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Valorization of the Algerian Plaster and Dune Sand in the Building Sector

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Abstract**—**The need for thermal comfort of buildings, with the aim of saving energy, has always generated a big interest during the development of methods, to improve the mode of construction. In the present paper, which is concerned by the valorization of locally abundant materials, mixtures of plaster and dune sand have been studied. To point out the thermal performances of these mixtures, a comparative study has been established between this product and the two materials most commonly used in construction, the concrete and hollow brick. The results showed that optimal mixture is made with 1/3 plaster and 2/3 dune sand. This mortar achieved significant increases in the mechanical strengths, which allow it to be used as a carrier element for buildings, of up to two levels. The element obtained offers an acceptable thermal insulation, with a decrease the outer-wall construction thickness.

Keywords**—**Local materials, mortar, plaster, dune sand, compaction, mechanical performance, thermal performance.

I. Introduction

THE role of a dwelling is to provide a shelter whose function is to create an interior element adapted to the needs of the occupant. Among these needs, thermal comfort must be taken into consideration because it represents a natural need of the human being. [1]

The evolution of construction methods, the need for more appropriate thermal comfort and the desire to save energy have given rise to an interest in improving the construction mode, i.e. the search for techniques in order to develop resistant materials, apt to reduce thermal wasting, through the building envelope.

Many regions in Algeria, mainly the Saharan areas and the highlands, experience significant changes in the temperature of the outdoor environment, both daily and seasonal. The energy consumption of Algerian homes could be greatly reduced if roofs and walls had better thermal insulation [1], [2].

In this study, we propose the integration of local materials into the design of mechanically resistant and thermally insulating components; by proposing an element in compacted blocks of a mortar composed of plaster and sand of dunes. The compaction increases the density, which acts favorably on the mechanical characteristics, and adversely on the thermal insulation.

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In the present work, we try to find a compromise between the mechanical resistance and the thermal insulation, i.e., trying to discern the best composition (plaster (P) and dune sand (S)), for which the gain in mechanical strength is greater in the loss of heat insulation, with a goal to use the obtained mortar for building individual houses of moderate heights.

It is imperative to point out that the building must be set up in regions where the basic components (plaster and sand of dunes) are available at a reasonable price, and also that this locality has low rainfall and humidity, to not affect the durability of the mortar. Because the mechanical performance of a material based on plaster is reduced in the presence of water or a high rate of moisture [3], [4].

II. Experimental Materials and Processes

A. Materials

a. *Plaster:* The plaster used is from the region of Ghardaia, whose density is 1361.80 Kg/m^3.
b. *Sand:* It is the dunes sand from the region of "Boussaad".
c. *Water:* We used drinking water.

The grain size curves of the plaster and dune sand are given in Fig. 1.

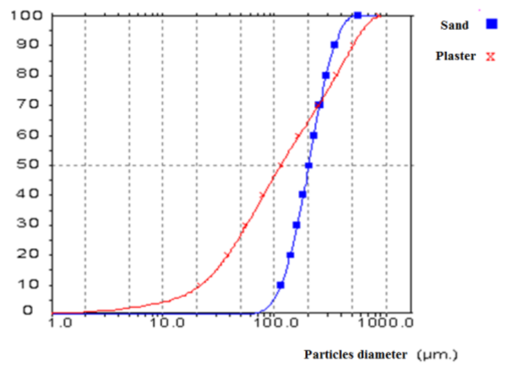

Fig. 1 Grain size curves of the used plaster and sand

B. Samples

The composition and characteristics of the studied mixtures are given in Table I.

TABLE I
Composition and Rates of Tempering of Simply Cast Mortars

Mortars	W/P (%)	Flow (mm)	setting beginning (mn)	setting end (mn)
100% P	58	170	3	15
2/3 P + 1/3 S	75	185	10	25
1/2 P + 1/2 S	88	190	15	38
1/3 P + 2/3	126	195	20	230

Depending on tests to be done, we have designed two types of samples:

1) Mechanical Testing

According to the norms ISO DIS 3051 and NA 527; the samples for mechanical testing are prismatic with the following dimensions [5]-[7]:

- Length: 160 mm;
- Width: 40 mm;
- Thickness: 40 mm.

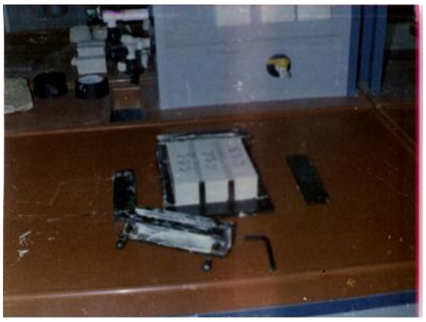

Fig. 2 Specimen unmolded

2) Thermal Tests

Two techniques have been used to determinate the thermal conductivity, namely: the method of boxes and CT meter. The samples dimensions are given in Table II.

TABLE II
DIMENSIONS OF THE USED SPECIMEN

	The Boxes method	CT meter
Length	270	110
Width	270	110
Thickness	50	110

Fig. 3 Device for the measurement of thermal conductivity by the method of the box

III. RESULTS

For the simply cast mortars we have seen no improvement in mechanical performance with the addition of sand. Moreover, the poor adhesion between the grains of plaster and sand caused the erosion of samples. So, we think to use the compaction, in order to enhance the attraction between individual grains of the mixture, and thus improve the referred performances.

Fig. 4 The measurement of thermal conductivity by the CT meter

IV. COMPACTION

The compaction has been chosen in order to design mortars, with an important dosage of sand, which can guarantee simultaneously interesting strength, with the minimum necessary to water (see Table III) [8]-[10].

The compaction is achieved on the fresh material, through a manual press which provides samples of specific dimensions 110x230xe mm. The thickness "e" varies from 35 to 80 mm.

The samples for various tests (mechanical, physical and thermal) were recovered by sawing according to the sizes of adequate samples in each test.

TABLE III
COMPOSITION AND RATES OF MIXING OF COMPACTED MORTARS

	W/P (%)	Mortars
Plaster	20	100% P
Plaster mortars	25	2/3 P + 1/3 S
	32	1/2 P + 1/2 S
	45	1/3 P + 2/3

V. RESULTS

A. Mechanical Strength

The whole mortars, including the plaster taken as reference material, have marked interesting increase of mechanical strength, which the age of the samples. On Figs. 5-8, Rc is the compressive strength and Rf is the bending resistance. The indices 0, 1 mn and 5 mn represent the duration of compaction samples test.

One can notice that the mortar made (2/3 P + 1/3 S) reached an evolution in the mechanical strengths of 28% to 31% respectively for 1 mn and 5 mn of compaction compared to the same mortar simply cast while the compressive strength performed an increase of 62% and 68% for respectively 1 mn and 5 mn of compaction, as is illustrated in Figs. 5 and 6.

Unlike the cement-based materials, which mark a very small decrease their mechanical properties at wet state; these latter are generally reduced, for a material-based on plaster. For this reason, one must take into account the mechanical characteristics at wet state for these materials. Figs. 7 and 8 illustrate the results for our mortars.

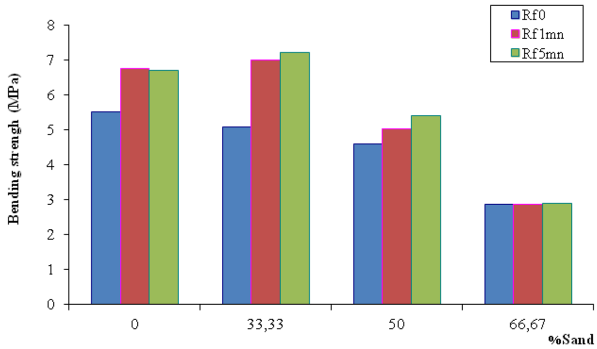

Fig. 5 Bending strength of dry plaster mortar

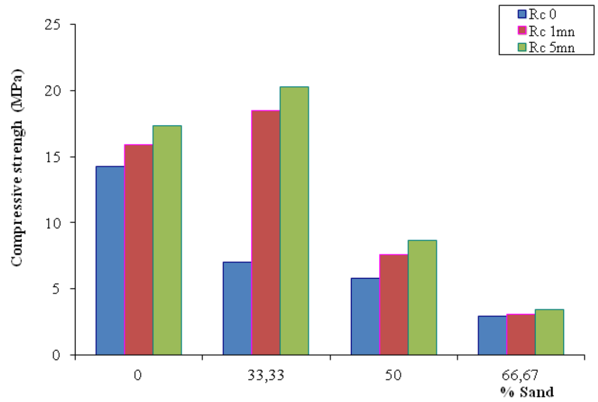

Fig. 6 Compressive strength of dry plaster mortar

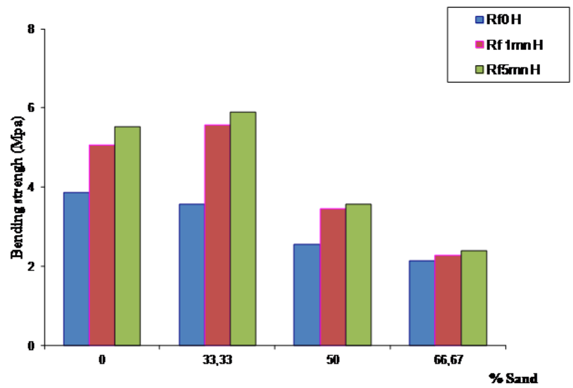

Fig. 7 Bending strength of plaster mortars

We notice that after 48 hours of immersion as required by [5] and [7], there is a small difference between the dry and wet mechanical performance. Despite this difference, they are kept beyond the threshold required by the recommendations of building with plaster. This is explained by the decrease of sensitivity to water of the plaster due to the compaction, which allowed overcoming this major problem by reducing the volume of the voids; it prevents the water from penetrating deeply. Hence, it will be easier to be evaporated later. This produces half-capillary material and its saturation speed is reduced to a rate ranging from 20 to 60%.

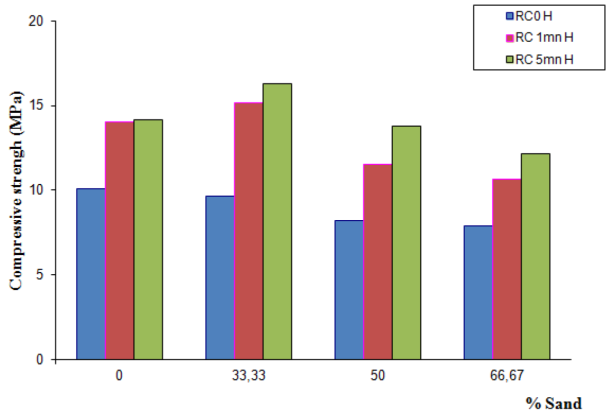

Fig. 8 Compressive strength of plaster mortars in wet state

B. Thermal Performance

The thermal performances (thermal conductivity and resistance) were also significantly influenced by the addition of sand. This addition acted adversely on the thermal conductivity. This one has evolved positively to low slope with the sand addition.

With an implementation by compaction, thermal conductivity at different sand dosages undergoes a more important evolution, the new values are almost doubled compared the same mortar simply cast. This increase is driven by the increase in density that occurs following the reduction of volumes of empty by the compaction [3], [4].

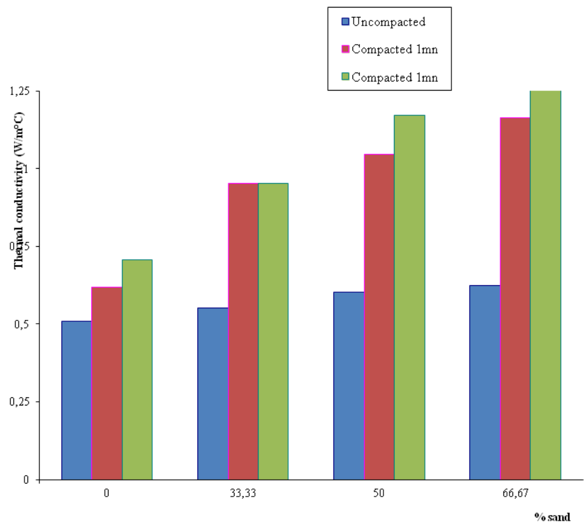

Fig. 9 Thermal conductivity of various plaster mortars at different times of compaction

The addition of sand to plaster has caused the increase of its thermal conductivity. This became more important for the compacted specimen. However, it is essential to lift it is the mortar with (2/3 P + 1/3 S) compacted which gave the best thermal conductivity compared to the other mortars [3], [4].

VI. Conclusion

The addition of dune sand to the plaster is studied in this paper where, the mechanical and thermal performances have been examined under the effect of this addition, for simply cast and compacted specimens.

The mechanical strengths have been negatively affected by the simple addition of the dune sand. Worse, the bad adherence between the plaster particles and sand caused the erosion of the specimens. To this reason, compaction seems to be the best solution.

Using compaction to perform new specimen allows an increase in the flexural strength of 28% when the compaction lasts 1 min, and is about 31% when it lasts 5 min. As for the compressive strength, it grows about 62% for a compaction during 1 minute, and about 68% when the samples are compacted during lasts 5 minutes.

Thermal conductivity has been subject to increase due to the addition of dune sand and the compaction.

The optimum between the mechanical and thermal characteristics is obtained for the mortar performed with 66% of plaster and 33% of sand, despite its thermal conductivity, it offers acceptable insulation compared to the two most used materials in construction: concrete and brick. Better, its thermal efficiency can be improved if one adopts a provision a double wall of 0.15 m of this mortar separated by 0.05 m of expanded polystyrene plate. Hence, the use of these mortars as walls for structures of no more than R+ 2, allows a considerable saving notably, in the regions where plaster and dune sand are locally available with low costs [3], [4].

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