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Local Materials: Application to Compressed Earth Bricks

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Abstract. In recent years, the development of housing construction in South Algeria, such as the Adrar region one of the largest regions in southern Algeria has generated a huge need for conventional building materials. Efforts have been directed towards the development of new construction methods using local materials to provide an adequate response to this crisis. Indeed, in our region, earthen building materials based on local materials have proved their use for millennia. However, earthen construction is a method of construction very well known throughout the world since it was the first building material used by man. Indeed, to build on earth is to build with material available in large quantities and virtually everywhere, ecological, recyclable and that offers pleasant isolation. The use of this type of material is suitable for high environmental quality since the process uses an abundant material that does not require too much processing energy. However, the benefits of land as a building material were gradually forgotten given the development of new materials. But in the face of ecological and social problems, interest in earthen construction is beginning to be felt. One solution is the compressed earth brick. This article encompasses an experimental study in particular: the design of earth brick (CEB) from clays extracted at selected sites as well as local crushed sand available in our region is presented. For this, an experimental study has been developed, which consists of the manufacture of mixtures of the earth with different dosages of clay. This after identification of the materials used followed by a study of sand and clay formulation.

Keywords. Clay, Crushed sand, Earth brick, Formulation.

INTRODUCTION

Raw earth building materials, which have been around since time immemorial, and which have a wide variety of techniques, are set to return as a solution to enrich the building sector. The techniques of the compressed earth brick (CEB) based on clay offer an adaptation to the desert environment of arid areas and meet the criteria of sustainability, in these regions such as Adrar.

In addition, several studies are devoted to the technique of CEB and the different modes of stabilization (Rigassi, 1995), for the improvement of mechanical strength as well as durability (porosity, erosion resistance, etc): (Winterkorn, 1975; United Nations, 1992; Symons, 1999; González-López, 2018).

This work presents the identification of the materials used: a new clay deposit that is found in abundance not far from the city of Reggane and crushed sand.

Subsequently, in this article, we have developed an experimental study that consists of preparing mixtures on the earth. We used four rates of sand content (90, 80, 70, and 60%). These different mixtures were used for the manufacture of different CEB to study their physical-mechanical characteristics. For this purpose, we adopted static compaction to intoptimize the density and the water content.

However, we performed a simple compression test on the designed specimens to variation of the compressive strength according to different manufacturing pressures (2, 4 and 8 MPa), as well as the effect of increasing the dry density on the evolution of the simple compressive strength.

Finally, our work aims to design a building material based on local materials that have proven their use through remarkable heritage sites. In this study, we have targeted the design of a compressed earth brick. The BTC expresses the modern evolution of the molded earth block (adobe), intending to inscribe a new technique of raw earth construction in this region offering a new opportunity to the Saharan environment and meeting the criteria of sustainability.

GEOGRAPHIC AND GEOLOGICAL CONTEXT OF THE SITE

From a geographical point of view, the study area is located in the Regagne sedimentary basin. This basin is part of the northwestern part of the Saharan platform, separated from the Alpine domain by the South Atlas flexure. It is presented in the form of a vast asymmetrical depression, roughly oriented North-West / South-East.

Geologically, the Reggane basin is formed by a volcanic and volcano-sedimentary bedrock folded and stratigraphically attributed to the Precambrian. Above, rests, in major discordance a sedimentary series of Paleozoic age that begins with Cambrian terrain and ends with Namurian terrain. It should be noted that in the axial zones, the thickness of this sedimentary series could reach 6000m (Sonatrach, 2007).

In this context, the Reggane area has a great mining diversity, such as clays and rocky deposits of sandstone-limestone nature.

EXPERIMENTAL STUDY

The experimental study presented in this paper encompasses material identification, formulation study, and specimen design.

Materials used

Clay: The soil used comes from the region of Reggane (Algeria), it is chosen based on its availability and abundance in the region.

Our standard of reference for the choice of soil proposed for the manufacture of CEB was the recommendations of CRATerre (International Center for Earthen Construction) (Houben and Guillaud, 1995) and the standard NF P 13-901, (2001).

Table 1. Geotechnical characteristics of the studied soil

Properties	γ_S	γ_d	Sand	Silt	Clay	LL	PL	PI	ω_{opt}	VB	SST	$CaCO_3$
	(g/cm^3)				(%)						(m^2/g)	
Values	2.66	1.55	10	48	42	64.7	33	31.7	23	7.25	151.74	4.5

The crushed sand: The sand used in this study is a crushed sand class (0 / 3) from the quarry, which is located east of the locality of the town of Reggane to 30 km towards the town of Aoulaf.

The geotechnical characteristics of the crushed sand, determined according to AFNOR standards, are presented in table 2.

Table 2. Properties of the sand used.

Properties	**Values**
Sand equivalent	62,70 (%)
Absolute density	2,64 (g/cm^3)
Apparent density	1,59 (g/cm^3)
Modulus of Fineness	3,12
Cu	6
Cc	0.66
VBS	0.5
SST	20.93 (m^2/g)

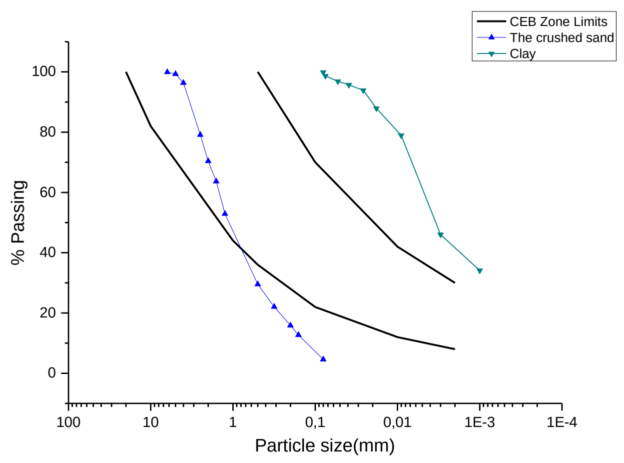

Fig. 1. Grain size curves of the soil and crushed sand used.

Figure 1 shows the grading curve of the soil used compared to the lower and upper limits given by NF P 13-901, (2001). However, the grading curve of this soil is not included in the spindle recommended by NF P 13-901, (2001) so it had to be corrected by crushing sand class (0/3) from the quarry Reggane, whose grading curve is shown in figure 1.
The liquidity limit of the soil is 64.7% and the plasticity limit of the soil is equal to 33%, so it is classified as a very plastic clay soil according to the diagram of Casagrande.

Formulation

According to CRATerre, the approach consists of plotting the curves of sandy and clayey soils on the same particle size diagram, as well as the optimal curve sought. This method makes it possible to give the proportion of the finest soil to be mixed with the coarsest soil to obtain a texture that approaches the optimal curve, which can be the average line of the spindle. From the grain size diagram shown in Figure 2, we chose four mixtures MR1, MR2, MR3 and MR4 containing 90%, 80%, 70% and 60% crushed sand respectively. It can be seen from figure 2 that the two mixes MR1 and MR4 are close to the two boundary curves of the grading range given by the NF P13-901, (2001) standard, as well as the two mixes MR2 and MR3 are inserted in the recommended range.
Moreover, we chose the MR3 mix, which is the closest to the average line of the recommended spindle. Thus, the mixture is within the range of plasticity recommended by the NF P13-901 standard (Fig.3).

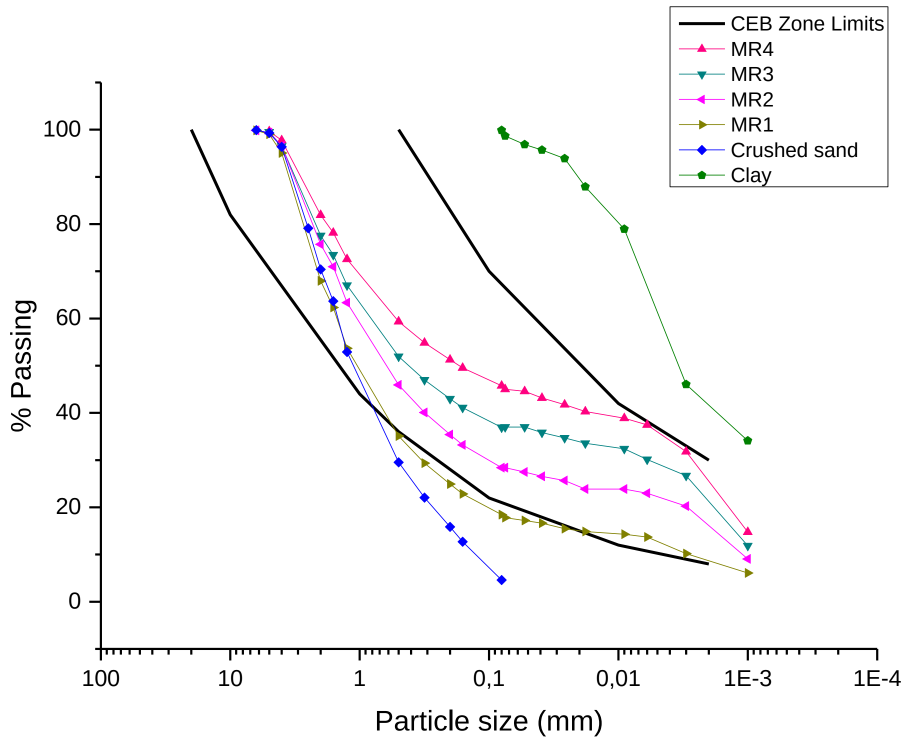

Fig. 2. Grain size curves of clay + crushed sand mixtures.

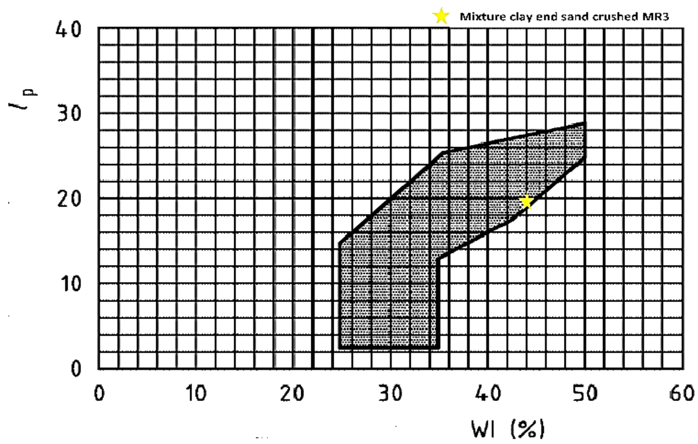

Fig. 3. Atterberg limits of the studied mixture and "recommended range NF P13-901".

Optimization, design, and preparation of specimens

To optimize the water content of the mixtures, we also based ourselves on the study carried out by Olivier and Mesbah, (1986). Which showed that whatever the materials, the stabilization method, or the compression forces implemented, the optimal water content of Wocs manufacture (OCS: Optimum Static Compaction) corresponds to both the maximum dry density and the maximum compressive strength.

The raw soil mixture (MR3) was compacted at three different pressure levels: 2, 4 and 8 MPa, manual presses work between 2 and 8 MPa. Before compaction, the raw material (MR3) is mixed with a specified amount of water in a mixer for 15 minutes. This time is sufficient to ensure a good homogeneity of the mixture (Kouakou and Morel, 2009). The wet sample is then placed in a sealed environment to prevent water loss for 24 hours. This step allows the homogeneous redistribution of the water content. Finally, the wet material is introduced into a hollow cylindrical mold (Fig.4), to obtain specimens of slenderness 2, and this by analogy with the concrete specimens. However, these specimens do not have the same dimensions as those of concrete since our maximum grain size is less than 5mm (P'kla, 2002) and compacted by applying the pressure level set by a press. The material is compacted vertically at the top and bottom using two cylindrical pistons. However, we made about five specimens for each compaction pressure

According to studies conducted by Mesbah et al, (1999) and P'kla A (2002), static compaction is better suited to clay soils, and that the determination of the optimum moisture content for CEB from the Proctor test is inappropriate because the compaction energy is not the same as that of static compaction used for the manufacture of CEB. However, this topic is part of the objectives of this study.

Fig. 4. Static compaction test.

Curing condition

After demolding, the specimen is carefully picked up manually, avoiding touching the edges because of the fragility of the specimen. All the specimens made from the clay-sand mixture are stored in the laboratory at a temperature of T=20 ±2°C until they reach a constant mass (Fig. 5).

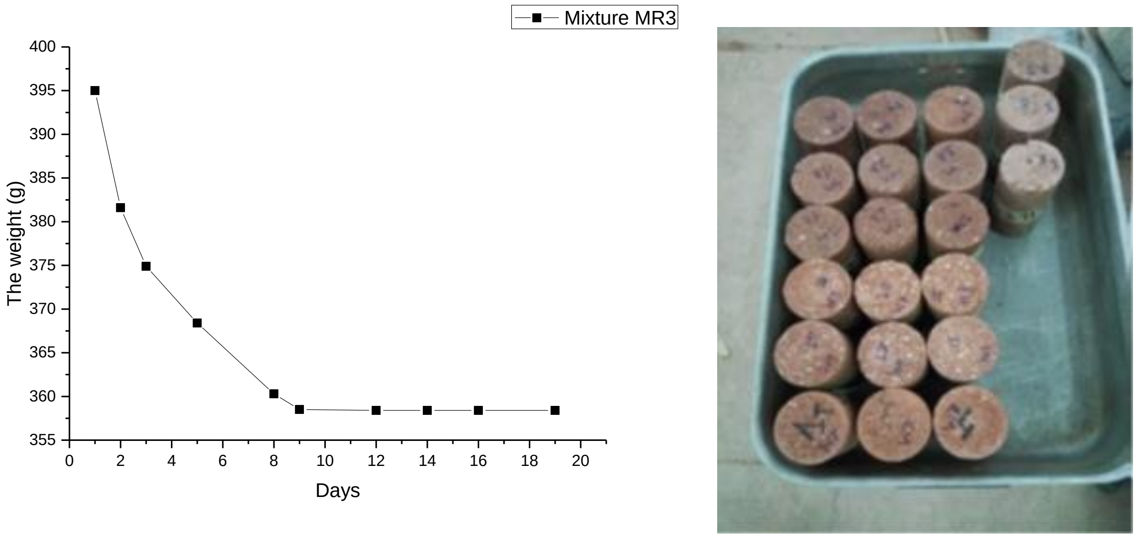

Fig. 5. Conservation of specimens.

RESULTS AND DISCUSSION

Optimal moisture content and maximum dry density

In this paper, we have presented the results obtained from the MR3 mix. Figure 6 shows the optimization obtained for MR3 for each compaction level (2, 4 and 8 MPa). The optimization method is similar to the method used by Olivier and Mesbah, (1986).

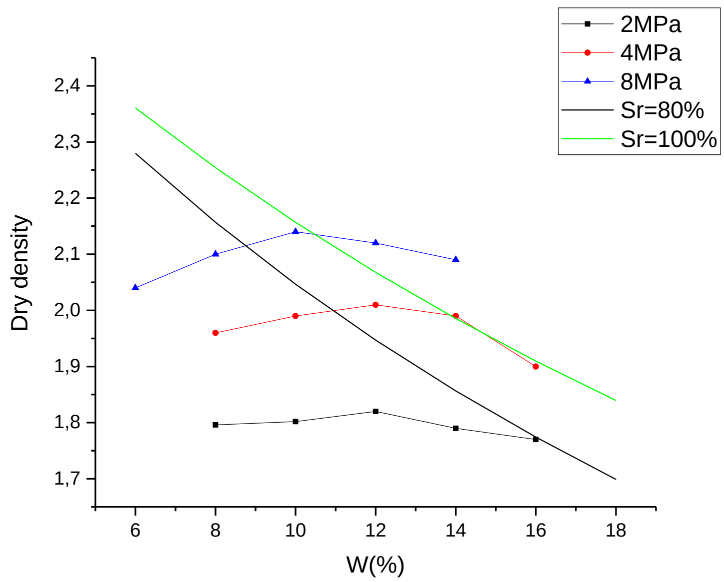

Fig. 6. Optimization of the water content of the mixture.

An increase of the dry density is noticed by the effect of the increase of the compaction pressure; but on the other hand, a small variation of the optimal water content of the mix was observed, which is situated between 0 and 2%.

Thus we have highlighted the small change in the optimal water content of the mixture (MR3) regardless of the change in compaction pressure and the relationship between dry density and water content obtained by static compaction of local materials in the region of Reggane (Fig.7).

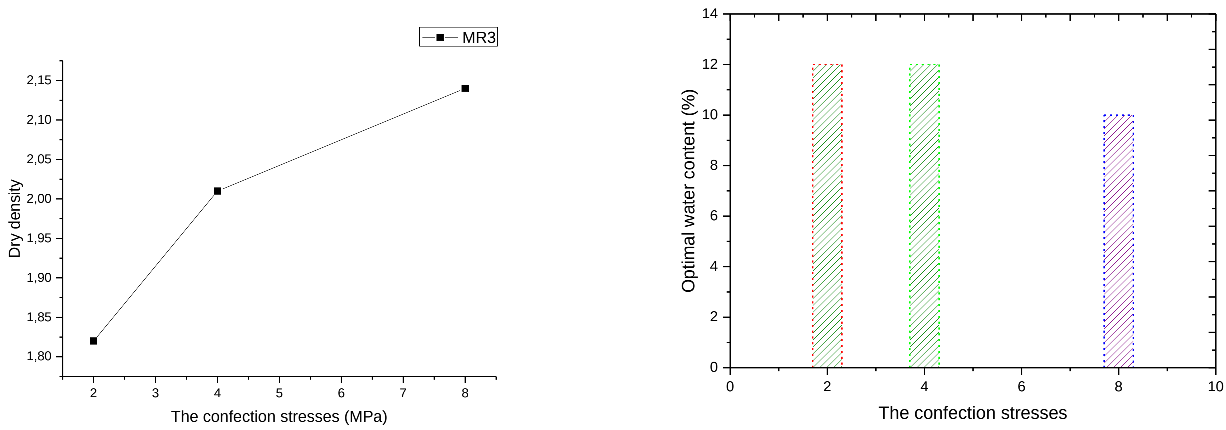

Fig. 7. Variation of max Dry density and Wopt as a function of compaction pressure (2, 4 and 8MPa).

MECHANICAL PROPERTIES

Compression test

It has been shown in several studies that for a given soil, the compressive strength increases with the density (Olivier and Mesbah, 1986; Kouakou and Morel, 2009). This is the reason for the dynamic or static compaction test: the optimum amount of water is sought that leads to the highest density of the compacted soil, as this also corresponds to an optimum of strength. The influence of the variation of the compaction pressure on the compressive strength of the mixture is shown in figure 8. It can be seen that the highest value was obtained with the highest density corresponding to 8MPa. In our case, the maximum strength recorded is 1.95MPa. In the same context, the results of the work of Guettala et al (Guettala, 2002), show that the mechanical resistances increase with the increase of the compaction stress

The translation of the results obtained on a cylindrical specimen in a laboratory to compressed earth bricks is to be confirmed on pieces of larger standardized dimensions. This seems to be relatively easy since we reason from the stresses.

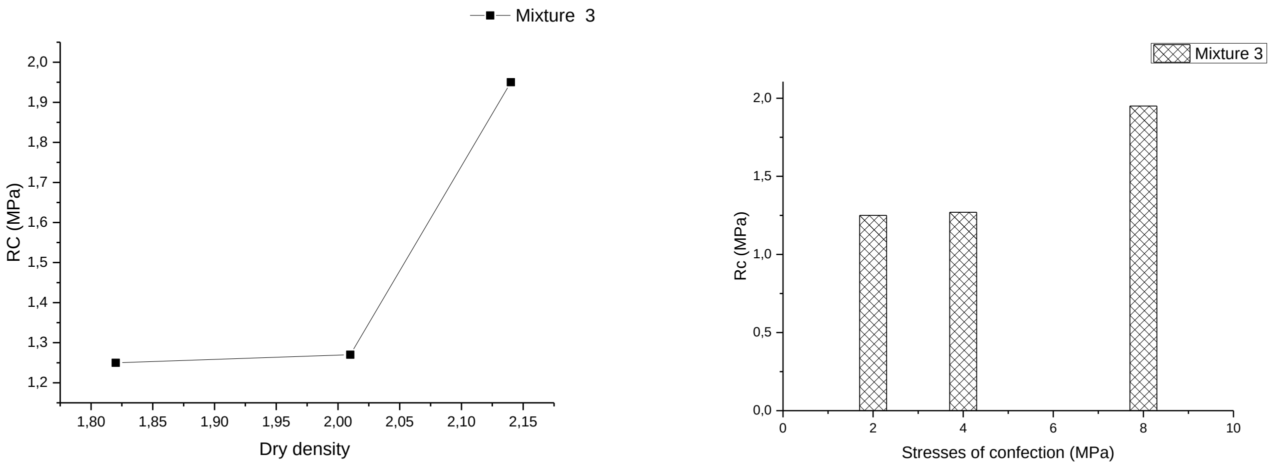

Fig. 8. Variation of compressive strength with compaction pressure and Dry density.

CONCLUSION

In this work, we have presented the geotechnical characteristics of local materials in our region, including Reggane clay and crushed sand. This presentation allows following the evolution of the characteristics of statically compacted mixtures, in particular the maximum dry density and the water content.

This study allowed presenting the interest of the optimization of the water content and the choice of the compaction mode (static compaction) in the case of samples with a granulometry lower than 5mm.

In addition, we studied the variation of the compressive strength of the MR3 clay and crushed sand mixture. After the analysis of the results, we can formulate the following conclusions:

- The increase in the packing stress causes an increase in the dry density of the mixture.
- The effect of the change in the packing stress is very small on the optimal water content of the soil material (clay-sand) in the range of 0% to 2%.
- The parameters that improve the compressive strength are high density, low water content.

Finally, in our region earthen building materials based on local materials have proven their use for thousands of years. We consider that given the results obtained that the deposits we have exploited can provide interesting raw materials for the region of Reggane.

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