International Course on Stone Conservation SC13

SESSION: Introduction to porous building materials and stone conservation

INSTRUCTOR: Giacomo Chiari (Lectures heavily based on Giorgio Torraca's course)

TIME: Wednesday, 17th April/ all day

SESSION OUTLINE

These lectures are dedicated to the memory of Giorgio Torraca, who was my mentor, my colleague and my friend for over 42 years. His ability to make complex concepts simple and understandable was proverbial. I will do my best in his honor.

ABSTRACT

By "stone" we mean here both the natural rocks and the artificial composites of mineral nature (like mortars, plasters bricks etc.) Stone decay is the result of various processes of physical, chemical or biological nature. Man, with his various activities (use, repairs, modifications, wars, vandalism, demolitions, tourism and even restoration), plays an essential role in stone deterioration. The factors that determine the course of the decay processes are the physical properties of the material (mainly, its porosity), its mineralogical composition (the texture, size and chemical nature of the crystals), and the type of environment to which it is exposed.

Water plays a major role in stone deterioration of most types, especially when it is in the presence of soluble salts. Biological processes of deterioration are not discussed in this lecture. Deterioration processes of different natures frequently act simultaneously, a fact that makes the diagnosis of stone diseases difficult, but here, for didactic purposes, they are discussed separately.

OBJECTIVES

To introduce the fundamental concepts of stone deterioration and conservation. The lectures will not delve into the chemical and physical details of the aforementioned phenomena nor will they cover the analytical procedures for diagnosis and data collection. These will be addressed by readings and by other lecturers in the course.

LABORATORY TEST

A lab exercise will be performed on the afternoon of April 17. It will deal with the measurement of open porosity. The students will be engaged in designing a simple test, useful for porous material samples. The test will be run in multiples (groups of two students will work on the same materials) and the results will be compared and discussed in detail with the class. Alternative methods will be demonstrated for porous surfaces that cannot be sampled.

CONTENT OUTLINE

<u>Characteristics of water and its role in stone deterioration.</u>

Water has very specific properties, different from most other substances. It freezes and boils at higher temperatures than comparable substances. It is the best solvent for salts. It adheres well (wets) to most minerals. It takes a large amount of energy to increase its temperature and to evaporate. It rises by capillarity in porous materials and has cycles of condensation/evaporation in the range of temperatures normally present in temperate climates. All these characteristics, and their implications for stone decay, are explained using very basic chemistry.

Mechanical decay processes.

Stone is a rigid and brittle material, exhibiting good compressive strength and low, unreliable tensile strength (varying from one test to another on the same stone).

Because of stress concentration mechanisms, the resistance of stone to stresses generated by the loads acting on the structure or by environmental factors (temperature and humidity cycles, human actions and others) depends upon the conditions of its surface. Two slabs of the same stone, one presenting micro-fractures and the other one without them have a very different tensile strength. Water plays a role, since a stone, when wet, has a different stress resistance than when dry.

Human activities (quarrying, carving, cleaning) result in an acceleration of deterioration rates if they cause the formation of fissures (micro-cracks) in the surface of the material.

Physical decay processes

Stones are porous "hydrophilic" materials, i.e. materials that show a marked tendency to attract water. This important phenomenon is described in detail. The penetration of water in pores and fissures, followed by frost (in cold climates) or salt crystallization (that is particularly dangerous in dry windy conditions) results in the formation of crystals (ice or salt) inside the pores; the intensity of the internal stresses that are generated by crystal growth depends upon the type of substance crystallizing, the environmental conditions, the total porosity and the pore size distribution. Stone may also deteriorate under improperly distributed loads.

Chemical decay

Acidic water solutions formed by natural or anthropic processes in atmospheric water (rain or dew) or in water rising from the soil can attack various minerals present in building materials. The result of the acid attack depends not only upon the acid concentration and the chemical and mineralogical composition of the stone but also upon the mechanism of "deposition" of the water on the object. It is important to know that water is required for chemical reactions to take place.

"Wet deposition" (i.e. the direct action of rain) on calcareous materials results normally in the erosion of the exposed surfaces and in the formation of white calcareous incrustations where the water evaporates. On the surface of siliceous stones, rainwater activates "leaching" processes that involve the partial transformation of some siliceous minerals into clay and soluble salts; the result is the formation of soft, slightly swollen, surface layers.

"Dry deposition" (dew) deposits on stones a film of water containing particulate matter and dissolved acids; in polluted atmospheres the process produces dark crusts in areas that are not periodically washed by rainwater. The dark crusts, rich in sulfates, are not a protective patina as they allow penetration of acid water. Deposition of soluble salts and thermal movements frequently result in the loss of cohesion of the crystalline structure of the stone.

"Rising damp" coming from the soil percolates through the material within a complex pores network and normally dissolves soluble salts, carrying them to the surface. Upon evaporation the salts crystallize either in the pores (subflorescences, much destructive) or on the surface (aesthetically disturbing efflorescences, generally white).

LAB EXERCISE 1: NORMAL 7/81
WATER ABSORPTION BY TOTAL IMMERSION (freely translated by Giacomo Chiari)

Application: Stone materials, deteriorated and not, treated and not.
Goal: Characterization of stone materials, their degradation and evaluation of preservation treatments.

1) Definition of the measured properties:

   Water absorption by total immersion: weight % (with respect to the dry mass of the sample) of the water absorbed by a sample completely immersed in water.

2) Sample preparation:

   Shape and dimensions: The shape should be regular, (cubes etc.) 3-5 cm (no more in order to have a surface/volume ratio 2-1.2 cm^{-1}). The minimum size needs to be compatible with the homogeneity of the material. Samples should be carefully washed to remove dust from the surface.

   Drying: In oven at 60°C (in order not to alter possible treatments) until constant weight.

   Number of samples: at least 3 to check for reproducibility and to estimate the error.

3) Measurement procedure:

   Dried samples are located in a container, minimizing the surface of contact of the base. De-ionized water is poured in until samples are completely covered (2 cm). At regular intervals of time (to be defined by a preliminary trial on the basis of the material) extract the samples, remove the excess surface water and rapidly weigh them. The measurements after 1 and 8 hours are mandatory. After each measurement the samples are again immersed in water. The measure continues at intervals of 24 hours until the quantity of water absorbed in two successive measurements is less that 0.1%.

4) Treatment of the results:

   Calculations: the quantity of absorbed water in the time t_i is given by:

   $$\mathbf{M_i - M_o / M_o \,.100}$$

   Where: M_i = mass of the sample with absorbed water at the time t_i

   M_o = mass of the dry sample M_i-M_o = mass of water absorbed at time t_i

   Since at least 3 samples were measured, the average value of the measurement is taken for M_i

5) How to present the results: A table with:

   Number, shape and dimensions of the samples; Values of the absorbed water at the various times of measurement; A plot of the absorbed water as a function of time.

LAB EXERCISE 2: OPEN POROSITY MEASUREMENT BY CONTACT SPONGE

General description: This is a noninvasive method to measure total porosity. It is based on the concept of water absorption, assuming that the stone pores would be impregnated by the water contained in excess in the sponge. It is almost impossible to control all the parameters at stake to be able to standardize the procedure and obtain quantitative results. For this reason it can be used mainly for comparison of different conditions, analyzed by the same operator, in order to obtain qualitative differences between similar situations (e.g. before and after a waterproofing treatment etc.). It is very similar in principle to the Karsten tube test (Normal 44/93), but it presents some advantages in the practice.

The method: a wet sponge (controlled amount of water) is left in contact with the surface for a given time. The amount of water transferred to the surface gives an estimate or the water absorption. This value can be influenced by the amount of water already present in the pores. Since it is noninvasive, in this method the sample cannot be previously desiccated. Therefore to compare measurements, they should be performed in the same environmental conditions (T and RH%).

Material needed:

- A precision scale (precision of 1 mg is advised).
- A contact sponge
- Polycarbonate container
- 10cc plastic syringe with a cut needle 0.9 mm in diameter
- Polyethylene bags.

Procedure methodology:

1) Thoroughly wet the sponge with distilled water until completely dilated. Squeeze it and dry it with absorbing paper leaving it slightly wet. Then insert it in the plastic container.
2) Using the syringe, add 6-7 ml of distilled water to the sponge. The water quantity should be tested by squeezing the sponge against the surface. The water should not run along the wall.
3) Close the plastic container and weigh it. This is called **Wi = initial weight**. Take note of it.
4) Remove the cover and position the sponge in contact with the surface, possibly on flat parts, pressing it so that the board of the container is touching the surface of the stone. It should be kept in position a given time t (1 to 5 minutes depending on the conditions of the material).
5) Close the container and weigh it again. This is called **Wf = final weight**.

Calculation of the absorbed water (Wa): expressed in gr/cm2.min

Wa = (Wi-Wf)/23.76 . t

Where: t is the contact time, in minutes

Wi is the initial weight and Wf the final weight in grams

23.76 cm2 is the contact surface of the sponge

How to present the results: it is advisable to make more than one measurement (at least three) and take the average value. Add to the final Wa the other three parameters, and when possible, the values of T and RH% during the essay.

This material was taken from the C.T.S. S.R.L. Via Piave 20/22 36077 Altavilla Vicentina, which provides a kit for this test, originally proposed by CNR-ICVBC. Translation by Giacomo Chiari.

READINGS

🕮 = Essential reading material
💻 = Available online

🕮💻 Torraca, Giorgio. 2009. *Lectures on Materials Science for Architectural Conservation*. Los Angeles: Getty Conservation Institute. Ch 1-3
http://www.getty.edu/conservation/publications_resources/pdf_publications/pdf/torraca.pdf

The printed book it is available on demand for a small sum at:
http://stores.lulu.com/gettyconservationinstitute

🕮 💻 Doehne, Eric, and C. A. Price. 2010. *Stone Conservation: An Overview of Current Research*. 2nd ed. Research in Conservation. Los Angeles, Calif.: Getty Conservation Institute.
http://www.getty.edu/conservation/publications_resources/pdf_publications/pdf/stoneconservation.pdf