Architecte DPLG – Expert	France
Fane	Yamoussa	Mission Culturelle de Djenné	Mali
Farenthold	Sissy	Smothers Bruni Foundation	USA
Farneth	Stephen	Architectural Resources Group	USA
Fecher	Birgit	Stagiaire DED, Mission Culturelle de Bandiagara	Mali
Feiglstorfer	Hubert	Architect	Austria
Fernandes	Maria Lopes Aleixo	Universidade de Coimbra, Instituto de Arqueologia, Fac. Letras	Portugal
Ferron	Amila	University of Pennsylvania	USA
Fletcher	Henry	Environmental Partnerships	UK
Fofana	Gaoussou	Conservateur du Fort Médine	Mali
Fokou	Emmanuel	Centre de Promotion des Artisans de Bafoussam	Cameroun
Folli	Luisa	Geologist	Italy
Fomba	Adama	E.C.I.C.A.	Mali
Fong	Kecia Lee	Getty Conservation Institute	USA
Fontaine	Laetitia	CRATERre-ENSAG	France
Fouhse	Sally	Santa Barbara Trust for Historic Preservation	USA
Friedman	Renée	British Museum, Hierakonpolis Expedition	UK
Fukuda	Takashi	Architectural Resources Group	USA
Gandreau	David	CRATERre-ENSAG	France
Ganduglia	Mauricio	Universidade Agostinho Neto-École d'Architecture	Angola
Garnier	Philippe	CRATERre-ENSAG	France
Gasper	Shalie	New Mexico Historic Preservation Division	USA
Gassama	Boubou	DRJSAC (Direction Régionale de la Jeunesse, des Sports, des Arts et de la Culture) – Gao	Mali
Gaul	Eryn	Peace Corps	Mali
Geyer	Daniela	Restorer	Germany
Godonou	Alain	École du Patrimoine Africain	Benin
Gonçalves	Aimé	ICOMOS EAMAU	Benin
Gounou	Colette	Musée Ethnographique Alexandre Senou Adande	Benin
Granier	Thomas	Association la Voute Nubienne	France
Grohp	Karin	Gothenburg University	Sweden
Gruber	Maria	University of Applied Arts	Austria
Gubler	Maria Elizabeth	Ceramicist	Switzerland
Guerrero	Antonio Arzaga	Universidad Autónoma Metropolitana Xochimilco	Mexico
Guerrero Baca	Luis Fernando	Universidad Autónoma Metropolitana Xochimilco	Mexico
Guillaud	Hubert	CRATERre-ENSAG	France
Guillaumin	Nathalie	Association Via Patrimoine	France
Guindo	Ibrahim	Commune de Bankass	Mali
Guindo	Moumouni	ENSUP	Mali

Last Name	First Name	Affiliation/Occupation	Country
Guindo	Pierre	Mission Culturelle de Bandiagara	Mali
Guindo	Tangara Néma	Université de Bamako, Département d'Histoire et d'Archéologie	Mali
Guirou	Gonogo dit Fidèle	ESIAU	Mali
Guntzel	Jochen Georg	Fachhochschule Lippe und Höxter	Germany
Hadian Dehkordi	Manijeh	Research Centre for the Conservation of Cultural Relics	Iran
Hadonou	H. Urbain	Musée Honmé	Benin
Hadya Kane	Mamadou	Direction Nationale du Patrimoine Culturel	Mauritanie
Hagbom	Lina	Ceramicist	Sweden
Haidara	Abdel Kader	Bibliothèque des manuscrits – ONG SAVAMA-Tombouctou	Mali
Haidara	Cheick Hamala	Ministère de la Culture, Administration et Finances	Mali
Haidara	Maimouna		Mali
Hajmir Baba	Majid		Iran
Hallé	Ousmane	Municipalité de Tombouctou	Mali
Haman	Mohaman	ICOMOS Cameroun	Cameroun
Hardy	Mary	Architect/conservator	USA
Hasseye	Baba Mahamoudou	Mosquée Sidi Yahya	Mali
Haupts	Hauke	Finmark County Authority	Norway
Hendili	Karim	Sector of Culture and National Heritage	Bahrain
Henningsson	Ulf	Claybuilding Association of Sweden	Sweden
Houben	Hugo	CRA Terre-ENSAG	France
Hunter	Grahame	Turquoise Mountain Foundation	Spain
Hurd	John	ICOMOS ISCEAH	UK
Ibrahim	Ahmed Baghdadi Youssef	Supreme Council of Antiquities	Egypt
Idman	Christina	La Parc AB	Sweden
Isik	Bilge	Istanbul Technical University, Faculty of Architecture	Turkey
Islam	Mohammed Shariful	Saitama University, Department of Civil and Environmental Engineering	Japan
Jadoul	Julie	Architecte	Mali
Jaeschke	Richard	Bristish Museum, Hierakonpolis Expedition	UK
Jerome	Pamela	Columbia University	USA
Joffroy	Thierry	CRA Terre-ENSAG	France
Jones	Michael	American Research Center in Egypt	Egypt
Jongbloet	Aurore	Étudiante	France
Joshi	Om	Gujarat Vidyapith Tribal Research and Training Centre	India
Joy	Charlotte	University College London	UK
Jurkiewicz	Ryszard	Firma BTM-JURKIEWICZ	Poland
Kaboré	Barthelemy	Direction du Patrimoine Culturel	Burkina Faso
Kampo	Ali	DRJSAC (Direction Régionale de la Jeunesse, des Sports, des Arts et de la Culture) – Mopti	Mali
Kanan	Maria Isabel	IPHAN	Brazil
Kanoute	Ousmane	ENSUP	Mali
Keable	Rowland	Ram Cast CIC	UK
Keita	Alou	Association SIGIDA YEELEN	Mali
Keita	Baba	ICCROM – Africa 2009	Italy
Keita	Boubacar		Mali
Keita	Daouda	FLASH	Mali
Kessou	Rodrigue		Benin
Khorosh	Yelena	Kazakh Scientific Research Institute on Problems of the Cultural Heritage of Nomads	Kazakhstan
Kienon-Kabore	Timpoko Hélène	Université de Cocody, Département D'Archéologie	Côte d'Ivoire
King	Joseph	ICCROM	Italy
Klinkhamer	Sacha	Rijksgebouwendienst	Netherlands
Konaté	Amadou	Chargé de Communication du Ministère de la Culture	Mali
Konaté	Gabriel Magma	Protocole, maître de cérémonie	Mali

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Konaté	Moussa	Maison Africaine de la Photographie	Mali
Koné	Mamadou	Bureau d'architecture AUDEX	Mali
Koné	Ousmane	Direction Nationale du Patrimoine Culturel	Mali
Koné	Sidi Lamine	Direction Nationale du Patrimoine Culturel-Division Sites Monuments Historiques et Architectures Traditionnelles	Mali
Korobara	Mahamane	Mosquée de Djenné	Mali
Kouassi	Kouakou Simon	Université de Cocody	Côte d'Ivoire
Kouroumansé	Boubacar	Corporation des maçons de Djenné	Mali
Kubioka	Daniel	Technicien Supérieur en génie civil	Angola
Lambert	Molly C.	Architectural Conservation, Inc.	USA
Langenbach	Randolph	Turquoise Mountain Foundation	USA
Lantum	Hoffman Moka	Baobab Cultural Center	USA
Lardinois	Sara	Architectural Resources Group	USA
Larsson	Eva	Royal College of Fine Arts	Sweden
Laureau	Vincent	Université Paris 10 (Nanterre)	France
Laurent	Jean-Paul	LTHE, CRATerre-ENSAG	France
Lekareva	Nina	Samara State University, Department of Architecture and Civil Engineering	Russia
Lemarquis	Anne	CRATerre-ENSAG	France
Lemineur	Philippe	Architect	Belgium
Li	Hongsong	Chinese Academy of Cultural Heritage	China
Licciardi	Guido	UNESCO	Italy
Lidwin	Jolanta	Architect	Poland
Lopes	Maria Conceicao	Universidade de Coimbra	Portugal
Lubiato	Pierre Jean		Mali
Maas	Pierre	Rothuizen van Doorn't Hooft	Netherlands
Macalou	Bintau		Mali
Machat	Christoph	Governmental Office for Monuments' Conservation of the Rhinelands	Germany
Machtey	Sarah	Builder, designer, artist	USA
Macias	Santiago	University of Algarve	Portugal
Madec	Annaig	Association BOTMOBIL	France
Mahdy	Hossam	ICOMOS, Vernacular Architecture Committee	Egypt
Maiga	Fadimata Mahamane	ENI	Mali
Maiga	Mahamane H.		Mali
Maïga	Abdou Talfi	Comité de Gestion du Tombeau des Askia, Gao	Mali
Maïga	Ali Badi	Comité de Gestion du Tombeau des Askia, Gao	Mali
Mankanguile	Madera	Étudiante	Mali
Marchand	Trevor H. J.	University of London (SOAS)	UK
Marchante	Patricia	Architect	Portugal
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Marouani	Alle Ould	Mission Culturelle de Nouakchott	Mauritanie
Mascarenhas	Alexandre Ferreira	Fundacao de Arte de Ouro Preto	Brazil
Mayogi	Adolphe	AMICOR: Amicale des Autoconstructeurs Ruraux	Congo
Mecca	Saverio	University of Florence	Italy
Meyer	Asta	Engineer/architect	Germany
Michai	Lydwine-Rosemonde	École du Patrimoine Africain	Benin
Mohamed Ag	Erless	Institut des Sciences Humaines du Mali	Mali
Moles	Olivier	CRATerre-ENSAG	France
Morales	Ricardo	Huaca de la Luna Archaeological Project	Peru
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Morris	Hugh	University of Auckland	New Zealand
Mortada	Hisham	King Abdul Aziz University, Department of Architecture, College of Environmental Design	Saudi Arabia

Last Name	First Name	Affiliation/Occupation	Country
Morton	Tom	Arc Chartered Architects	UK
Mottuel	Bernard	ACROTERRERRE	France
Murga	Margarita	ICOMOS Michoacan Mexico	Mexico
Naji	Salima	DPLG, APDPS	Morocco
Nandjee	Ferid	Aga Khan Development Network	Mali
N'Diaye	Idrissa	Bureau d'architecture AIA	Mali
Ndonde	Festo	Caritas Tabora	Tanzania
Nejati	Mahmoud	Iranian Cultural Heritage and Tourism Organization	Iran
Ngoma	Gaspard	Ministère de la Construction, l'Urbanisme et l'Habitat	Congo
Niambélé	Mamadou	OMATHO (Office Malien du Tourisme et de l'Hotellerie) – Bamako	Mali
Nishiura	Tadateru	Kokushikan University	Japan
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Ogega	Julius Juma	National Museums of Kenya	Kenya
Okada	Yasuyoshi	Kokushikan University	Japan
Oloja	Godwin	New Consultants	Nigeria
Opoku	Linus Yas	Diocese Development Office of Catholic Diocese of Sunyan (SDDO)	Ghana
Ortiz	Marylise	Association Nationale des Villes et Pays d'Art et d'Histoire	France
Ould Sidi	Ali	Mission Culturelle de Tombouctou	Mali
Ouologuem	Issa	Direction Nationale de l'Urbanisme et de l'Habitat	Mali
Pajulampi	Mailis	ICOMOS Germany	Germany
Palmgren	Lars Allan	La Parc AB	Sweden
Palumbo	Gaetano	World Monuments Fund	USA
Paradis	Juliette	ENI	Mali
Peixe	Dalila Silva	Ordem dos Arquitectos Portugueses	Portugal
Penido De Rezende	Marco Antonio	Universidade Federal de Minas Gerais	Brazil
Pereira	Honório Nicholls	Federal University of Bahia	Brazil
Petrin	Katherine	Architectural Resources Group	USA
Piqué	Francesca	Conservator	Italy
Porter	Douglas	University of Vermont, School of Engineering	USA
Potter	Rebecca	University of Bath, Department of Architecture & Civil Engineering	UK
Prieto	Valeria	ICOMOS CIAV	Mexico
Rainer	Leslie	Getty Conservation Institute	USA
Rajan	Rahim	Aluka	USA
Rakotomamonjy	Bakonirina	CRATerre-ENSAG	France
Razzokov	Abdurauf	Historical and Archaeological Reserve of Sarazm	Tajikistan
Reese	Margie	Ford Foundation	Nigeria
Reis	Sofia	ARGUMENTUM	Portugal
Rigotti	Chiara	Architects without Barriers	Burkina Faso
Roby	Thomas	Getty Conservation Institute	USA
Rovero	Luisa	University of Florence	Italy
Samah	Essoavana Ouro-Djobo	Centre de la Construction et du Logement (CCL) Cacavelli	Togo
Samake	Mamadou Amadou	Mission Culturelle de Djenné	Mali
Samaké	Diarrassouba Assitan	Direction Nationale du Patrimoine Culturel-Division Parcs Publics et Monuments	Mali
Sanchez Gama	Clara Eugenia	Universidad Nacional de Colombia	Colombia
Sangare	Moussa	CFP/SK	Mali

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Sangaré	Mamadou	AGETIER Mali	Mali
Sangaré	Moussa	Direction Régionale de l'Urbanisme – Urbanisme Mopti	Mali
Sanogo	Abdoulaye Klessigüe	Direction Nationale du Patrimoine Culturel	Mali
Sanogo	Kléna	Institut des Sciences Humaines du Mali	Mali
Sarré	Habibou	Direction Régionale de l'Urbanisme – Koulikoro	Mali
Sastre Martin	Jose Maria		
Scherrer	Olivier	ACROTERRERRE	France
Schmidt	Annette	National Museum of Ethnology	Netherlands
Schweikhardt	Erik	GTZ GmbH (German Technical Cooperation)	Yemen
Séchaud	Laurent	Cellule d'Appui à la Gestion Communale (CAGEC), Direction du Développement et de la coopération (DDC)	Burkina Faso
Seck	Vincent	UNESCO	Mali
Shabani	Juma	UNESCO	Mali
Shemdin	Gouhar	ICOMOS Canada	Canada
Shittu	Theophilus Adeyinka	University of Plymouth, Centre for Earthen Architecture	UK
Sidibé	Samuel	Musée National du Mali	Mali
Sikka	Sandeep	Superstructures	USA (India)
Silva	Filipe Jorge	ARGUMENTUM	Portugal
Silver	Constance	Preservar, Inc.	USA
Simon	Stefan	Staatliche Museen zu Berlin	Germany
Simpson	Caroline	Quma History Project	UK
Sinamai	Ashton	Midlands State University, Faculty of Arts, Dept. of Archeology	Zimbabwe
Siravo	Francesco	Aga Khan Trust for Culture	Italy
Sissoko	Cheick Sidiya	Direction Régionale de l'Urbanisme – Bamako	Mali
Sissoko	Diarra	Bureau Atelier 21	Mali
Sissoko	Sékou	Atelier d'Architecture ALDI – Bioclimatic Designs	Mali
Sissoko	Sidi		Mali
Sogoba	Gaoussou	CFP/SK	Mali
Sogodogo	Diakalia	E.C.I.C.A.	Mali
Sosa	Mirta Eufemia	CRIATIC, FAU, UNT	Argentina
Soumaré	Mustaph	Architecte	Mali
Spears	Beverley	Spears Architects Inc.	USA
Stebler	Werner Karl	Dipl. Architect Eth/SIA	Switzerland
Stoller	Magali	Programme International de Recherche "Peuplement Humain et Evolution Paleoclimatique en Afrique de l'Ouest"	Switzerland
Swan	Simone	Adobe Alliance	USA
Sy	Mariam	Architect, Aga Khan Trust for Culture	Mali
Taberna	Judit	Taberna-Casquero Arquitectura SCP	Spain
Taha	Badawy Sayed Abdel-Rehim	Supreme Council of Antiquities	Egypt
Taxil	Gisèle	Aga Khan Trust for Culture	France
Tembély	Ibrahim	Commune de Bandiagara	Mali
Teng	Stan	Architectural Studio	USA
Terki	Yasmine	Centre de Conservation des Ksour	Algérie
Terrasson	Adeline		
Teutonico	Jeanne Marie	Getty Conservation Institute	USA
Tiegbe	Sylvain	Ministère de la Culture et de la Francophonie	Côte d'Ivoire
Tita	Jean-Pierre M.	Mission Culturelle de Kidal	Mali
Tizi bi	Koffi	Ministère de la Culture et de la Francophonie	Côte d'Ivoire
Togo	Sara	FLASH	Mali
Tonietti	Ugo	University of Florence	Italy
Torrealva	Daniel	Catholic University of Peru, Civil Engineering Department	Peru
Touré	Alhousseini	Architecte, ARCADE SARL	Mali
Touré	Awa	FLASH	Mali
Touré	Boubacar	DRJSAC (Direction Régionale de la Jeunesse, des Sports, des Arts et de la Culture) – Tombouctou	Mali

Last Name	First Name	Affiliation/Occupation	Country
Touré	Hama dit Baba	Centre National de Recherche et d'Experimentation des Matériaux de Construction	Mali
Touré	Ibrahim B.	DRJSAC (Direction Régionale de la Jeunesse, des Sports, des Arts et de la Culture) – Koulikoro	Mali
Touré	Oumar Balla	OMATHO (Office Malien du Tourisme et de l'Hotellerie) – Bamako	Mali
Townsend	Lesley	South African Heritage Resources Agency	South Africa
Traore	Abdramane Y.	E.C.I.C.A.	Mali
Traore	Aboubacar	CFP/SK	Mali
Traore	Aminata		Mali
Traore	Assitan		Mali
Traore	Daouda	ENI	Mali
Traore	Yousseuf	FLASH	Mali
Trappeniers	Marina	CRATerre-ENSAG	France
Ullal	André	Turquoise Mountain Foundation	Afghanistan
Usman	Yusuf Abdallah	National Commission for Museums and Monuments of Nigeria	Nigeria
Uviña	Francisco	Cornerstones Community Partnerships	USA
Van Damme	Henri	École Supérieure de Physique et Chimie Industrielles de Paris (ESPCI)	France
Van der Linde	Sjoerd	University College London	Netherlands
Van Vuuren	Chris	University of Unisa	South Africa
Vargas Neumann	Julio	Catholic University of Peru, Civil Engineering Department	Peru
Vatandoust	Rasool	Research Centre for the Conservation of Cultural Relics	Iran
Vyshkin	Efim	Samara State University, Department of Architecture and Civil Engineering	Russia
Walker	Peter	University of Bath, BRE Centre of Innovative Construction Materials, Department of Architecture & Civil Engineering	UK
Wdidye	Mahamadou		Mali
Weydt	Jana	UNESCO World Heritage Centre	France
Whelan	Debbie	Archaic Consulting	South Africa
Wieczorek	Jean-Pierre	CAUE de la Meuse	France
Wong	Lorinda	Getty Conservation Institute	USA
Wowui	Kossi	Direction de la Promotion du Patrimoine Culturel et Touristique	Togo
Yager	Karen	Karen Yager Fine Art Conservation	USA
Yalcouye	Hamadou	ESIAU	Mali
Yalcouyé	Abass	AGETIER Mali	Mali
Yeo	Arouna	Université de Cocody	Côte d'Ivoire
Youlou	Seri		
Yu	Bing	Chinese Academy of Cultural Heritage	China
Zentner	Edoardo	Achi Association	Switzerland
Zerquera Amador	Duznel	Oficina del Conservador de la Ciudad de Trinidad	Cuba
Zourkaleini	Djibrilla Ali Maiga	Ministère de l'Urbanisme et de l'Habitat	Niger

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Earthen architecture, which constitutes one of the world's most diverse and universal forms of cultural heritage, is also one of the most challenging to preserve. Earthen architecture is found on all continents and dates from all periods of history. Sites range from ancestral cities and settlements in Mali, the royal palaces of Abomey in Benin, and monuments and mosques in Iran to Buddhist temples on the Silk Road in China and Spanish missions in California. Earthen architecture is particularly prevalent in Africa, where it has been a building tradition for centuries.

The many historic and contemporary earthen buildings in Mali made that country the ideal setting for Terra 2008, the Tenth International Conference on the Study and Conservation of Earthen Architectural Heritage. This volume contains the proceedings of that conference, organized jointly by the Getty Conservation Institute and the Mali Ministry of Culture.

Leslie Rainer, a wall paintings conservator and senior project specialist at the Getty Conservation Institute, is coauthor of *Palace Sculptures of Abomey: History Told on Walls*. Angelyn Bass Rivera, a conservator based in Santa Fe, New Mexico, and principal of Conservation Associates, is coeditor, with Leslie Rainer, of *The Conservation of Decorated Surfaces on Earthen Architecture: Proceedings from the International Colloquium, 22-25 September 2004, Mesa Verde National Park, Colorado, U.S.A.* David Gandreau is an archaeologist and researcher at the Center for the Research and Application of Earth Architecture (CRA Terre) in Grenoble, France.



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