

Influence of Sand on the Mechanical Strengths of Compressed Earth Blocks Based on Sindia Laterite Stabilized with Cement

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Abstract More than a third of the world's population now lives in earthen dwellings which have many environmental, social and cultural advantages. In Senegal, compressed earth blocks (CEBs), using laterite as the base material, are by far the most widely used technique. Indeed, lateritic gravel borrowings are relatively well distributed throughout the national territory. But blocks made with laterite are often stabilized with a good dose of cement. This study aims to verify whether the stabilization of CEBs made with Sindia laterite is necessary and to see the influence of the incorporation of 10% sand on the mechanical resistance to compression and traction of the blocks. Several dosages of cement (6%, 8% and 10%) are used, and the blocks are 28 days old. During this period, they are wrapped in plastic film to preserve their water content. Resistance measurements were carried out by crushing the blocks with a press with a capacity of 1500 kN for compression and 50 kN for traction. The results show that with 10% sand, the compressive and tensile strengths of the blocks are improved: the compressive strength increases from 2.08 MPa to 2.29 MPa with 6% cement, from 3.08 MPa to 3.33 MPa with 8% cement and from 4.36 MPa to 4.62 MPa with 10% cement; the tensile strength by splitting increases from 0.12 MPa to 0.16 MPa with 6% cement, from 0.19 MPa to 0.25 MPa with 8% cement and from 0.28 MPa to 0.33 MPa with 10% cement. Thus, sand can reduce the amount of cement used for the stabilization of BTC based on Sindia laterite and thus reduce the carbon impact of these blocks.

Keywords: Compressed earth block, laterite, cement, compressive strength, tensile strength

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1. Introduction

For nearly 10,000 years, men have been building cities with earth, even if at one point this material was abandoned in favor of stone and wood, which were considered more noble. Then, with the creation of new construction methods, industrial production was favored to the detriment of traditional techniques (earth construction).

But with the energy crisis, greenhouse gas pollution and the economic situation that has been raging in the world in recent years, builders are trying to develop geosourced and biosourced materials by engaging in training, research, and applications.

For developing countries like Senegal, earth construction could become an effective means of saving energy, reducing greenhouse gas emission rates and building social housing.

Thus, the use of earth materials can also be a deliberate choice because they meet very diverse needs from an architectural, ecological and technical point of view (resistance, thermal comfort, etc.) adapted to our

tropical climate.

The main objective of this study is to make a mechanical characterization of compressed earth blocks based on Sindia laterite available in abundance in the Thiès region. The reserves of lateritic materials are very important in Senegal and were estimated at 1,384,950 m³ in 2017 [1]. More precisely, the study aims to evaluate how sand influences the compressive and tensile strengths of BTCs. The results from the evaluation of the mechanical properties of compressed earth blocks will help civil engineering stakeholders to make informed decisions when designing and constructing buildings.

2. Equipment and Materials

2.1. The Manual Press

The bricks used in this study were manufactured using a Cinva-Ram type hand press (Figure 1) with a compaction pressure of 2 MPa. The best presses provide a pressure between 2 and 6 MPa, although lower pressures

may be sufficient provided that at least 0.7 MPa is obtained [2].



Figure 1. Manual press

2.2. Laterite

The laterite used comes from the Sindia lateritic quarry, located in the Thiès region, more precisely in the Mbour department (Figure 2).



Figure 2. Location of the lateritic quarry of Sindia [3]

The granulometric analysis of the laterites shows that the curve is outside the range of soils suitable for use in CEB according to the XP P13-901 standard [4] (Figure 3). To eliminate the big size particle and repair the texture defects, sieving is carried out, and it is the elements passing through the 5 mm sieve which are used to make the blocks.

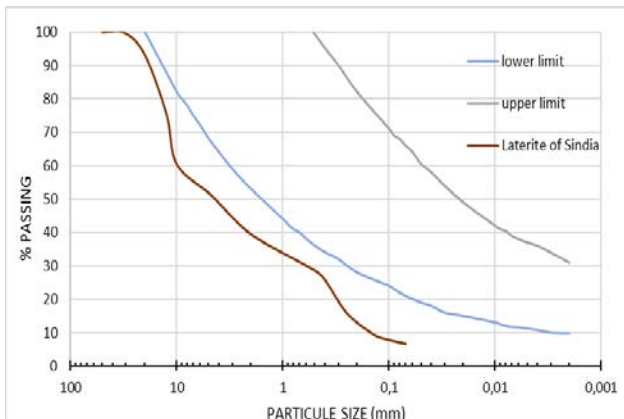


Figure 3. Curve of the total granulometric test of the laterite of Sindia in the spindle

The granularity of the soils (Table 1) shows that the laterite is not too clayey ($\% 2\mu\text{m} < 30\%$) which will avoid risks of shrinkage cracks weakening the blocks.

Table 1. Soil granularity

Gravel	Sand	Fine sand and silt
60.42%	13.04%	26.54%

The plasticity index which provides information, in a certain way, on the clayiness of the material is $I_p = 14\%$ for the Sindia laterite, it shows that it is moderately plastic.

Table 2. Material condition according to plasticity index [5]

Plasticity index (I_p)	Material condition
$0 < I_p < 5$	Non plastic
$0 \leq I_p < 15$	Moderately plastic
$15 \leq I_p < 40$	Plastic
$I_p \geq 40$	Very plastic

The normal Proctor test of laterite gives an optimum water content of 9.3% for a maximum dry density of 2.675 g/cm³ for Sindia laterite.

2.3. The Sand

The sand comes from Mboro, which is a coastal town in the northwest of Senegal, located on the section of the coast called the Grande-Côte, precisely in the department of Tivaouane, region of Thiès (Figure 4).

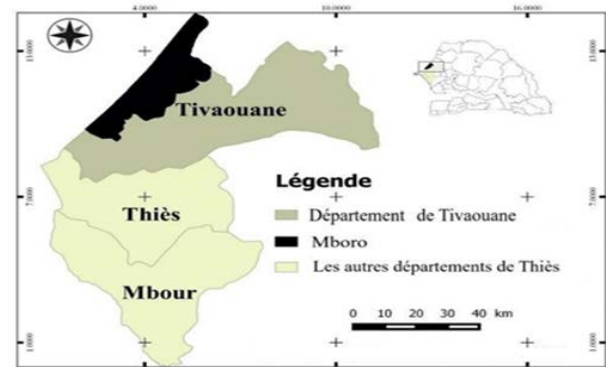


Figure 4. Localisation de la carrière de sable de Mboro (Source DTGC)

The results of the sand granulometric test are shown in Figure 5 and show that the grain sizes of our material are less than 1 mm, with a percentage that passes through the 0.4 mm sieve is estimated at 98.33%.

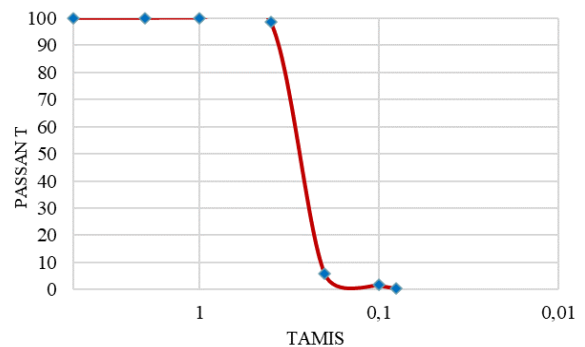


Figure 5. Courbe granulométrique du sable

Table 3 shows that this material is a fine sand.

Table 3. Grain size distribution

0 - 0,08	0,08 – 0,4 mm	0,4 – 1 mm
0,53 %	98,33 %	1,67 %

The apparent density value of is:

$$P_{app} = 1330 \text{ kg/m}^3.$$

The sand equivalent (S.E) which is an indicator, used in geotechnics to characterize the cleanliness of a sand is:

$$E.S = 78,86$$

Since $70 \leq E.S < 80$, it is a clean sand with a low percentage of clayey fines.

2.4. Cement

The cement used for the entire study is a Portland composite CEM II-M 32.5 R.

2.5. Formulation of the Samples

Different mixtures of laterite, sand and cement were prepared in order to estimate their influence on the mechanical behavior of CEBs. Blocks were made from six formulations (S94C6, S92C8, S90C10, S84S10C6, S82S10C8 and S80S10C10) (Table 4).

Table 4. Brick formulations

N°	Designation	Meaning		
		Laterite (%)	Sand (%)	Cement (%)
1	S94C6	94	0	6
2	S92C8	98	0	8
3	S90C10	90	0	10
4	S84S10C6	84	10	6
5	S82S10C8	82	10	8
6	S80S10C10	80	10	10

For each composition, 3 blocks of 29.5 x 14 x 8 cm³ (Figure 6) were prepared and after the tests an average value was retained.



Figure 6. CEB

3. Results and Discussions

3.1. Total Immersion

Unstabilised blocks (S90S10) were subjected to total immersion in a container filled with water (Figure 7). The results showed that they turned into paws as soon as they

were immersed in water. They didn't even last 5 minutes.

Which shows the need to stabilize the Sindia laterite to produce CEBs.



Figure 7. Total immersion of unstabilized CEB

3.2. Influence of Sand on Dry Compressive Strength

The compression tests were carried out using a hydraulic press with a pressure force of up to 1500 kN and the splitting tests were carried out using a press with a maximum force of 50 kN. The load is applied continuously and smoothly at a speed of 0.02 mm/s until rupture.

The results of the compression test show that all the blocks have a resistance greater than the minimum value of 2 MPa set by the NOR 98 standard [6]. An increase in resistance with the addition of 10% sand is noted. Indeed, with 6% cement (S94C6) the resistance is 2.08 MPa, if 10% sand (S84S10C6) is added, it increases to 2.29 MPa. 8% cement (S94C8) gives a strength of 3.08 MPa and with 10% sand it increases to 3.33 MPa. With 10% cement (S94C10) the strength is 4.36 MPa and the addition of 10% sand it increases to 4.62 MPa (Figure 8).

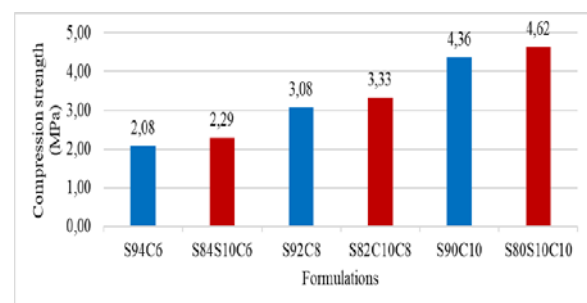


Figure 8. Effect of sand on compressive strength

With 10% sand, a strength gain of 10% is observed for 6% cement, 8% for 8% cement and 5% for 10% cement (Figure 9).

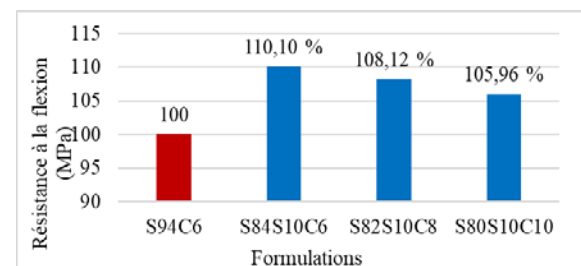


Figure 9. Comparison of compressive strengths of CEBs

The results show that the more the quantity of cement increases, the more the gain in resistance decreases (Figure 10).

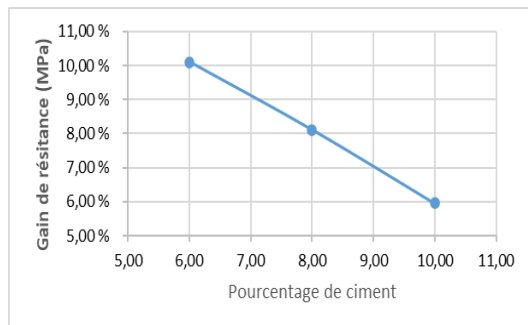


Figure 10. Evolution of the resistance gain compared to the base CEB (S94C6) as a function of the percentage of cement at the resistance

3.3. Influence of Sand on Tensile Strength

The results of the splitting tensile test show an increase in strength with the addition of 10% sand. In fact, with 6% cement (S94C6) the strength is 0.12 MPa, if we add 10% sand (S84S10C6), it increases to 0.16 MPa. 8% cement (S92SC8) gives a strength of 0.19 MPa and with 10% sand it increases to 0.25 MPa. 10% cement (S94C10) the strength is 0.28 MPa with the addition of 10% sand it increases to 0.33 MPa (Figure 11).

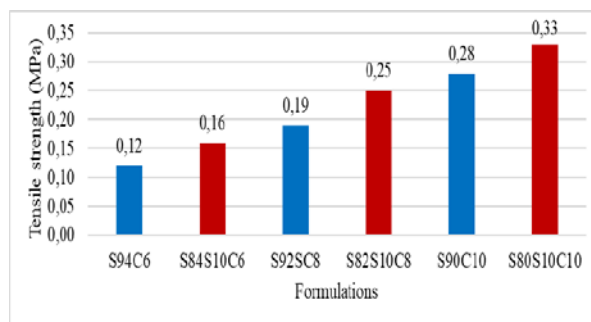


Figure 11. Effect of sand on tensile strength

With 10% sand, a strength gain of 33% is observed for 6% cement, 31% for 8% cement and 17% for 10% cement (Figure 12).

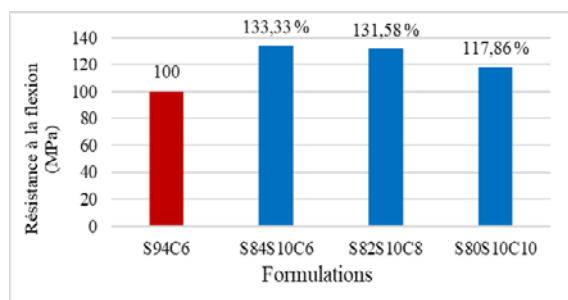


Figure 12. Comparison of tensile strengths of CEBs

The results show that the more the quantity of cement increases, the more the gain in resistance decreases (Figure 13).

The results of the mechanical tests show an improvement in resistance with the addition of sand. This can be explained by the fact that the sand repairs the texture defects of the laterite, and makes the grain size much more spread out, because a soil with a spread grain

size can be more strongly compacted [2]. The addition of sand can also improve stabilization, because Harries [7] recommends adding sand for soils with a high clay and silt content to make the stabilization of the material with cement more effective. In the case of this study, the sand seems to have a role rather of reinforcing the structure of the earth. Indeed, the more sand is added to a clayey soil, the more the quantity of resistant elements increases [8].

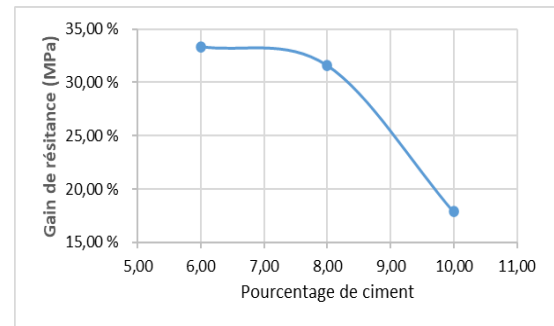


Figure 13. Evolution of the resistance gain compared to the base CEB (S94C6) as a function of the percentage of cement at the resistance

4. Conclusion

This work shows that adding 10% sand increases the mechanical strength of the blocks, but that the more the amount of cement increases, the more the gain in strength decreases. Sand allows BTCs based on Sindia laterite to obtain significant strength gains for small quantities of cement.

The use of these blocks with the addition of sand can reduce the carbon impact of constructions.

In perspective, the study of the water absorption rate of sand-reinforced blocks, the mechanical characterization of compressed earth blocks with a variation in the amount of sand. As well as the thermal characterization of CEBs based on Sindia laterite reinforced with sand.

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