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Full Length Research Paper

Characterization of a composite material in adobe subjected to natural weathering: The case of El Hara Djelfa- Algeria

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This work presents an experimental study carried on the characterization of a local material polyphasic used for the interior temperature control in a climatic environment subjected to very important temperature variations. The physical and structural properties of the composite allowed a durability of the buildings during millenia. However, the raw ground is weakened by deterioration due to the effect of the atmospheric parameters. The taken samples were the subject of chemical, mineralogical and micro structural analysis. The results showed that there is a relation between the structure, miniral and chimical, and the durability of material.

Key words: Believed ground, physical properties, structure and durability.

INTRODUCTION

The Construction of masonry in adobe is a very old manual mode. It consists on the manufacturing of blocks in metal or wood moulds, that have a squared form of 30 to 40 cm with a thickness of 10cm approximately dried by sun heat (Yetgin et al., 2008), in which we put a mixture of clay material (0/2 with 0/5 mm), mixed with a water content of about 30%, and can be reinforced by imputrescibles selected vegetable or animal fibers (Guillaud et al., 2006; Pignal, 2005).

The raw clay material is a porous environment multiphase including a mineral solid phase made up mainly of unaltered primary minerals such as the gravels (2-20 mm), sands [quartz (0.06-2 mm)], which form the granular skeleton and confer to the material a rigid frame structure and altered or colloidal secondary minerals, like clays (lower than 63 µm), ensuring cohesion. The liquid phase is mainly made of water and the gas phase (Fountain, 2004).

One of the principal goals of construction with clay is to protect the occupants from the climatic effects (heat, cold), by creating a satisfactory interior microclimate for the exercise of various activities (Steven and Richard, 2005; Parra-Saldivar and William, 2006). It is a question of protecting the occupants against the climatic factors: rain, wind, direct solar radiation (Bentz et al., 2000).

However the adobe is a natural material with weak environmental impact because of its porous structure (Millogo et al., 2008; Atzeni et al., 2008). The capillarity effect is a constraining factor for a broad use of the adobe (degradation in moisture) (Xian-qing et al., 2003). The objective of this work is double: on the one hand it is a question of developing a new local adobe, and on the other hand to study the damage of raw clay material in relation to its microstructure, with an aim of better understanding the mechanisms of deteriorations of material. The results obtained put forward the relation between the degradation of material and its structure.

EXPERIMENT

In order to answer to the objectives of this work, we must characterize construction material of the place of the palace El Hara built at the time of the othomans in 1720. It is located at the Ain Ibel daira in Wilaya of Djelfa (south of Algiers) and determines the various types of deteriorations which affect them.

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N = The similarities found in different places in palace, led us to limit our work on the chosen wall according to description related to the architecture, the structure, the color, the forms of degradations and their localization according to the site (the base, medium and the top) and according to the exposure to the sun, the rain, the wind and the anthropic activity, which reflect coarsely what we observe on the other walls.

On that wall, we took the composite of adobe and we performed the characterization of its chemical and mineralogical compositions. This we realized with a diffractometer of the type Philips MPD X PERT Pro which has copper anticathode equipped with a detector X' accelerator (220 W, 55 MY, 40 Kv) at the laboratory with Center and Technology of Construction Materials of Boumerdes (Algeria).

The pétro-physical parameters such as: the apparent bulk density by hydrostatic weighing (NF P 98.250-6) and specific to water (NF P 94-054), and then calculated its total porosity of the composite, were determined at the Ceramic Laboratory of Boumerdes University.

To better understand the manufacturing process of this composite material we determined the organic content of matter by calcination (XP- P 94-047), which indicates the quantity of the introduced straw, and the granular distribution of the components in this mixture.

After having dissolved this block in 60°C water and avoided the crushing of the brick to keep true the dimensions of the components. The solution of composite is washed with the 63 µm fraction, the recovered and dried remaining unsifted fraction by sifting according to standard NF P 94-056.The particles inferior of 63 µm determined by sedimentation method (by the pipette of Robinson (NF P 94-057)).

The study of the degradation of this material consists to follow the evolution of the vertical deterioration of this composite in the studied wall by changes of their physical and petrography parameters.

A tightened sampling of the studied sections was carried out by coring of the surface of the wall following the core intervals: 30, 70, 100,150,180 and 220 cm height of the wall, in order to study the physical properties such as the apparent density and the porosity which were done according to standard NF P 98.250-6. These results make it possible to provide a first indication on the degree of compaction of construction material, like on its capacity for absorption and storage of the fluids according to the height of the wall.

The carbonate content is determined with the calcimeter of Bernard, according to standard NF P 94-048. However, the extraction of soluble salts was carried out on 100 mg of the composite sample dried beforehand with the drying oven at 60°C and finally crushed (Pansu and Gautheyrou, 2003). Each sample is then put poured in 100ml of water, which is then poured in a flat-bottomed polyethylene bottle. After 72 h of shaking in a thermostated place at 20°C, the conductivity of the solution is measured, then others measures are performed every 24:00 until the conductivity stabilizes. The proportioning of the available anions and cations in the solution is done after filtration.

The microstructural changes were deduced by a petrography study on thin blades prepared by specific protocols of the composite taken from the three levels (the base, the median part and the top) of the wall, studied with a photonic microscope polarizing of type NIKON (objective X4, graduation = 25 µm) at the laboratory of geology, university of Meknès, Morocco.

RESULTS AND DISCUSSION

Characterization of material

The chemical composition of construction material highlights high percentages of SiO_2. They represent more than 69% of the total chemical composition. The other chemical elements present low contents with light variations are given in Table 1.The spectrum of diffraction of x-rays of the composite indicated in the Figure 1 shows up the peak charac-teristics of quartz to 65%. The presence of other minerals is also noted: calcite (7%), Feldspars `K' (7.5%), the gypsum (8%) at identical frequencies in the whole of the sample, considered as products of deterioration, formed by the crystallization of soluble salts such as sulphates of ammonia (NH_4) $2SO_4$ or sulphates of calcium $(CaSO_4)$.

Table 1. Chemical composition of the ground composite.

Components	Percentage (%)
SiO_2	69.26
Al_2O_3	5.58
Fe_2O_3	2.49
CaO	8.13
MgO	1.13
SO_3	3.77
Na_2O	0.15
K_2O	1.76
P_2O_5	0.06
TiO_2	0.39
Loss on the ignition	7.28

The presence of muscovite, 4.5% in the matrix of the composite, causes risks of cracking in the total structure, and results from the trapping of water in the structure of this clay minerals (muscovite), which involves a reduction in porosity and inter-connections caused by their swelling.

The hydration/dehydration alternation leads to a loss of consistency of material and makes it still more sensitive to the phenomena of swelling/shrinking of muscovite. It appears that the clay particles will be organized locally until perfect anisotropy (propagation of micro fissuring, exchanges of the fluids) (Dudoignon et al., 2004).

Figure 2 shows the granular distribution of the skeleton of the composite, with a presence of 40% of the fraction end (0.063 mm), considering it as the clay fraction and remainings in the sand.

The sedimentation method shows us three classes of introduced clay: coarse silt (40%), average silt of 20% and the fine silt of 40% which are responsible with filling of the pores on the microstructural level.

By simplifying the maximum that environment, and breaking down into two chemical species (quartz and clay), particle interaction forces involved are different. Both species can be considered as electrically charged objects have surfaces, surrounded by water molecules. For quartz surfaces are covered with hydroxyl groups-OH, whose charge changes according to pH of the aqueous solution (Van Damme, 2002a).

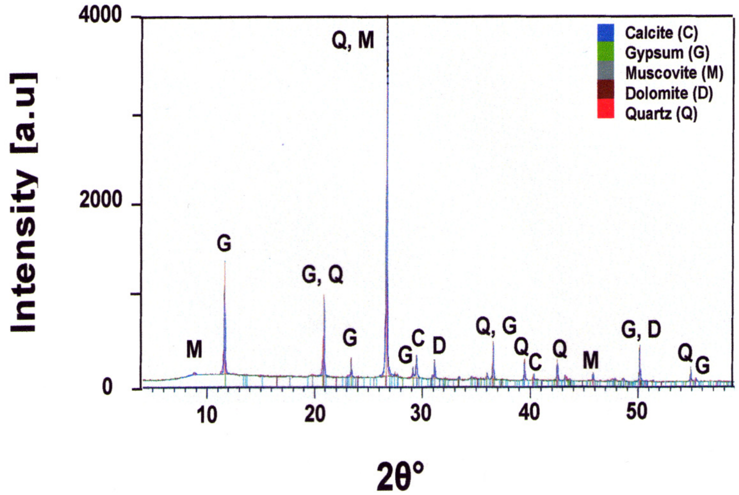

Figure 1. Analysis with x-ray of the composite.

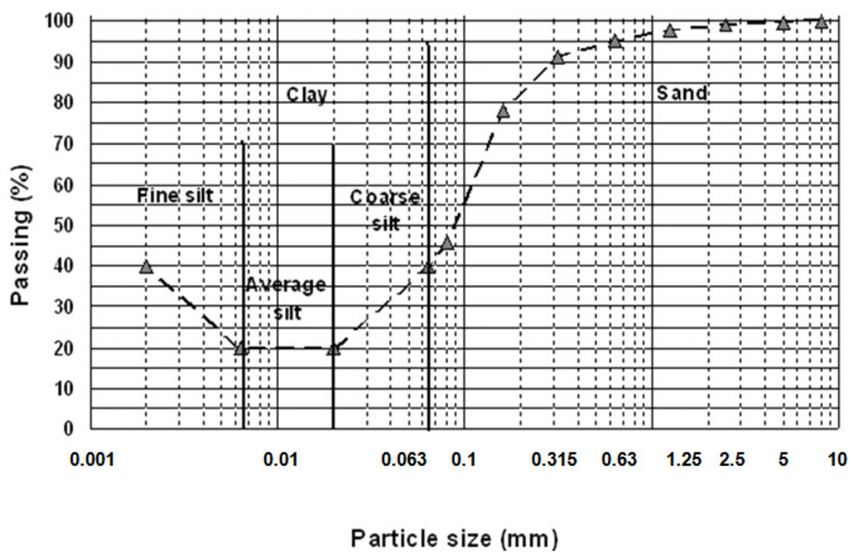

Figure 2. Granulometric distribution of the composite.

The forces of cohesion, allowing link physicochemical Van der Waals forces are relatively weak.

A dominant force that makes it essentially concerns millimeter grains, it was shown that two other forces can play an important role: the frictional contacts 'dry' type Coulomb and contacts 'lubricated' respectively in aging contacts (micro-roughness and capillary condensation) and therefore the damage in granular assemblies. It becomes clear that the holding of a building can be expressed only by the presence of other physico-chemically different species (clay).

Thus, the studied raw clay is a mixture of clay and sand and their granular distribution play an important role on the texture (porosity and micro porosity) and their physical and petrography behaviour.

Characterization of deterioration

Petrophysic study

The apparent densities over the studied section are relatively similar, and the percentage of porosity makes it possible to distinguish three segments along the part studied (Figure 3):

1. Height lower than 1 m, we note a reduction in porosity towards the base of the wall;

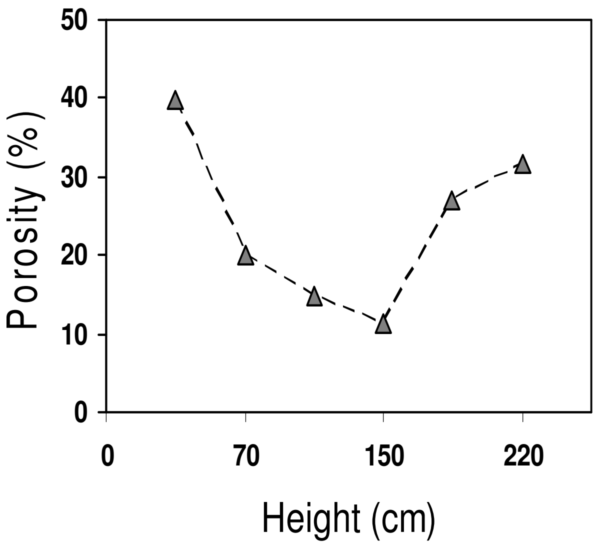

Figure 3. Evolution of porosity in the composite of the wall of palate Hara.

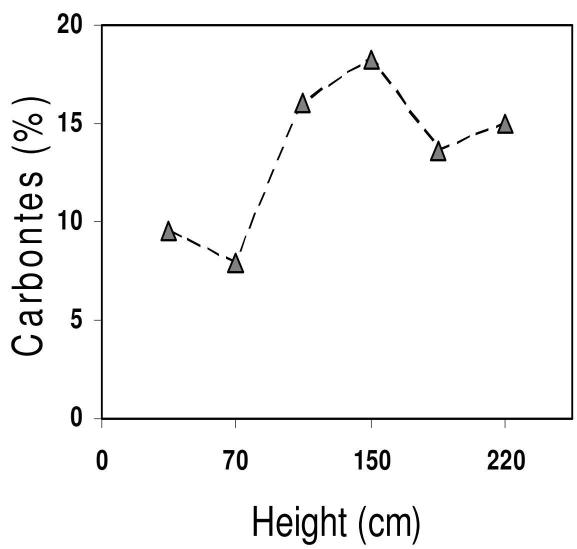

Figure 4. Distribution of the percentage of carbonates in the wall of palate Hara.

2. Height ranging between 1 and approximately 2 m, porosity is relatively high and constant;
3. Height higher than 2 m, porosity increases again.

On the lower part and higher of the wall, the circulation of fluids would be responsible for dissolution and crystallization by the phenomena of adsorption and the capillarity (Salif, 2001; Ajakane et al., 2005). Thus, modifying the porosimetric character of materials. This is confirmed by the observations of the thin blades which show signs of important dissolution, towards the top of the profile, whereas towards the base it is a healthy material with a closed porous network. In the median part (between 1 and 2 m), the high value of porosity supposes a material less compact, and thus, would facilitate the drain of rain water towards the low part.

The evolution and the variation of porosity previously described are certainly related to the heterogeneity of material as well as to the capillary increase, which recrystallize.

The curve representative of the percentage of carbonates according to the height of the studied section (Figure 4) can be subdivided in three segments in the same way as the other petrophysic parameters previously studied.

From the base of the wall, we note a reduction in the calcite, which we can allot to a washing of this one by ascending capillary water. In addition, the increase in the percentage of calcite since the top of the section up to approximately 2 m would be the result of a washing of this one in relation to rain water. Between the two segments, the fluctuations are not very significant.

In the wall studied, the water contents are practically constant (goshawks of 3%) along the first meter and decrease abruptly between 1.5 and 2 m height approximately, beyond that the tendency is reversed, and the water content starts to increase.

The evolution of the water contents thus described can be explained by two types of circulation of solutions: one ascending related to the capillary increase, strongly felt towards the base of the wall; the other, downward could correspond to a contribution of rain water.

The brutal reduction in the water contents between 1 and 1.5 m height is to be put in relation to the degree of differential compaction of the material, which governed the draining of water.

Figure 5 shows that the nitrates are by far the most abundant salts, with a percentage of determination generally higher than 0.5%. However, at the base of the profile the salt concentrations reach 3%. Though, higher than the usual values, the contents of chlorides and sulphates are relatively weak; their concentrations are respectively of 0.8% and 1.30%.

According to the distribution of salts in the section studied, one notes that the nitrates develop less beyond 1m 50 above the ground. They would be thus related to the capillary increase and corroborate our assumption of an important water circulation to the top of the wall, but the presence of sulphates and chlorides on all the height with relatively constant and very weak concentrations compared to nitrates which can probably be dependant on another type of circulation of solution from top to the bottom related to the rain water (Ajakane et al., 2005). This circulation is made possible by the deplorable state of the coating and also by the presence of an aqueduct in the summit part of the wall.

The nitrates frequently met on the surface of bricks of composite of the old monuments can have several

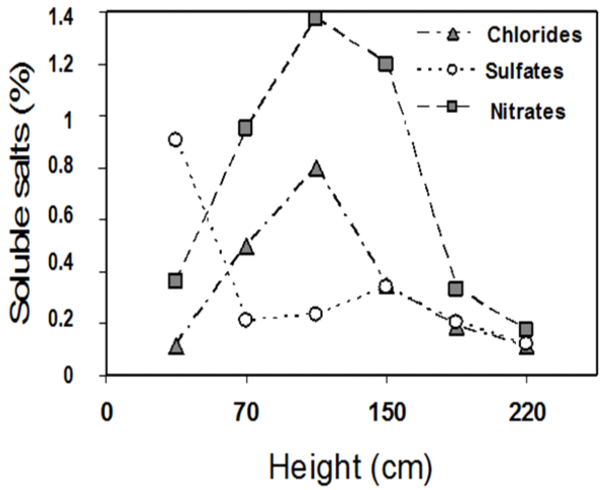

Figure 5. Distribution of soluble salts in the wall of palate Hara.

origins. Indeed, the nitrates can result from reactions between carbonates of construction material and the sulphates (Billault, 2004).

They can also result, in particular, from the biological activity of the bacteria which oxidize ammonium in nitrous acid, which is then oxidized in nitric acid by nitrous-bacterium. In its turn, the nitric acid reacts with carbonated minerals of construction material to produce nitrates. This second assumption is most plausible considering the intense development of algae, lichens and possibly of bacteria on this level (Avrami et al., 2008).

Petrography study

The construction material of the palace is a natural composite of red color brown, very friable especially towards the base and less and less friable while going to the top of studied surface. It is composed of a mixture of more or less stony clay ground, sand, limestone which we often find in form of white grains and a small amount of vegetable fiber of the straw in general.

The microscopic observations of the adobe show a micritic matrix; by order of importance these elements are: Quartz grains (Q), sandy limestone Aggregate (c), clay matrices (mica), the Orthoclase (feldspar K) and of the traces of the metamorphic rock present in the form of the quartzite (Q)

On the basis of observation indicated in the Figure 6, we deduce that the quartz grains of millimeter-length size are more abundant compared to the remainder of the elements due to the introduction of a quantity of sand during manufacture. While the composite of the ground is rich in pores, we meet vacuoles and cracks developing an important porosity on all the length of the wall. Indeed, we witness, here, an increase in porosity especially towards the top and the base of the section always coupled with a reduction in the concentrations of carbonates. In a general way, the studied profile presents three segments from which the behaviours is different with respect to the parameters petrophysic. These behaviours are to be put in relation to the degree of differential compaction.

This phenomenon can be explained by a modification of the intergranular bonds, on the one hand by the pressure which a part of water generates on the not drained pores and on the other hand, by the trapping of part of water in certain minerals which use the composition of material, which generates two different phenomena.

The microscopic observation of the grades at the bottom (Figure 6a) and top (Figure 6c) of the wall correspond to the phenomenon of the dissolution of material and the draining of certain chemical elements in the direction of circulation of solution, in agreement with the water contents which shows two types of circulation of solution: first the downward related to the rain infiltration of water and the second related to the shown again capillary.

In both cases the dissolution of calcite allowed the creation of an important porous network. About the middle of the section (Figure 6c) the variation of porosity is the consequence of a water loss and crystallizations of new compounds.

Indeed, as water evaporates we notice that the opposite phenomenon to the dissolution, which is relative to the concentrations of calcite that is responsible for the reduction of porosity. This phenomenon is sometimes observed in other cases, such crystallisation of nitrate, chlorides and sulphate caused by the relative humidity and temperature variation.

Conclusion

The study of the degradation of the natural composite of palace El Hara has brought invaluable information to us:

1. The circulation of water solutions in the pores is responsible with the phenomena of crystallization and compaction for the composite;
2. The loss of mass of the adobe composite in the first meters form the ground is related to dissolutions by the capillary increase;
3. The petrographic observations led us to confirm that the phenomenon of dissolution has increased the permeability of the adobe gradually caused in exfoliation and the crumbling of material. Particularly, on the frontages exposed to rain water, which soaks the adobe. The socking can cause many separations affecting the coating on all the height of the wall;
4. The evolution of the petrophysic and chemical parameters of construction material highlight two types of

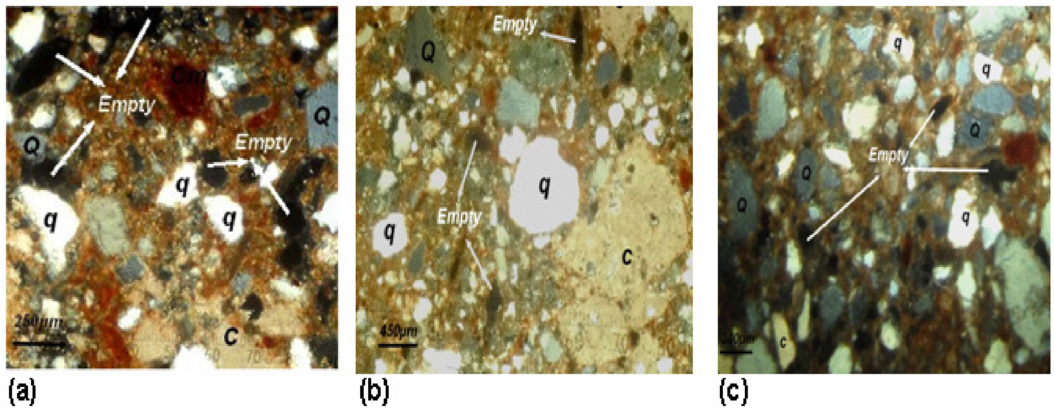

Figure 6. microscopic Characteristics of the composite of the wall of palate Hara of the thin blades under polarized light.

circulations: one ascending related to the capillary increase that is marked on the basis of section, which transport calcite and nitrates to the top of the wall. These capillary increases, are responsible for the recrystallization and the concentration of calcite at higher levels (filling of porosity). The other is the downward visible between 1.5 and 2m and corresponds to the contribution of water. The last phenomenon (rain water) is responsible, amongst other things, with washing of the material from top towards the base of the section, leading to the filling of the pores on the base of the wall of and a dissolution matter of top;

5. Through, there are other parameters, as entropic and biologic, which can degrade the adobe construction; water remains the main factor responsible of this degradation;

6. Finally this work is interesting and appreciable present experimental result can be used for traditional construction. Adobe raw materials exist with a very large amount in the south of Algeria and are used for the conservation of the palace of Djelfa. In terms of comfort adobe studied give a good climate control to traditional construction.

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