Effect of Manual Compacting and Semi-Automatic Compacting on Behavior of Stabilized Earth Concrete

Sihem Chaibeddra, Fattoum Kharchi, Fahim Kahlouche, Youcef Benna

Abstract**—**In the recent years, a considerable level of interest has been developed on the use of earth in construction, led by its rediscovery as an environmentally building material. The Stabilized Earth Concrete (SEC) is a good alternative to the cement concrete, thanks to its thermal and moisture regulating features. Many parameters affect the behavior of stabilized earth concrete. This article presents research results related to the influence of the compacting nature on some SEC properties namely: The mechanical behavior, capillary absorption, shrinkage and sustainability to water erosion, and this, basing on two types of compacting: Manual and semi-automatic.

Keywords**—**Behavior, compacting, manual, SEC, semi-automatic.

I. Introduction

RAW earth has been one of the earliest building materials used by man. Through the ages, people have built their living spaces by providing each time, improvements to this natural use. Currently, with the evolution of technology in the field of building materials, the use of the earth has fallen into disuse. Most earth buildings are located in arid areas where rainfall is low. However, recently a return to the use of the stabilized earth concrete SEC in construction has been favored, as this building material proved ecological. Thus, in order to safeguard natural resources and prevent contamination of the environment by polluting industrial wastes, the return to stabilized earth concrete SEC is of a great interest. Nevertheless, some reluctances are still evoked, because of the less satisfactory properties that the earth is likely to show in severe weather conditions.

The behavior of the SCE under solicitations may be influenced by a number of factors including: the water/binder ratio, the degree of hydration, moisture, temperature, and finally compacting. This latter greatly affects the strength of the material. Compaction reduces the amount of voids and increases the contact between the particles. A higher density has always been associated with a higher strength and a better durability [1].

The study presented in this article focuses on the characterization of stabilized earth concrete blocks SEC, produced from two types of soil (silty and sandy). Many aspects of behavior are investigated.

Sihem Chaibeddra, Fahim Kahlouche, and Youcef Benna, are with the National Centre of Studies and Integrated Research on Building Engineering, CNERIB. Cité Nouvelle, El Mokrani Souidania, 16097, Algeria (phone: (+213) 21-380-357, fax: (+213) 21-380-431; e-mail: sihemchaibeddra@yahoo.fr, mail@cnerib.edu.dz).
Fattoum Kharchi is with the University of Science and Technology Houari Boumediène, BP 32 El Alia, Bab Ezzouar, 16111, Algeria.

II. Identification of Soil Samples and Manufacture of the Samples

Materials characteristics (Table I) and the soil grading curves (Fig. 1) are given below. The blocks made of the sandy soil were stabilized with 10% of cement (10CM); those made of silty soil were stabilized with 10% of cement-lime mixture (10CML), lime being the best satisfying agent for fine soils. The mixing water content corresponds to 10% of the dry materials weight. This latter was deduced experimentally. All samples containing cement have been tested on the 28th day. Those containing lime were tested after 42 days because this one requires more time to harden [2].

TABLE I
Materials' Characteristics

	Sandy soil	Silty soil	Cement CEM II	Lime
CaO %	3.09	12.4	58.2	47
Al_2O_3 %	16.9	13.7	4.28	0.076
SiO_2 %	62	41,5	17.6	0.15
MgO %	2.43	2.37	1.78	32.76
Fe_2O_3 %	4.98	5.21	2.91	0.048
K_2O%	3.5	1.53	0.63	0.00
Na_2O%	2.97	1.61	0.088	0.019
MnO_2%	0.10	0.047	0.049	0.010
TiO_2%	0.53	0.7	0.22	---
Cl %	0.086	1,42	---	---
SO_3 %	0,015	0,77	2,8	---
P_2O_5%	0.17	0.27	0.13	0.069
Lost on ignition	4,45	21,17	10,53	17,55
Liquidity limit LL %	-	44		
Plasticity limit LP %	-	25		
Plasticity index IP %	-	19		
Dry density Ɣd (g/cm^3)	1,75	1,62		
Water optimal content %	12	19		

The first part of the study consisted of manufacturing blocks using two types of compacting (Fig. 2). The first one with a hand press which produces a block of dimensions 290 mm × 140 mm × 110 mm, with an initial compaction force of 2 MPa. We increased the compaction force by installing an oil pump. This latter has allowed us to achieve a pressure of about 20 MPa. The second compaction was provided by a semi-automatic press, which produces two-dimensional blocks of

295 mm × 85 mm × 140 mm, with a compaction force of 7.5 MPa.

SEC blocks were characterized in simple compression in air dry, humid (24h immersion) and oven dried (48 h) conditions in order to observe the evolution of the mechanical strength under imposed conditions of humidity and temperature. Partial absorption test [3] was conducted to assess the porosity of the material and the extent to which water is absorbed. The drying shrinkage [4] was measured as it allows assessing the stability of fine particles under the effect of desiccation. Finally, the material has been subjected to immersion tests in water followed by drying in an oven [2] in order to follow its performance under conditions that simulate the causes of deterioration.

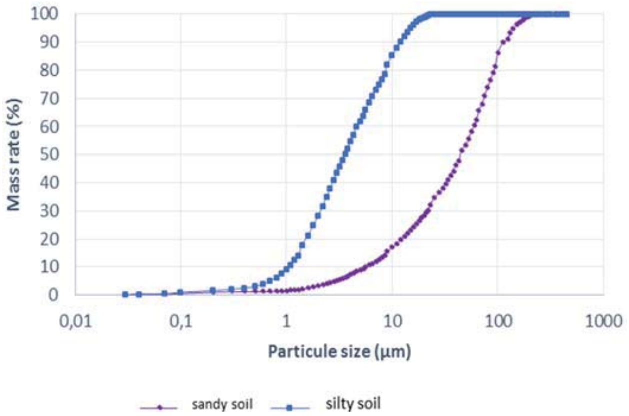

Fig. 1 Soil grading curves

Fig. 2 Compacting types used for samples manufacture

III. Results

A. Mechanical Strength

The compressive strength is considered to be a universally acceptable base unit for measuring the quality of the masonry elements [5]. The values of the compressive strength give an overall representation of the quality of the blocks.

- Blocks Made of Sandy Soil

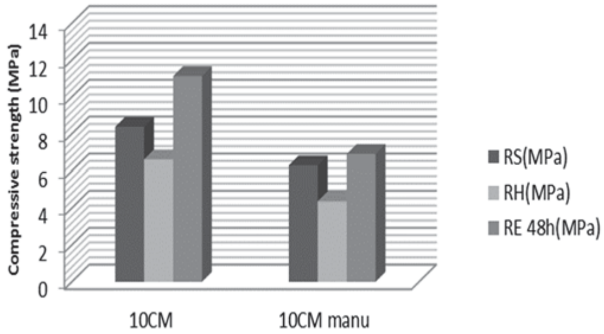

Fig. 3 Compressive strengths for dry, wet and oven dried samples for both compacting types (sandy soil)

The dry strength (Rs) obtained with a semi-automatic compaction is of 8 MPa. The one obtained with a manual pressing does not exceed 6 MPa. Humidity affects the mechanical properties of the material. The blocks stored 24h in water lose strength but moderately since this loss does not exceed the half of the initial strength (maximum tolerated) [2]. However, they are gaining strength when oven dried. This is valid for both types of compacting. Stoving is more effective when the blocks are compressed with the semi-automatic machine. With a semi-automatic compaction, the strength increases by more than 30%.

- Blocks Made of Silty Soil

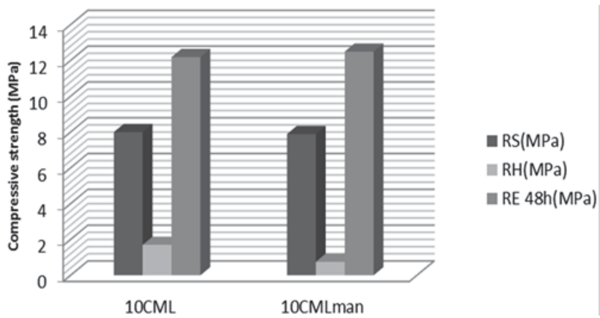

Fig. 4 Compressive strengths for dry, wet and oven dried samples for both compacting types (silty soil)

The dry strength values do not exceed 8 MPa with the two types of compacting. However, the samples are too affected by moisture. This observation flows from the large strength loss observed when the blocks are stored 24 h in water. Indeed, strengths decrease considerably (over 50% of the initial strength). The stoving however, appears favorable since the strengths are seen over up. They reach 12 MPa, representing an increase of 50%. This increase in resistance is valid for both types of compaction.

The temperature influences the progression of the strength. The hydration rate of the stabilizing binders increases with the temperature increase. However, the resistance falls are due to the weakening of the bonds between particles and their dispersion in the presence of moisture. The phenomenon is promoted when the structure is less densified. Furthermore, sandy samples appear better withstanding the wet conditions comparing those based on silt. These latters are acquiring much resistance when stoved, through the contribution of fine particles rigidity when their water content is at minimal.

Generally, the semi-automatic compaction appears to improve greatly the mechanical properties.

Bahar et al. [6] noted that by using a dynamic compaction energy, the dry compression strength increased by more than 50% but with a vibro-static compaction, it slightly increased by 5%. Guettala et al. [7] also concluded that the increase of the press force from 5 to 20 MPa, would improve the compressive strength to 70%. In addition, a dynamic compaction can reduce the optimum water content from 12% to 10% with a considerable increase in compressive strength of about 50%.

B. Capillary Absorption

The absorption capacity of SEC blocks gives a general idea on the presence and size of voids. Compacting pressure greatly influences the extent to which water is absorbed. When a volume of soil is subjected to the action of a stress, the material is compressed and the void volume decreases. Soil density increases and less water can enter [8]. The capillary absorption test was performed according to [3].

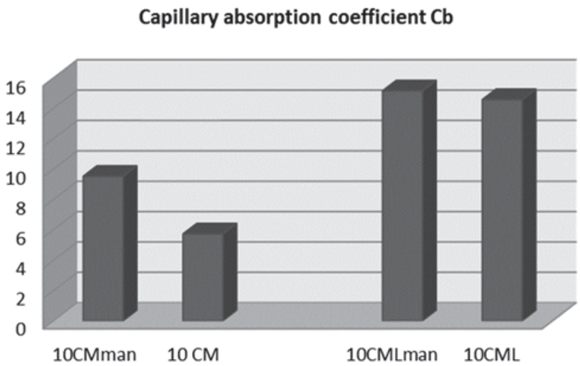

Fig. 5 Capillary absorption coefficient for samples made with the two compacting types

The SEC blocks made of sandy soil absorb less water by capillarity. This is particularly observed when the compacting is semi-automatic. Blocks manufactured with the silty soil show a greater affinity for water since their absorption rate is important. The type of compaction in this case does not affect too much the absorption. According to [9], all blocks are considered as weakly capillary Cb <20.

C. Shrinkage

The volume of a soil stabilized with binders (generally cement) is subject to shrinkage during drying. The amount of free water present in the material will be expelled from the pores, accompanied by a reduction in the sample volume. The loss of water helps the retraction of the clay fraction. This shrinkage and subsequent cracks, in addition to being dependent on the cement content, curing conditions and plasticity index of the soil, dependent on the degree of compactness.

The shrinkage test was performed following the SANS 1215 (2008) method described by [4].

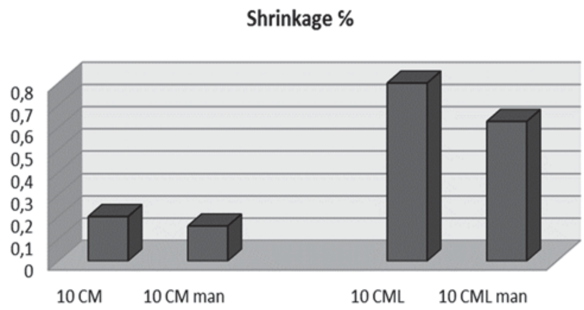

Fig. 6 Shrinkage values for samples made with the two compacting types

The type of compacting does not have much influence on the shrinkage values for the sandy soil blocks. The shrinkage values are considered acceptable. The sandy samples appear more stable against desiccation. For the silty soil blocks, shrinkage values are important compared to the tolerance limits (0.1%) [10]. Fine particles tend to shrink more in high temperature conditions. The shrinkage observed with a manual compacting is slightly lower than that observed when using the semi-automatic press.

D. Compressive Strength After 12 Cycles of Wetting Drying

The durability testing method corresponds to that related to the ASTM D 559-57 standard, which consists in subjecting the samples into wetting / drying cycles. The strength losses were estimated.

- Blocks Made of Sandy Soil

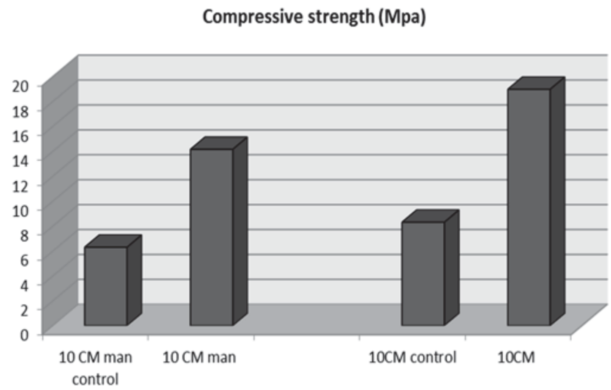

Fig. 7 Compressive strength after durability tests for both compacting types (sandy soil)

- Blocks Made of Silty Soil

The compressive strength of the sandy blocks which have not undergone any immersion is around 8 MPa. After 12 cycles of conservation in water/drying in oven, there is an increase of more than 50%. These findings are valid regardless of the applied compacting type. The effects are more pronounced when this latter is done using the semiautomatic press.

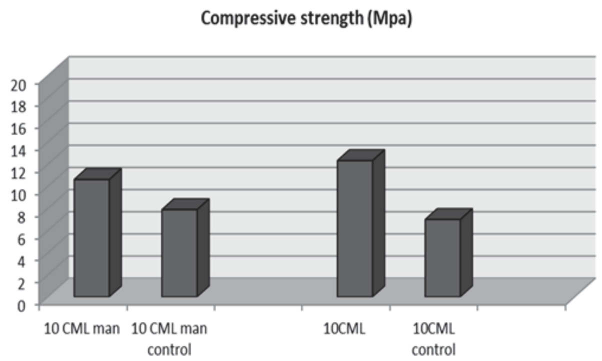

Fig. 8 Compressive strength after durability tests for both compacting types (silty soil)

The blocks made of silty soil are gaining little strength when preserved in water, then stoved. The type of compaction however, does not seem to influence significantly the evolution of the strengths.

It should be noted that the blocks have accused some chipping at the end of the cycles, but these small weight losses have not prevented the strength gains to occur. These strength gains can be explained partly by the hydration reactions that have been favored and accelerated in water and during the stoving. The conserving in water has proved beneficial for the sandy samples. On the other hand, the temperature played a role in accelerating the drying process and thus contributed to the development of strength. Reference [11] observed almost similar phenomena with tuff specimens treated with cement and conserved in water for 7 days. It has been found that after saturation, the compressive strength increased in function of the immersion time.

IV. Conclusion

Based on the investigation results presented in this article, the following conclusions can be drawn:

- Concerning the mechanical behavior, the semi-automatic compacting contributes favorably in the development of the compressive strength compared to the manual compacting. This is all more significant on the sandy samples.
- Capillary absorption of the sandy samples is mitigated with a semi-automatic compacting. However, it varies a little for the silty samples regardless of the compacting type.
- The shrinkage rate is not influenced by the compacting nature for the sandy samples. It is however, slightly lessened for the silty samples compacted with the semi-automatic press.
- The compressive strengths after durability tests (wetting / drying) were not affected. The acquired strength gains are considerable for the sandy samples. This goes for both types of compaction. The increase in strength values is lower for the silty samples. It varies few with the nature of the compacting.

In light of this study, it was concluded that the semi-automatic compacting has proved best satisfactory, comparing to that provided by the manual press. However, it is clear that under real manufacturing conditions of large-scale for construction purposes, it makes sense to make the choice of compacting according to a good compromise: quality/cost price, in order to converge to the base idea that is to build with earth, whose use particularity is a low energy, and low costs.

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