Reflecting on Materials and Structure: Building Cultures and Research Methodology in the Project of a Seismic Building Code for Traditional Materials in Morocco

Mohammed Hamdouni Alami and Stefania Pandolfo

Abstract: *This paper presents the project of a Building Code for Traditional Materials conceived and developed in Morocco with international cooperation in the aftermath of a ruinous earthquake that struck the city of Al-Hoceima in February 2004. Several actions have been executed within an organized and phased framework. To date, the implementation of the project is reaching the second of a three-phase schedule.*

We will first give a brief and broad overview of the project. Then we will discuss the necessity of developing a better knowledge of local structural systems and the theoretical hypotheses about a local building culture that helped us in defining the related architectural and structural typologies. Here, building culture is not perceived simply as a surplus "topping" of rites and know-how but as a theoretical view of materials, form, and structure, an ontology and related epistemology. The views of master masons about earthen material, workmanship, and construction techniques are presented in connection with architectural forms. On the basis of these views and other observations, a preliminary definition of architectural and structural typologies was made, the corroboration of which was sought by way of an extensive survey conducted in three discrete regions of the country.

Introduction

In February 2004 the northern Moroccan city of Al-Hoceima was struck by a powerful earthquake that caused hundreds of casualties and triggered heated debates about disaster relief and intervention, and about the safety of rural and urban housing, illegality, and the need for regulation. Soon after, a new law was issued that requires all new buildings, in both urban and rural areas, to comply with earthquake safety regulations within the coming five years. Construction permits, which until now have not been required in rural areas, will become a legal obligation, and compliance with the seismic building code will be required all over the country.

The law known as Loi 04-04 was approved by the Moroccan government (Conseil des Ministres) and is currently pending approval by the parliament. The existing Moroccan building code, known as R.P.S. 2000, provides seismic regulations exclusively for steel and reinforced concrete. A related law, also prepared by the Ministry of Housing and City Planning in 2004, Le Règlement Général de Construction (General Building Code), similarly ignores all the possible uses of traditional construction materials. This means that if nothing is done before the five-year deadline, all traditional construction techniques—already strongly challenged by the concurrent use of industrial materials—will be outlawed.

The social and cultural consequences of such a situation would be catastrophic. Over 70% of the construction in rural areas is of earth or stone masonry, and the inhabitants do not have the means to move to different housing. This problem is dramatically coloring the aftermath of the Al-Hoceima earthquake. Almost two years after the event, many families were still living in tents, according to a survey we conducted in the region of Al-Hoceima in winter 2006. The lack of resources has caused the reconstruction process to be characterized by the simultaneous presence, on the same sites, of tents,

thatch, and wattle dwellings, and the reinforced concrete foundations of the projected new homes. It should be noted that despite galloping urbanization (more than half of Morocco's population now lives in urban areas [Morocco 2004]) and the massive introduction of modern building techniques (notably the use of reinforced concrete—in many cases of poor quality), vast and environmentally significant regions still display high-quality vernacular architecture. Keeping this vernacular architecture alive is critical for the preservation of Moroccan building traditions and cultural patrimony, as well as for the possibility of building legal and safe affordable housing in rural areas. At the macroeconomic level, it is also a means of saving on imports by using local materials.

To meet that goal, one of the authors, Mohammed Hamdouni Alami, then professor at the École Nationale d'Architecture of Rabat, Morocco (ENA-Rabat), initiated a research project with CRATerre and the UNESCO Chair of Earthen Architecture, Building Cultures and Sustainable Development. To the initial partners of the project were added the Engineering School of Casablanca (École Hassania des Travaux Publics, EHTP), the Laboratoire Public d'Etudes et d'Essais (LPEE), and the Getty Conservation Institute (GCI). The project became fully operational when an international scientific advisory committee met in Rabat in May 2005.

Prior to the meeting, a research team composed of the authors; Mary Comerio, Department of Architecture, University of California, Berkeley; Khalid Mosalam, Department of Civil and Environmental Engineering, University of California, Berkeley; and Mel Green, Mel Green and Associates, wrote an initial research project. This document was further developed by Abdelkader Cherrabi, Casablanca School of Engineering; Hubert Guillaud, CRATerre; and author Mohammed Hamdouni Alami, and it was submitted and discussed with participants at a May 2005 workshop in Rabat.

The project aims to study techniques of earthen construction that have acceptable performance for earthquake safety regulations and are adequate to the needs of low-cost housing in developing countries. Our methodological premise is that research on such techniques should focus on preservation of the local building culture, and that preference should be given to the use of vernacular materials, such as stone, earth, wood, textile fibers, and other locally available solutions. Consistent with these premises, our project engages in a dialogue with a local Moroccan tradition of building and does so at the level of its core conceptual formulation. It seeks to promote a creative exchange between contemporary engineering modes of analysis and solutions and other traditional construction methods, taking seriously that tradition's different understanding of structures and materials, and relying on the active engagement of engineers with that tradition and its conception of structure and materials, as well as on the mobilization of local know-how to come up with original solutions. Yet—and inasmuch as we think that both approaches are necessary and complementary—we see our intervention as an attempt at preserving and transforming local building techniques while, at the same time, taking into account the requirements and solutions made available by contemporary engineering.

In recent years some research and systematic improvement of building techniques has been carried out in several countries (see "Earthquake Resistant Design Criteria and Testing of Adobe Buildings at Pontificia Universidad Católica del Perú" and "New Zealand: Aseismic Performance-Based Standards, Earth Construction, Research, and Opportunities," both in the present volume). These studies have applied modern engineering concepts to traditional building materials such as earth. They would benefit by integrating knowledge of local building traditions into their methodologies.

Whereas most of the research conducted thus far has been focused on the study and improvement of materials rather than on traditional building techniques and structural typologies, the objective of our research and educational efforts is to develop and implement a methodology to evaluate and to improve the reliability of adobe buildings subjected to seismic forces. Our work takes its lead from the possibility of improving upon the highly sophisticated vernacular techniques that are found in Morocco and in many other countries in order to make them seismically safe. Indeed, some of the ancient techniques developed in highly seismic regions—such as Central Asia, the Himalayan Mountains, and Anatolia—demonstrate their effectiveness by their survival over long periods of time (see "Observing and Applying Ancient Repair Techniques to Pisé and Adobe in Seismic Regions of Central Asia and Trans-Himalaya" and "Seismic Rehabilitation Study in Turkey for Existing Earthen Construction," both in the present volume).

The improvement of traditional building methods through laboratory experiments and cutting-edge scientific analysis would provide populations with the seismic safety techniques required by modern building codes. It would also make possible the promotion of the social image of earth as a competitive building material vis-à-vis industrial ones and facilitate its readoption by local populations. This would be a major achievement because it would provide a large part of the world's population with seismic safety, as well as aid in the struggle against poverty and the deterioration of the environment. The production of an earthen architecture for the very rich in Marrakech and the widely recognized disastrous climatic performance of modern materials in low-cost housing are strong arguments in favor of traditional materials. Our own survey in southern Morocco has shown that people who moved from the traditional earthen structures to concrete and cement block homes experienced hardship in the summer due to extreme heat, and they often returned to spend the summer in the old villages when the earthen structures were still standing.

Fostering the development of that awareness is part of this project. Among the actions we consider as our goals are (1) the introduction of seismic-engineering-based design in architectural education; (2) seismic engineering training of practicing engineers and architects; (3) training contractors and master masons to correctly use the seismic techniques required and described in the projected building code; (4) informing municipal administrations and *agences urbaines* of the content and the philosophy of the projected building code, including training of their architects and engineers; and (5) providing public information about seismic building techniques and maintenance of earthen structures. This last goal is an important one because the code concerns self-help construction, without an architect or an engineer, and because the workmanship in building and maintenance is partly provided by the people who own or live in the buildings. All of these aspects make the project a long-term one.

Defining Contemporary Architectural Typologies and Structural Systems

The writing of a building code adapted to the local building tradition requires in-depth acquaintance with the architectural and structural typologies of the country and of the building tradition itself. This also means that local typologies should be approached and understood in their cultural context as both cultural forms and productive forms of knowledge. Consistent with this view, we take the notion of a building tradition as a theoretical view of materials, form, and structure, as well as the embodied practice of a particular know-how related to a way of being in the world. In our understanding—and far from its reduction to a superficial or cosmetic addition of rites and workmanship—such a notion of building tradition is critical to any understanding of structure and must be engaged by engineers. For this reason, the issue of architectural typologies and structural systems has been addressed in terms of an anthropology of science and on the basis of anthropological fieldwork conducted in Morocco in recent years.

To begin, it should be noted that the question of typology is twofold. On the one hand, it has to do with existing structures and historic buildings, and with the retrofitting measures that may be applied in order to make them seismically safe. On the other hand, it is related to future buildings and the seismic design safety principles they should comply with. For existing structures, the question of architectural and structural typologies is mainly a question of defining the criteria established on the basis of earthquake engineering and the principles of architectural preservation, and it relies on direct observation in the field. For future buildings, defining architectural and structural typologies not only has to do with engineering criteria and with the observation of recently built structures, it *must also imagine future architectural evolutions* based on social, technical, and economic factors. Our case research has shown that the highly sophisticated and structurally complex traditional architectural types of the Moroccan pre-Saharan regions have been progressively and irreversibly abandoned, at least at this point in time (fig. 1). To address this issue, we dedicated our project's first workshop (May 2005, in Rabat) to the analysis of typological and sociocultural research on the evolution of spatial forms and to the impact current typological and structural transformations have on earthen buildings' seismic resistance.

In our second workshop (September 2005, Rabat) we tried to further our reflection on the relationship between traditional typologies and building techniques,

FIGURE 1 Most of the residents of Ait Ben Haddou have moved from the old village (lower) to the new village (top).

and on the evolution of that relationship in contemporary building practices. We focused on the detailed study of one region in the Moroccan south, where some of us had previously conducted research and where further research has been and will be conducted (Pandolfo 1997; Hamdouni Alami and Bahi 1992). We were able to show that in their contemporary use, traditional building techniques had lost their symbolic and epistemic foundations. The housing building process had transformed from what local master builders described as an interconnected vertical growth, to a horizontal development of discrete elements from which connections and all form of juncture or "attachment" were excluded (between walls, stairs, and between walls and roof). This technical change was of great significance, for the "vertical structure" was technically conceived and phenomenologically experienced as a coming into being of form and life (as a network of articulated joints) (fig. 2).

The issue is twofold. On the one hand, the spatial exodus from the walled, multi-story, and highly dense *qsar* village form that is characteristic of this region (*qsar*, plural *qsour*, are walled earthen village/town settlements) toward multiple scattered settlements composed of independent housing units reflects a typological and sociocultural mutation that cannot be overlooked—and one that is related to the experience of modernity in this peripheral region. The architecture and building technique of these new homes is novel, and the use of earthen or hybrid building materials is the only vestige of a local building tradition. Studies of seismic resistance and vulnerability of earthen buildings have to take this mutation into account.

On the other hand, any attempt to identify seismic resistant structural typologies and techniques must also seriously engage with the historic architectural forms and structural typologies, and with the highly sophisticated building traditions that are today being abandoned because the *qsar* village form is perceived as uninhabitable. As documented in our architectural and structural survey, it is unquestionable that the new typologies of scattered housing units are less seismically resistant than the old typologies. This is because the structures are built incrementally and without a preconceived plan, and all successive additions are adjoined without any structural connection (unpublished preliminary survey conducted in 2005, and general survey conducted in winter 2006). New houses outside the walls are no longer attached and interconnected with everything else. The issue, however, is not to return to a connectedness that today is perceived as uninhabitable from a cultural/social point of view, as well as in its technical sense. The question is instead that of the creation of something else that might newly interpret some key formal principles that might have rendered the *qsar* constructions more structurally stable and spatially dynamic.

In our first workshop, we described the evolution of the architectural typology of housing in the southern valleys of Morocco and discussed the social factors that

FIGURE 2 Aerial view of new houses across the river from the historic settlement at Ait Ben Haddou.

FIGURE 3 *Qasba* of Amerdil, Skoura.

determine this evolution. We also tried to show that this evolution led to the creation and adoption of new types, including the *qasba* (small castle) and the Ecochard housing unit (the so-called *habitat économique*, after the name of its original designer, Michel Ecochard, head architect of the French Protectorate in Morocco from 1947 to 1953).

Starting from observations in the field, and from a limited but interesting literature (Jacques-Meunié 1962; Chorfi 1991; Ben el-Khadir and Lahbabi 1989), we have attempted to show that this evolution started very early, perhaps with the building of homes in the midst of the cultivated gardens in the seventeenth through the nineteenth centuries. As D. Jacques-Meunié suggested in her *Architectures et habitats du Dadès* (1962), very early, powerful families started leaving the *qsour,* the collective settlements, and settled outside, either just next to these *qsour* or in the gardens (on agricultural land). Designed as improved and fortified garden houses, the first *qasbas,* or small castles, were single-family homes with or without patios, depending on the altitude of the site (fig. 3). In the first half of the twentieth century, around 1920–30, the typology of the *qasba* with patio was sometimes abandoned in favor of an urban typology, that of Marrakech *riyads,* or houses with large internal gardens.

Because of the safer and freer nature of present days, the exodus from the collective settlements accelerated after Moroccan independence, in particular in the 1980s. Many of the *qsour* of the region are now being abandoned (fig. 4), and people are rebuilding and settling outside in completely different spaces, from the point of view of architecture and urban design. Seeking more spacious houses, most families are leaving the overcrowded old settlements. An outspoken longing for "freedom" is driving everyone out of the traditional housing forms. More strikingly, traditional housing and even traditional materials are identified with the old way of life, with the overcrowded homes and lack of freedom that resulted from living with the extended family in constricted spaces. Whereas the traditional agricultural way of life in the region was organized around a seasonal rhythm, with daytime in the gardens and nighttime at home, the shift from an agricultural economy to a migration economy, which relies on remittances from migrant workers, put an end to the importance of gardening. In the new context, old housing forms are no longer perceived as shelters for nighttime and hard times, but as oppressive "family prisons," where only the poor are constrained to remain.

Moving out of the *qsour,* to be near the road and public services (the weekly market, the school, the infirmary), whatever little these services may appear to us, has become the driving force of the settlements and townscape of the region. With the new urban and village fabric, the housing typologies changed as well, for better and for worse.

FIGURE 4 An abandoned *qsar* (a walled earthern town settlement), Tineghir, province of Ouarzazate.

These observations and the Earthquake Engineering Research Institute (EERI) World Housing Encyclopedia Report form (see www.world-housing.net/) were the basis on which a preliminary survey of architectural typologies and structural systems was conceived. Some of the Getty Seismic Adobe Project publications, particularly the *Survey of Damage to Historic Adobe Buildings after the January 1994 Northridge Earthquake* (Tolles et al. 1996), have been a model for us, especially in attracting our attention to certain specific vulnerabilities of earthen buildings in terms of their seismic behavior (such as water erosion and basal conditions of walls). The preliminary survey was conducted in the region of Ouarzazate, southern Morocco, in October 2005 (it was carried out by two architects from CRATerre and one from ENA-Rabat, following an anthropologically informed training seminar in Rabat). It confirmed our previous findings concerning the loss of symbolic values, particular techniques, and connections of structural features, and of know-how as well. The practical knowledge lost concerns the capacity to recognize different qualities of earth, good preparation of earth bricks, appropriate proportions and compacting of rammed earth, and efficient maintenance techniques. It also confirmed our preliminary hypotheses concerning the loss of structural connectedness in new buildings and related increased vulnerability from architectural and structural evolution.

All of the issues mentioned above were discussed in the particular geographical context of the southern valleys. However, since our research aimed at drafting a national code, those issues had to be addressed nationwide. Were our conclusions also valid for other parts of the country? Are the contemporary architectural and structural types of the south comparable to those of other regions? Of course, the problem takes different forms for existing and historic structures, and for future and contemporary types.

Perhaps we should first explain why, given the large number of documents and studies of Moroccan regional architectural typologies available to us, we decided to conduct new surveys on the subject. Indeed, Moroccan regional architecture has been an object of interest for scholars as well as for the Moroccan state. The Department of Housing and City Planning has commissioned many studies that resulted in official reports on vernacular architecture. Most of these studies were conceived within the same intellectual mold and were inspired by French colonial literature on typology and morphology. One such study, *Les architectures régionales du Centre Sud* (Chorfi 1991), defines architectural typologies on the basis of the six following criteria:

1. The site: because architectural objects are always viewed in their natural or urban environment
2. Urban fabric, or *formes de groupements*: because urban fabric determines the access to buildings, their relation to streets, their relations to one another, and their visibility
3. Housing organization: groups of functional spaces, their two-dimensional characteristics, and their relations to outside spaces
4. External morphology: external volumes, facades, surfaces, colors
5. Internal morphology: internal spaces both as colored and lit volumes and living spaces
6. Materials, techniques, and building systems (*systèmes constructifs*)

Despite mention of the phrase *systèmes constructifs,* or building systems, as a component of the sixth criterion, a systemic approach to structures is absent. Structural elements are barely described, and connections between them are completely ignored. The approach is mainly concerned with materials, and it remains totally separate from earthquake engineering. When compared to the American approach, it simply reveals the absence of a preoccupation with structural systems. For instance, the approach of the U.S. National Park Service (NPS) to buildings, as set forth in *Guidelines for Preserving, Rehabilitating, Restoring, and Reconstructing Historic Buildings* (Weeks and Grimmer 1995), is based on a set of features that reveals a different view of architectural typology. Among these are:

- Building exterior
  - Materials: masonry, wood, architectural metal
  - Features, roofs (shapes, cupolas, chimneys, vaults), windows, entrances, porches (general forms and shapes, volumes)
- Building interior
  - Structural systems

- Spaces, features, and finishes (interior floor plan, the arrangement and sequence of spaces, primary and secondary spaces defined according not only to their function but also to their features and finishes)
- Mechanical systems

In the NPS *Guidelines,* the preoccupation with structural systems is stated clearly. This is perhaps a consequence of the American culture of earthquake preparedness. On the other hand, the French model, which was the implicit referent for studies of Moroccan regional architecture, was not developed with regard to any logic of earthquake preparedness.

Consequently, our survey was inspired by the American model, with recourse to the World Housing Encyclopedia Report form. Not only did we introduce the notion of structural systems as a criterion of architectural typology, we also adopted a distinction between architectural and structural typologies. If in vernacular architecture the rule is that an architectural type is almost always associated with a structural system, we have noted that in the contemporary context, an architectural typology can be associated with different structural types. The traditional Moroccan urban house can be built with earth in Marrakech, with sandstone masonry in Fez, and with concrete frame in the two cities and elsewhere. A contemporary rural house can be built with traditional materials or with reinforced concrete. Thus, in today's experience an architectural type is no longer connected to a particular material. As Le Corbusier said, "Architecture has emancipated itself from technique. It is the [building] technique which must now bend to the architecture" ("L'architecture s'est émancipée de la technique. La technique doit maintenant se plier à l'architecture") (*Vers une architecture* [Paris: Cres, 1923], 37). Because of this contemporary mutation, the survey was conducted with the aim of characterizing architectural typologies independently from structural systems or types, which had to be characterized on their own. Different entries were devoted to each typology.

Reflecting on Materials and Structure in Local Building Tradition

During our second workshop, traditional housing types and building techniques were presented from an anthropological perspective. The discussion of the earthen construction process and of spatial organization was drawn from Stefania Pandolfo's research in the Wâd Draʿ region of southern Morocco during the 1980s and early 1990s (Pandolfo 1997), with additional information from trips in 2004 and 2005. It was based on the observation of buildings and *qsar* formations; on in-depth interviews with residents on their histories, memories, and poetry (from written documents, property and inheritance deeds, and oral accounts); and, most prominently, on interviews with master builders (*mʿaallem,* plural *mʿaallmin,* in colloquial Arabic and in Tashelhit)—one in particular, Brahim Dagdid, who was still practicing at that time. It is also based on Pandolfo's experience living in one such space in the late 1980s and witnessing the process of the resettlement of a *qsar* community in the desert area outside of its perimeter walls, which was newly constructed in a sprawling, scattered architectural style consistent with contemporary changes in the perception of built space, family structures, cultural reconfigurations, and traumatic disconnections as they are reflected in the growth of new architectural typologies in this area.

Conversations with *mʿaallem* Brahim Dagdid took place in 1985, 1986, and 1989, and they resumed in 2004 and 2005–06 in the context of the present research. These conversations were primarily with author Stefania Pandolfo. Author Mohammed Hamdouni Alami met with several master builders between 2004 and 2006, in the regions of Zagora as well as Tazzarine, in the pre-Saharan region. Of particular interest were master Ait Zayd from the *qsar* of Tamnugalt and master Ourzazi from Tazzarine. These conversations focused on the technique and process of building, on the form of the house, and on the nature of materials, including their transformation and dynamic workings. In spite of their plastic potential, houses inside the *qsar* have a sophisticated structure, conceived according to a specific geometry expressed in the symmetry, interconnection, and internal articulation of the buildings. From the anthropological point of view—but also arguably in order to appreciate the flexibility of these structures in terms that might be of interest to the engineers (who look at structures for their objective properties in order to assess their seismic vulnerability)—it is important to pay attention to the local (technical/symbolic) conception underpinning the process of building, which is expressed in the Arabic and Berber technical vocabulary and in the exegeses of

FIGURE 5 New houses sprawling away from an old *qsar,* Tissergat, province of Ouarzazate.

local master builders. Many knowledgeable *m'aallmin bennay* (craftsmen/master builders) are still alive and are the recipients, if not necessarily the transmitters, of a sophisticated know-how that is practical but also theoretical. In this project on seismic vulnerability and prevention testing and evaluating, in the last instance, are the prerogatives of the engineer, yet the intermediate stages should take other knowledge into account.

Traditional housing types and building techniques were presented on the basis of detailed notes taken by Stefania Pandolfo during and after conversations with *m'aallem* Brahim Dagdid in Beni Zouli, Zagora, in 1985 and 1986. At that time, the *m'aallem* was still working, and people were still living inside the old *qsar.* However, the communal land outside the walls and in the direction of the open, arid pre-Saharan plateau, where there is an alternation of cultivated and irrigated oasis and rocky wasteland (away from the river and the gardens), was in the process of being divided and allocated; in the space of less than four years, the *qsar* would be abandoned, quickly transformed into a ruin. A new village was built in the open land at a small walking distance from the old *qsar,* and a new architectural style was introduced and quickly spread over the entire territory (a grid plan had been brought in by the local authorities and had been adapted to the needs of the community). As mentioned above, this process is not specific to the *qsar* in question but is characteristic of a general transformation in the southern valleys and in Morocco at large (fig. 5).

In telling about the technique of construction, the *m'aallem* Brahim Dagdid was referring to other houses in the *qsar* of Beni Zouil, to houses he has built or visited in other *qsour,* and to the house in which he was living. He was also contrasting that technique to the new ways of building outside the walls, the techniques developing in the "new village."

Dagdid's description and interpretation of his art and technique, which he had practiced for more than fifty years, took place over many conversations and was composed of four parts:

1. A description of the qualities and properties of different types of soils appropriate for specific tasks—such as making mortar, adobe, or rammed earth, or waterproofing—and the preparation of the *l-'ajina dyel at-tub,* or earth dough.
   a. Preparation and construction of *l-luh* (*l-luh*—literally, board—refers at the same time to the wooden formworks and to the rammed earth wall itself).
   b. Preparation of *at-tub,* or adobe bricks, and construction techniques.
2. The structure of the house inside the *qsar* and, in particular:
   a. The *as-swari,* or columns, as constituting the structural space within which the house will grow (fig. 6).
   b. The *'tabi,* or wooden beams, that connect different elements of the structures, and the connection with the ceiling and the floor of the upstairs.
3. The *sallum,* or staircase, as an elevated, growing structure articulated and intertwined with wood. This is one of the permanent elements of the house, as are the well and the bearing columns, which may be incorporated into some spatial modification but cannot be eliminated. Each of these "fixed" places is marked by a sacrifice (*debiha*) involving the ritual slaughter during construction of a sheep or, in certain cases, a cock.
4. The relationship between the structure of the house and the structure of the *qsar,* superimposing and merging one into the other.

FIGURE 6 Remains of a four-column structure.

In the master's view there is a *tashbih* (a structural parallel or an analogy) between the transformation of matter/materials and the articulation of structure in the construction technique of the house. Both have to do with coming into being from an inanimate prior state: the coming into being of *ar-ruh* (breath, soul—but also simply the articulation that generates movement and life). Such metaphysical understanding is actually central for the understanding of the building culture, as well as for the logic underpinning its structural dynamics.

In the preparation of the earth dough of which adobes are made, the key point is fermentation, or rotting. The earth used for *l-luh* (rammed earth) is not the same as that used for *at-tub* (adobe). The first is taken from the building site. It is usually coarse and contains a small amount of rocks that need to be removed by hand or by sifting. In contrast, the earth used for adobes is very fine. It is dug out of selected regions inside the gardens and palm groves, and it is usually earth that contains clay and sometimes sand; in traditional practice, the proportion of clay to sand is determined by the touch of the hand. In both cases a shallow pit is dug, water is placed in the pit, and earth is added and left to rest. In the case of *at-tub,* straw (*t-ben*) is added to increase the rotting. The point of this process is to cause swelling and "transformation" in the original material, which is no longer just earth but *modified earth*, subject to chemical modification through fermenting or rotting—a modification that gives birth to "form." Swelling is related to the coming into being of *ar-ruh,* a "soul" or vital principle.

The *m'aallem* went into much detail in explaining the technique of *at-tub* made with rotten earth dough formed in a mold and then dried in the sun, and in explaining the technique of *l-luh*, where the mold is the *luh* itself, the wooden board inside which earth is pressed. But while the *at-tub* bricks are left to dry in the sun until they are ready, the *al-luh* is pressed and beaten down or compressed. While the technique of fabricating adobe bricks is relatively solitary, the technique of *l-luh* is collective—or at least a group task. In the old days when a construction in *l-luh* was begun, the *qsar* would call *hadd as-saym*—those of fasting age—to participate in collective works, such as construction tasks or the clearing of irrigation canals.

According to the *m'aalem,* inside the old house the parallel is between the coming into being of form through rotting (as in the earth dough) and the production of form through articulation, via a systematic network of imbrications and articulations. Indeed, there is a concept in Arabic central to the argument of the master builder that vividly summarizes this central point, the concept of *t'shkal*. Linguistically related to the term *shakl,* or shape, it means making connections through a creation of forms.

The structure of a house inside a *qsar* is vertical, and it is conceived and described by masons as growing around a central void or opening (*'ayn ddar, rahba*—the eye/source of the house) generated by the work of bearing columns (*sariya*, plural *swari*). In the course of our survey in the region of Zagora, the engineer Khalid Mosalam from the University of California, Berkeley, observed that the bearing structure resembles an elevator shaft. A second vertical element is the staircase (*sallum*), which is conceived in a similar style and enacts verticality. The staircase is an articulated wood-and-earth structure. It exemplifies a crucial principle of construction in these houses, which is the articulation and reciprocal imbrications of wooden elements and earthen bricks, and the making of a knot between two elements (the bearing beams of successive flights of steps), which

FIGURE 7 Interior of a house, Tanmougalt.

creates "breathing" (*ruh*), a dynamic articulation and a "soul." It also exemplifies the "movement" of the house itself, growing away from the ground and developing in a standing position. The main difference from the *riyads* in Marrakech is that these are conceived as structures surrounding a garden, whereas the house we are describing in the *qsar* is conceived and built as a structure springing from the bearing columns, which literally generate the space (fig. 7).

When built with traditional materials, the new houses located outside the perimeter walls are built exclusively in *l-luh* (rammed earth), and the manufacture of mud bricks, used in the old houses, is declining because of the change in typology. The new typologies no longer use two of the main structural elements that require bricks—that is, bearing columns and the staircase. When still made, bricks are bigger and less cohesive because the technique of fermentation of the earth dough (*l-'ajina dyel at-tub*) has become less rigorous. There is a general perception that *at-tub,* or mud bricks, belong to the world of the old *qsar* and to the structural requirements of building vertically within a contained and yet connected space, where everything was *mshebbek,* or interconnected with everything else. Not just the mud bricks, but the system of *'tabi,* or horizontal articulations (wooden beams or thresholds), and of the columns themselves was associated with the representation and perception of the old *qsar*. The result is that new houses located outside the walls likely have less stability and flexibility because they are no longer attached and interconnected with everything else. The issue, however, is not to return to a connectedness that today is perceived as uninhabitable—and this from a cultural/social point of view as well as in its technical sense. The question is rather that of the creation of something else, which might newly interpret some key formal principles that might have rendered the *qsar* constructions more stable and dynamic.

In the light of the description of the building practices we observed, the structural typologies of the southern valleys could be defined as follows:

1. A traditional structural typology (*dar dyel bkri,* "the house from the past." *Bkri* is a remote past, a past perceived today as distant, even if from a few years ago, a past perceived as severed from the speaker). This is the model found in the vertical structure of houses inside the *qsour*. It is conceived and described by masons as growing around a central void or opening (*'ayn ddar*, *rahba*) generated by the work of

FIGURE 8 Interior of a house, Tanmougalt.

FIGURE 9 New house, Ait Bouguemmaz.

bearing columns (*sariya*, plural *swari*), with structural components that are interconnected, *mshebbek* (fig. 8).

2. The new structural typology with traditional local materials. This is the model described as horizontal structures where components are no longer attached and interconnected (fig. 9).
3. A mixed typology that is structurally similar to the new typology but makes use of new conventional materials, in particular reinforced concrete (fig. 10).

FIGURE 10 House in Zagora.

In both the north and the south of the country, houses are built around patios. The dimensions of the patio vary with rainfall variations, snow, and altitude. They are larger in the dry lowlands and smaller in humid and snowy places. The classical description made by Jacques-Meunié (1962), according to which the size of the patio decreases down to nothing with higher altitude, applies all over the country. The same observation was made in the northern Rif Mountains by Ben el-Khadir and Lahbabi (1989). There exist, however, differences in the roofing systems. Traditional horizontal roofs observable everywhere are replaced with sloped and gabled roofs in the humid areas of the northern mountains. Structural typologies are similar in different regions, with, of course, a diversity of local materials (wood and stone) and variations in the quality of those materials and workmanship.

To validate these typologies, a preliminary survey was conducted in the regions of Ouarzazate (south center) and Al-Hoceima (northeast) in October and November 2005. Following this preliminary survey and the corroboration of the chosen classification of typologies, a second and more complete survey was conducted in three selected regions, Ouarzazate, Tadla-Azilal (located east of Marrakesh in the High Atlas Mountains), and Taroudant (to the south of Marrakesh), in January and February 2006.

Throughout these regions, and in terms of a more in-depth survey, our hypothesis of the existence of three main typologies was confirmed: an "old" structural typology characterized by a spatial compactness and the tight articulation of structural elements; a "new" structural typology characterized by incremental additions and a loose articulation of discrete elements producing the effect of sprawling structures and settlements; and a mixed typology structurally similar to the latter but making use of a combination of conventional and earthen materials. While the "old" typology, found in old earth-and-wood structures, is no longer in use, the "new" typology maintains the use of local materials and somewhat degraded traditional techniques that highly increase the vulnerability of buildings. In the course of our survey, however, we saw a small number of extremely well built structures at sites where master masons were motivated to perfect their technique, for the know-how is still alive. The structures that make recourse to a mixed typology are paradoxically the least resistant, in

spite of the use of concrete. They are less resistant precisely because concrete is perceived as evidence of strength and social success but is used without respect for the rules of good practice (for example, salty or muddy waters are used in making the concrete, concrete beams are constructed without sufficient iron bars, and posts are installed without a footing or foundation). Slight variations were found in the size of openings, the width of walls, the quality of the workmanship, and the inclusion of stone masonry in the construction, particularly at the level of the ground floor. Variations were also found in the technical vocabulary, but generally the typological transformation is quite consistent over the regions we surveyed.

FIGURE 11 Structure exhibiting a mix of materials that reveals ignorance of rules of good practice.

Conclusion

While visiting a construction site in Tanmougalt, a *qsar* in the upper Wâd Draʿ region of southern Morocco, on February 26, 2006, the *mʿaallem* Ayt Zayd, who has forty years of experience, was interviewed by author Mohammed Hamdouni Alami. In this interview he indicated an old wall and said,

> Look at that wall, it is a hundred years old yet it looks in great shape. Now look at this one, it is not more than four or five years old, and it is already badly eroded. It is the same earth, the same material. . . . New buildings do not last because they are badly made. Workmanship is not good nowadays. In the old days the rammed earth was watered during eight to ten days, until it fermented enough, until it was ready. Only then was it worked in the *l-luh,* and it was worked well, well compacted until it became hard like stone. The test was to leave the mold of the newly rammed portion of the wall and to cover it with water. If the water was still there the next day, the rammed earth was said to be good and building could proceed, but if the water was absorbed by the rammed earth, that meant that this was not properly compacted. That portion of the wall had to be destroyed and rebuilt anew. . . . A master and his aides could make only two or three *luh* (blocks of rammed earth) per day then. The master permanently had to check the quality of his rammed earth. Nowadays it is different. No tests of quality are performed. Masters think in monetary terms. They see their work as a cash flow: thirty Dhs [about three U.S. dollars] per *luh.* To make more money, they have to work faster. Today a master with his aides makes up to eight or even ten *luh* per day. He doesn't care about compacting well enough or tying adjacent walls or anything of the sort. He sees his work through money. In the old days money was not an issue, what people sought in the work was quality, work that had stood the test.

The *mʿaallem* kept explaining the fatal downslide of workmanship and building traditions (see figs. 11 and 12), yet his attitude was serene. Time was doing its work, that's all. Good practice may prevail again some time in the near future. It is hoped.

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FIGURE 12 Building a rammed earth wall today, Ait Bouguemmaz (notice joint defects).

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