Study Of The Hydric Behavior Of The Composite In Earth Elaborated With The Local Raw Materials

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Abstract: Our study aims at developing compatible raw compositions of earth with building materials in the desert zones, for an adequate restoration. To arrive at our objective, we developed compositions of adobes in bases of the local raw materials (red clay of Adrar, sand of dune, the black sand and the chopped straw). The results of the mineralogical characteristics, physical (density, the humidity and the grading analysis) used raw materials, showed successful and compatible characteristics with the building materials of the Saharan ksour. The formulations are based on compositions witnesses as reference (1 Volume of clay + 2 Volume of sand + water). The objective of this study, concerns the identification of the various mechanical characteristics (mechanical resistance in the flexion and in the compression), followed by an ultrasound study (mechanism of change in front of hydric behavior), of the compatible adobe with the local building materials.

Keywords: Adobe, elaboration, ultrasound, structures in earth, hydric behavior, restoration.

1 INTRODUCTION

The adobe is used as material of construction since millenniums and its use is worldwide extremely spread. We estimate, globally, that approximately half of the world population is accommodated in such a housing environment [1]. The earth is a natural material and a piece of furniture, a mixture of gravels, sands and clays; it is an extremely heterogeneous material, the characteristics of which are very diverse from a region to another one. His characteristics were, until very recent period, relatively badly known because of the varieties of the traditional modes of construction in earth [2]. The properties of the earth are: his plasticity (property to undergo deformations without notorious elastic reaction), his compressibility (capacity to be allowed compact according to its rate of humidity), its cohesion (traction resistance of a test tube of raw earth) and its granularity. The more or less red color of the earth is essentially due to its more or less important content in iron oxide. These oxides have only not much impact on the physical qualities of the material of construction [3]. The brick of Adobe consists of clay, water, straw and diverse aggregates in variable quantity (mostly sand, gravel), these used aggregates depend on their availability on the site of the construction [4]. Originally, the bricks of Adobe were trained (formed) in the hand, later (and even today), they are made by means of molds in the various wooden forms or in metal. They are air-dried during several days [5]. The presence of the constructions in raw earth is widely associated with the rural circles, with the desert. For the construction in raw earth, we use the available materials in the environment which we add to the solid matrix such as the sand, the natural fibers and the other additions. The necessary presence of a sociable disposition (the clay) of natural origin assuring the cohesion of the solid matrix.

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Nevertheless the use of this plentiful natural material and the techniques of its implementation are more and more endangered. The ignorance of the qualities of this material made that several countries reject him to the detriment of the new materials. The objective of our work is the elaboration and the characterization of a formulation of Adobe of compatible raw earth with the building materials of ksour Saharan of Algeria. So we try to bring clarifications on mechanisms changes (hydric behavior), and of answer as for an adequate restoration for the old build in raw earth.

2 EXPERIMENTAL TECHNIQUES

To answer the objectives of this work, we have to characterize materials first ones (clay and sand of dune of the wilaya of Adrar and the unrefined black sand of the sand pit of the wilaya of Boumerdes) used for the formulation of the bricks of adobes, and determine the various chaps and the mechanisms of change which affect them. We make it with a diffractomter of the chap Philips MPD X PERT Pro which has anticathode of copper equipped with a detector X accelerating (220 W, 40 KV) in the laboratory of the technology of the building materials of Boumerdes (CETIM-Algérie). The petro-physical parameters such as: the density is similar (NF P 98 250-6), the absolute density (NF P 94-054), and determination of the weight moisture content (NF P 94-050), grading Analysis by sieving (NF P 94-056) sands, and grading Analysis by sedimentation of the clay (NF P 94-057), were determined to the laboratory of ceramic at the university of Boumerdes. The elaboration and the characterization of a formulation of compatible adobe with building materials, in raw Saharan earth of ksour in Algeria. Several formulations of adobes were developed at the level of the laboratory. The choice of the elaborate compositions is based on a bibliographical synthesis, experiments lived by architects and the results of the works realized in this domain. The preparation of samples is realized in molds prismatic wood of size (4x4x16 cm). The protocol of elaboration of the present adobes of the main stages in the formulation:

- Preparation of the mixture: drying in steam room of raw materials (clays, sands) during 48 hours in 110°C; weighing of the clay, the sand and the straw in the desired proportions. Dry kneading (between 5 and 10 minutes) then progressive addition of the quantity of water wished (approximately 15 minutes); packaging in bag blows up tight laying 48 hours.

- Elaboration of test tubes: transfer of the mixture in the wooden molds covered with a plastic film; manual Compaction 4 to 5 sleep with use of a needle between every layer; vibration textbook (manual worker);

Drying and storage: the drying was made at room temperature (free Drying has the hombre), the temperature varies according to the days of (22 in 38°C ±2). Calculates him masses of the constituents of every formulation of all the compositions is made by following the method described previously.

Composted them chosen as these studies are:

Cp1: 1 Volume of clay + 2 Volumes of sand of dune + water

CP2: 1 Volume of clay + 2 Volumes of sand of dune + 3 % of the straw + water;

CP3: 1 Volume of clay + 2 Volumes of unrefined sand + water;

CP4: 1 Volume of clay + 2 Volumes of unrefined sand + 3 % of the straw + water.

The necessary mass of every constituent in the formulation of adobes is determined according to the densities of very constituting to arrive at the more exact quantity of every component in every formulation. Calculates him of the mass of every raw material establishing every formulation is realized as continuation: We take as example the first formulation of the composition CP1: 1 Volume of clay + 2 Volume of sand of dune + water

We have:

$$\mu = m / v \ (g/cm^3).$$

Where:

µ: The density of the material (g/cm^3);

m: The mass the material (g) ;

v: The volume of the material (cm^3).

We have the following conversion:

$$1 \text{ liters} = 10^3 \ cm^3.$$

Case of the water:

µ Clay = m/v for 1 Volume = 1 liters,

The quantity of water is 1 kg.

Calculation of the mass of the red clay:

µ Clay=1, 73 g/cm^3, determined experimentally in the laboratory. We have: µ =1, 73 (g/cm^3) for one volume equals one liter and equals $10^3 cm^3$;

Where from:

$$\text{Mass of clay} = \mu \cdot v = 1,73 \ (g/cm^3) \times 1\text{Liters}$$

$$\text{Mass of clay} = 1,73 \ (g/10^3 \ cm^3) \times 10^3 cm^3$$

Thus:

Mass of clay=1730 g

For a one Volume of clay rouge.

Calculation of the mass of sand dune:

Mass of sand= 1,49 g/cm^3, determined experimentally in the laboratory .We have:

µ =1, 49 g/cm^3 for one volume equals one liter equal 10^3 cm^3

Where from:

$$\text{Mass of sand} = \mu \cdot v = 1,49 \ (g/cm^3) \times 1\text{Liters}$$

$$\text{Mass of sand} = 1,49 \ (g/cm^3) \times 10^3 \ cm^3.$$

Thus:

Mass of sand =1490 g

For a one Volume of sand dune

Where from:

Mass of sand =2980 g

For 2 Volume of sand dune

The final formula of the first formulation of the composition witness is:

1730 g of clay + 2980 g of sand of dune + water.

The mass of straw in a composition is taken in percentage by the mass of the clay used in the same composition. The samples of adobes were characterized (the mechanical resistance was made after 14 and 28 days. The mechanical characterization of adobes was made according to the method of the NF standard P-196 for ages 14 and 28 days, and followed by a study of ultrasound of model (58-E0049/A) [6]. The study consists in determining the speed of propagation of ultrasound waves in the samples of adobes formulated (the thickness of measure is 160 mm) by the direct method [7], so informing about the presence of cracks, empty, giving and a fast estimation of their mechanical behavior. The test of change is realized with test tubes adobe initially dry (drying in 105°C counterparts 24 h). The device experimental and established by a desiccate contains one salt saturated Solutions (the water and the sulphuric oxide) has a relative humidity of 75 %, the whole being covered with a lid to avoid any evaporation. The essay consists in determining the variation of the mass of the sample (adobe) by contribution in time (1 minute, 3 minutes, 5 minutes, 10 minutes, 15 minutes, 30 minutes, the 1 hour, 2 hours, 3 hours, 4 hours, 3 days and 7 days). The speed of sound is dedicated to the study of the mechanical behavior of adobes according to their degree of saturation in water (determination of the speed of propagation of adobes moisten every weather which corresponding to him). The obtained results allow moving forward hypotheses on the optimal traditional use of this composite.

3 RESULTS AND DISCUSSION

3.1 Characterization of material

The results of mineralogical analyses realized by diffraction of the X-rays (Fig1) raw materials used in the formulation show that the mineralogical composition of the clayey raw material (red clay) contains generally (quartz, illite, orthoclase), the hematite and the calcite. The hematite which is an iron oxide (Fe_2O_3) confers the red color on the clay. Thus the red clay is a raw material averagely plastic because of the absence of the mineral montmorillonite.

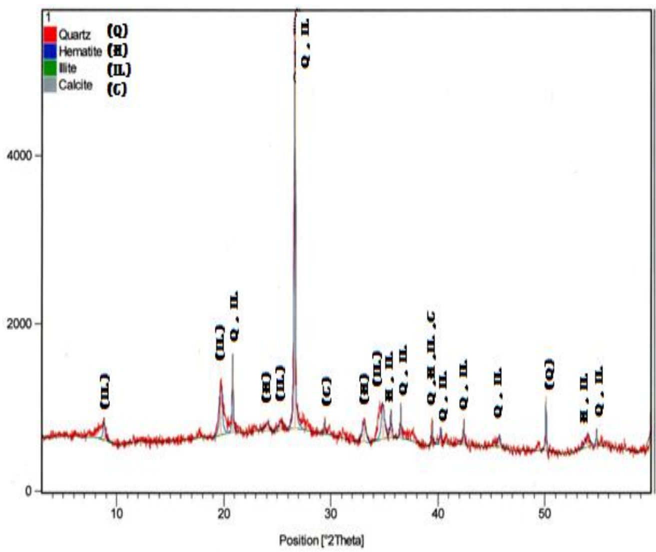

Fig .1. Mineralogical analysis of the red clay.

The Fig 2 shows that the sand used for the formulation is a natural quartzes rock with the presence of the gypsum.

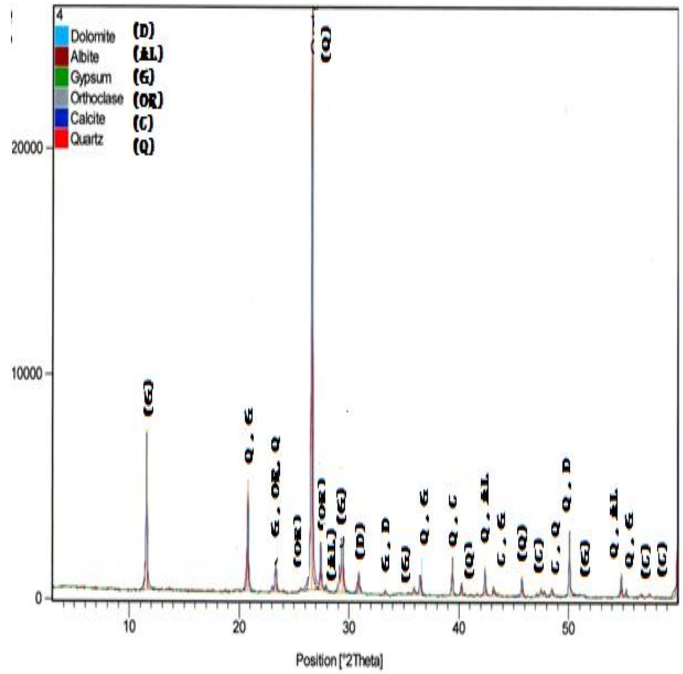

Fig .2. Mineralogical analysis of sand dune

3.2 Petrophysic study

The results of the physical characterization of raw materials used for the formulation of samples are presented in the table 1:

Table .1. Physical characteristics of raw materials used for the formulation of the samples

Raw materials	Density (g/cm3)	Specific mass (g/cm3)	Humidity (%)
Red clay	1.49	2.25	3.10
Sand of dune	1,58	2.59	1.19
Coarse sand	1.24	2.17	0.40

The clay has by definition a very fine size grading, of the order of the micrometer (2 µm). We notice in the curve (figure 3) that the clay in 20 % of grains between 0-63 µm and 20 % 70 % (63 µm 630 µm) and 70 % 100 % between 630 µm has 800 µm some red clay used, what confers the less plastic character with regard to (compared with) the other clays [8].

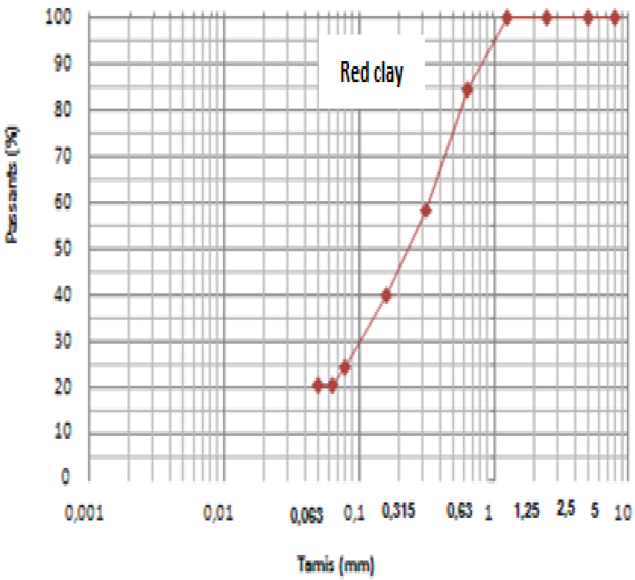

Fig.3. Curve of particle size analysis of the red clay.

The results of grading analyses of various sands (dune and black) are represented by the Fig.4:

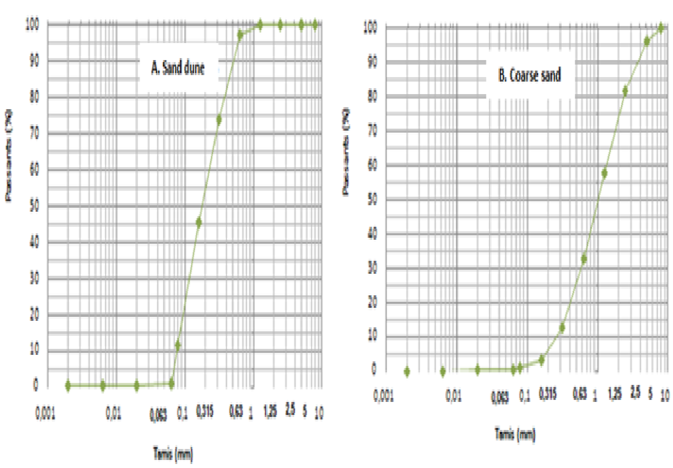

Fig. 4. Curve of particle size analysis of sands used. (a: sand dune b: coarse sand)

The grading analysis and the module of calculated sharpness show well the classification of various sands (dune (Mf=1.17) and (Mf=2.60): unrefined sand). The physical characteristics and the mineralogical analysis show good that the red clay is a material capable of the manufacturing of adobes and mortars particularly in the desert zones due to a normal plasticity, what avoids an excessive inflation and a fissuring. The grading analysis will allow us to choose well the nature and the percentage of the sand which it is necessary to add to the composition of Adobe.

3.3 Characterization of adobe made

The composition (1Volume of clay + 2 Volume of sands of dune + 3 % straw + water) gave the best mechanical characteristics (compression resistance of 1.23 Mpa,) and in compliance with the recommended specifications [9].

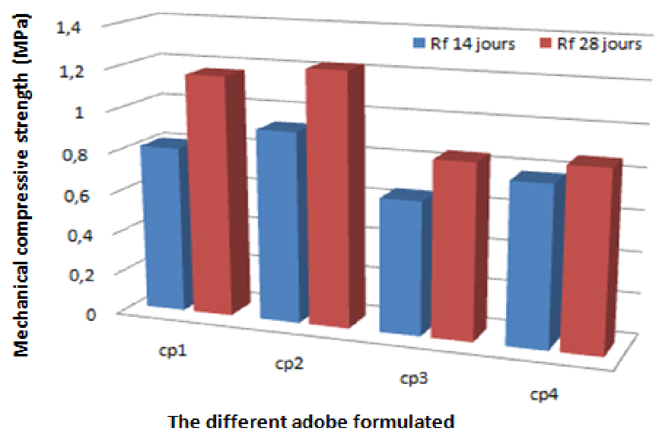

Fig.5. Mechanical compressive strength of adobe made

The results go up only the substitution of the unrefined sand to the place of the sand of dune in the formulation; makes increase the porosity (texture and size) of the pores of the granular matrix and decrease in the mechanical resistance [10]. We notice generally that the introduction of the straw makes increase the compression resistance and in the flexion and the improvement of the physical characteristics of adobes (stabilization of the retreat) [11]. The histogram of speeds (Fig.6) is a useful statistical representation which allows quantifying the structural state of the formulated adobes. The example given by the following graph allows to notice that the measures are situated for the greater part by 1500 m/s. this value stays in compliance with the values of the standard of the porous materials; where concretes compact materials have a superior value in 3800 m /s [12].

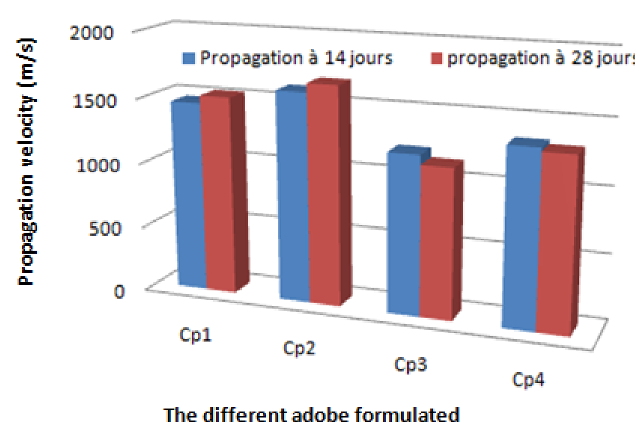

Fig.6. Histograms of time and speeds adobes made by the ultrasonic test.

The composition CP1 presents a high speed of distribution of the waves by contribution to the other compositions, fact is understandable its compactness and its internal micro porosity. The results show that the speed is low in adobes formulated with unrefined sand, due to the dimension (size) of pores create by the unrefined sand in the global matrix (the increase of the time of transfer from 14 days to 28 days is due to the evaporation of the water free of the formulated adobe, which favors the increase of the open firm porosity). The results of analyses of distribution of the speed of sound by the ultrasound, confirm on one hand the various mechanical results of the formulated adobes realized by the destructive method, and on the other hand the structural character of the adobe. Thus the obtained results, led to us to choose the composition (1 Volume of clay + 2 Volume of sand of dune 3 % straw + water) as reference basis of our study for various changes.

3.4 Hydric behavior Study

The figure 8 of the adsorption of Adobe shows that, the water is confidentially connected to the poral distribution of the adobe. Indeed, it is mainly the capillary generated strengths by the various pores which allow storing the water. To obtain information on the poral space and more particularly on the distribution in size of pores [13, 14]. The various stages of the saturation of the adobe are: At first (until 30 minutes), there is monomolecular adsorption on the walls of the solid skeleton. The transfer of water is essentially made under shape vapor by gaseous distribution (broadcasting). Secondly (from 30 minutes till 12 pm), there is multi-molecular adsorption, capillary phenomena of condensation can appear in the finest pores. The transfer is mainly made always under shape vapor. This process of transfer is described as a transfer of vapor assisted by liquid because the zones of liquid water reduce the course of distribution of the vapor [15]. Indeed, the air can be trapped in a macro-pore by diversion of this one for the benefit of a finer capillary (the meniscus in the capillary reaches the summit of the system before the macro-pore is completely saturated, the latter so trapping an air bubble), either the air can be trapped in a macro-pore by the presence of a roughness of surface (trained pores) which work. The fluid wetting (the water) hides walls and fluid not wetting (air), fills almost totality of the macro-pore. Progressive training of continuous liquid one movie of water about the walls of the skeleton of Adobe develops. It is what we call the hydraulic connection where the liquid phase is continuous through the entire porous network and where the water can migrate along walls. At this stadium, the movements of water cross of a regime of transfer vapor assisted by liquid a diet of liquid transfer assisted by vapor. Beyond 24 hours the absorption becomes low, the liquid water can fill the major part of the poral space. The hydric transfer is then made essentially in liquid form by flow in the capillary pores whether it is in totally saturated middle (saturation).

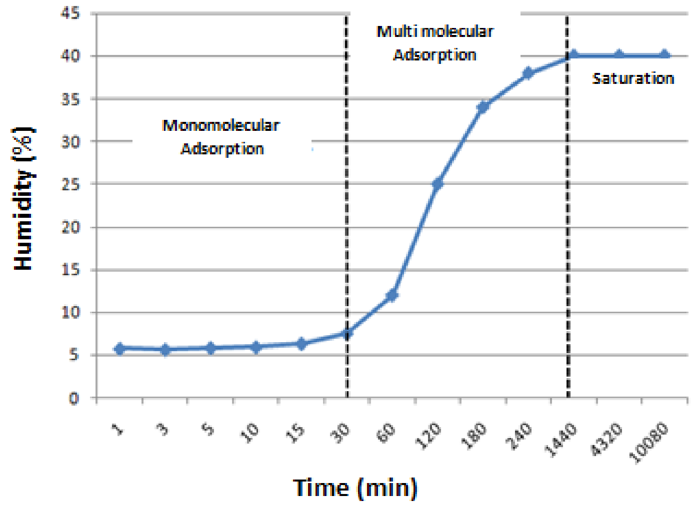

Fig. 7. Evolution of moisture as a function of time

The measure of the speed of sound measured show that: The speed of ultra-sound waves is rather low, of the order of 1500 m /s (dry state) for the adobe what is characteristic porous materials [15]. An increase of the speed of sound in the State saturated towards 2045m / (the speed of sound is bigger in the water than in the air). These values of kinetics are particularly important and testify of the big capacity of these materials in earth (ground) believed to absorb the water. We notice well that it is not the total porosity which is the factor the most importing in the phenomenon saturation but the property the size averages pores. In this domain of saturation, the system passes of a solid two-phase environment (middle) and the water in a three-phase environment (middle) with the emergence of air bubbles which fill gradually the space pore. We thus have an increase of the number of interfaces (water/sight) which comes to be added to the solid interfaces and the water [17]. This multiplication of passages from middle to another one would lead then a mitigation of the distribution of the waves. The water not training any more a continuous liquid movie about the walls of the solid skeleton, the number of interfaces «water / sight " would begin to decrease, so facilitating the distribution of the wave.

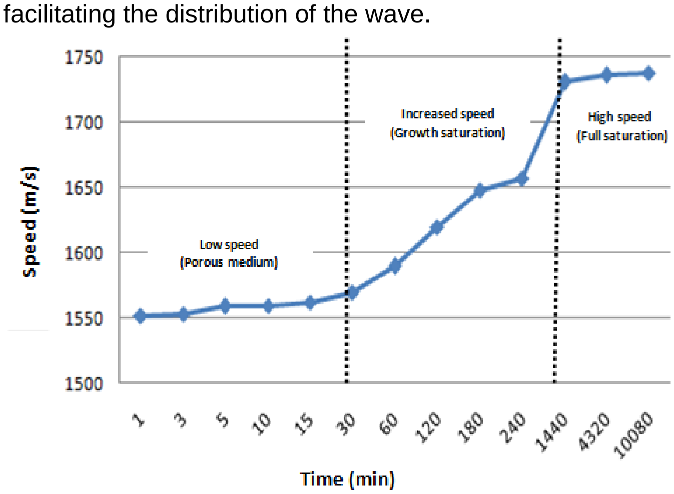

Fig.8. Changes in the speed of wave propagation as a function of moisture.

At the approach of the dry state, and thus for the very low degrees of absorption, we observe a sudden increase of the speed of sound. This could correspond to the progressive disappearance of the film of water adsorbed recovering the walls of the adobe. Thus; through measures of the speed of propagation of ultra-sound waves in not saturated middle. Indeed, the speed of sound depends on the porosity but also on their saturation in fluid. And the variations of the speed of sound, so, by means of an adequate calibration and on a homogeneous material of micro-cracks parasites, this non-destructive measure could allow to estimate the moisture content of the material and the mechanical resistance which results from it.

4 CONCLUSIONS

The local raw materials (red clay), as well as the sand of dune and the chopped straw, are capable of being used for the elaboration of the bricks of adobes. The red clay taken by the careers of Adrar is averagely plastic, is capable of the production of the bricks of Adobes. The role of clayey minerals in the clay is very important, the red clay contains of the quartz, the illite and feldspars. The kaolinite can swell (7 - 10 angström), illite of (10 in 14 angström), montmorillonite (14 in 20 angström), the composition of our clay is situated in the middle between kaolinite and montmorillonite. As well as the specific surface of the illite (100-175 cm^2/g) is situated between both, what confers on him one facilitates for the shaping and the drying. The elaboration of adobes based itself on test tubes witnesses who were only made with earth, with some sand and with some water, chosen in bibliographical references and of experiment real-life of the architects Algerian. The composition witness (1 Volume of clay+ 2 Volume of sand +3 % of the straw + water) to show the physical and mechanical better results with regard to (compared with) the others and was chosen as the other formulations. The addition of 3 % of straw, can well improve the physical characteristics (porosity, retreat) and the mechanical characteristics (compression and flexion) in the adobes (the earth) as material of construction has no important mechanical characteristics, but the addition of the straw remedies this defect). The raw earth is a porous environment (middle) trains a network consisted of pores which are individualized objects representing the main part of the porous volume, and the accesses or the connections between pores. It is these connections which determine the capillary and hydraulic properties of the adobe, even if they represent only a low fraction of the volume pore. The curve of water retention and thus various stages of saturation of the porous network are essential for the knowledge of the various modes of transfer of the water in the porous network of adobes in raw earth. Indeed, the transfer by vapor, which is majority, passes gradually in a transfer by liquid when the majority of pores begin to be filled by the liquid phase. This transition is made during the hydraulic connection, that is when a movie of water can be considered as continuous through the entire porous network, of which the degree of critical saturation. The results of analyses of distribution of the speed of sound by the ultrasound, confirm on one hand the various zones changes exposed to the rain and to the ascending and downward humidity, and on the other hand the character thermal regulation of adobe.

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