American Journal of Civil Engineering and Architecture, 2023, Vol. 11, No. 3, 89-93
Available online at http://pubs.sciepub.com/ajcea/11/3/4
Published by Science and Education Publishing
DOI:10.12691/ajcea-11-3-4

Mechanical Characterization of a BLOCK of Compressed Earth, Stabilized with Cement and Reinforced with Typha Fibers

Mbaye WADE*, Makhaly BA, Mapathé NDIAYE

Laboratoire de Mécanique et Modélisation, UFR SI, University Iba Der Thiam of Thies, Thies, Senegal.
*Corresponding author: Mbaye WADE, mbaye.wade@univ-thies.sn

Received July 16, 2023; Revised August 17, 2023; Accepted August 24, 2023

Abstract The use of raw earth materials reduces the environmental impact of buildings, naturally regulates humidity and improves thermal comfort inside homes. This is why in recent years there has been a renewed interest in Senegal, for these so-called traditional materials but especially for compressed earth blocks (CEB). But the use of these blocks faces a number of problems including low tensile strength, shrinkage, cracking and lack of durability. The incorporation of Typha, which is an invasive plant in the rivers and lakes of northern Senegal, can help strengthen the matrix of these blocks. This article deals with the influence of crushed Typha on the mechanical behavior of laterite-based blocks. Several formulations based on Laterite, Typha and cement were made and CEB made with a CINVA-RAM type press. The mechanical characteristics were obtained from tensile, compression and bending tests on blocks containing between 0.5 and 1.5% Typha and 10% cement. The results show that Typha reduces the resistance of the blocks but within acceptable limits for the construction of non-load-bearing walls.

***Keywords**: Laterite, cement, Typha, Compresses Earth Blocks, mechanical characteristics*

Cite This Article: Mbaye WADE, Makhaly BA and Mapathé NDIAYE, "Mechanical Characterization of a BLOCK of Compressed Earth, Stabilized with Cement and Reinforced with Typha Fibers." *American Journal of Civil Engineering and Architecture*, vol. 11, no. 3 (2023): 89-93. doi: 10.12691/ajcea-11-3-4.

1. Introduction

Global warming, the depletion of fossil resources and the economic crisis are prompting construction players to turn to local and bio-sourced products. Indeed, the construction sector is responsible for more than 36% of total energy consumption and alone emits 39% of greenhouse gas emissions [1]. The cement industry alone causes between 5 to 7% of CO2 emissions worldwide [2]. In addition, a lot of waste is generated by this sector. This is the reason why in recent years there has been a renewed interest in our country, for these so-called traditional materials but especially for compressed earth blocks (CEB). Indeed, several works (TER stations, schools, hotels, etc.) are made in Senegal with this product, the use of which is unfortunately accompanied by shrinkage, cracking and low tensile strength. The incorporation of Typha in the material can overcome these drawbacks and fight against the proliferation of this plant which has become invasive in the River Valley. The use of aggregates derived from vegetable plants in the manufacture of building materials can contribute to effectively reducing greenhouse gas emissions thanks to their capacities to capture CO2 [3]. Most of the studies carried out on the addition of Typha in cementitious or earthen materials are oriented towards thermal insulation. This study, for its part, attempts to see its impact on the reinforcement of the cementitious matrix. Total particle size, Atterberg limits and methylene blue tests are carried out on the laterite and the particle size of the crushed Typha, its apparent density as well as its absorption rate are determined. The compressive, tensile and flexural strengths are determined from blocks of different formulations, produced with a CINVA-RAM type manual press.

2. Equipment and materials

2.1. The manual press

The bricks used in this study were made using a manual press (Figure 1) of the CINVA-RAM type made with the help of local craftsmen.

The characteristics of the press are as follows:

- Force exerted by the operator: 60 daN
- Reduction rate: 1.7
- Compaction pressure: 2 MPa.

The best presses provide a pressure between 2 and 6 MPa, although lower pressures may suffice provided you obtain at least 0.7 MPa [4].

Figure 1. Manual press

2.2. Laterite

The laterite used comes from the lateritic quarry of Sindia, located in the region of Thiès, more precisely in the department of Mbour (Figure 2). It is chosen on the basis of its availability and abundance in the region.

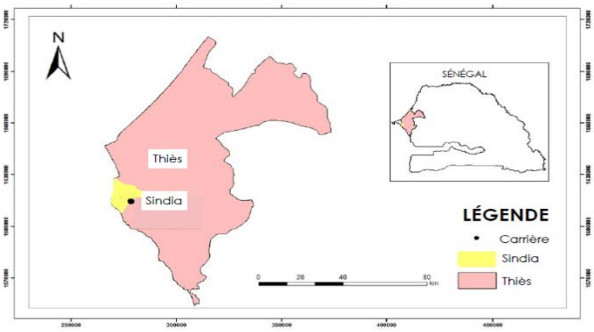

Figure 2. Location of the lateritic quarry of Sindia [5].

The particle size analysis of the laterite shows that the curve is in the spindle of the soils suitable for use in CEB according to the XP P13-901 standard (Figure 3).

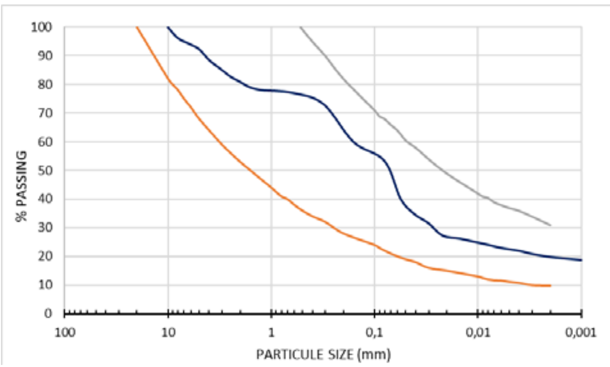

Figure 3. Curve of the total granulometric test of the laterite of Sindia in the spindle

It contains the following percentages (Table 1):

Table 1. Soil granularity.

Gravel	Sand	Fine sand and silt
17%	55%	28%

This soil is not too clayey (% 2µm < 30%) which will avoid the risk of shrinkage cracking weakening the blocks.

The Atterberg limits (Table 2) and the classification on the Casagrande diagram of fine soils (Figure 4) show that the laterite of Sindia is a low plastic clay.

Table 2. Atterberg limits of the Sindia laterite

Atterberg limits		
Liquidity Limit (WL)	Plastic limit (WP)	Plasticity index (IP)
26.97	16.12	10.85

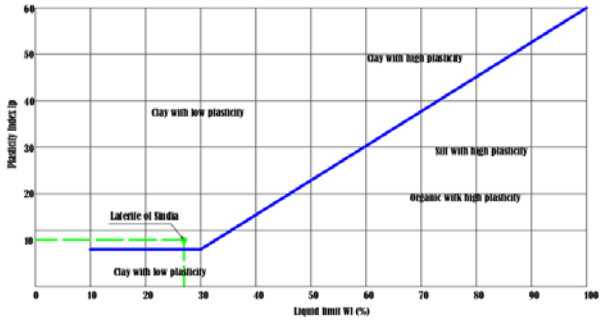

Figure 4. Classification of Sindia laterite on the Casagrande diagram of fine.

The results of the methylene blue test of the Sindia laterite shown below (Table) show that it is a low plastic silty soil.

Table 3. Methylene blue value (MBV) of Sindia laterite

	MBV
Laterite of Sindia	2.2

Sindia laterite is found in the spindle of soils suitable, according to their plasticity and liquidity indices, to be used in CEB according to the XP P13-901 standard (Figure 5).

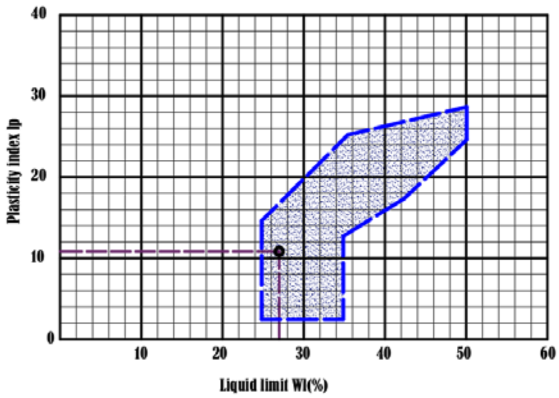

Figure 5. Representation of soil plasticity in the spindle of the soil plasticity diagram.

The normal Proctor test of laterite gives an optimum water content of 13.4% for a maximum density of 1.915 t/m3.

2.3. Typha Australis

Typha australis (Figure 6) is defined as a genus of monocotyledonous plants commonly called cattails, widespread in aquatic or humid environments (rivers, lakes, backwaters, canals, etc.) at water depths not exceeding 1.5 m. It is found in both tropical and Mediterranean areas [6].

Typha produces seeds when mature. The inflorescence has the shape of a candle 15 to 20 cm long, brown in color when ripe, inside which the flowers are very numerous and tight. Each candle can contain between 20,000 and 700,000 seeds hence its high reproductive capacity [7].

Figure 6. Typha plants

The particle size is obtained by dry mechanical sieving, using standard square-mesh sieves, from a crushed sample (Figure 7) and previously passed through a 10-mesh sieve.

Figure 7. Crushed typha

The results show the coarse nature of the plant particles used, indeed a refusal at the 2 mm sieve equal to 77.20% is observed (Figure 8).

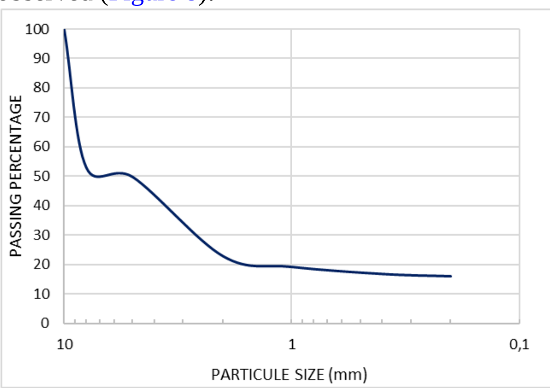

Figure 8. Particle size test of crushed Typha

The bulk density of Typha aggregates is 52.88 kg/m3. A significant mass absorption of water by immersion of 230% in 24 h was observed for ground Typha fibres (Figure 9). This hydrophone character also observed for Kenaf fibers [8] and flax straw [9] is due to the porosity and the presence of hemicellulose in these plants.

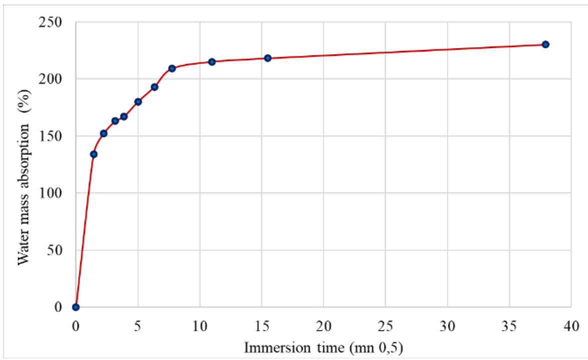

Figure 9. Curve of massive absorption of water by immersion of crushed Typha as a function of time.

2.4. Formulation of the samples

Different mixtures were prepared (Table 4) in order to estimate the influence of the mass of Typha on the mechanical behavior of CEB. Blocks were made from four formulations (S90C10; S89.5C10T0.5; S89C10T1 and S88.5C10T1.5).

Table 4. Brick formulations

N°	Designation	Meaning	
		Laterite (%)	Typha (%)
1	S90C10	90	0
2	S89.5C10T0.5	89.5	0.5
3	S89C10T1	89	1
4	S88,5C10T1.5	88.5	1.5

All formulations contain 10 % cement.

For each composition, 3 blocks of 29.5×14×8 cm3 (Figure 10) were prepared to measure the mechanical characteristics. After the tests, an average value was retained.

Figure 10. CEB

3. Results and discussions

The mechanical tests were carried out on the CEB. The compression tests were carried out using a hydraulic press with a pressure force of up to 1500 kN and the splitting and bending tests on 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 failure.

The results of the tensile (Figure 11), compression (Figure 12) and 3-point bending (Figure 13) tests are shown below.

Tensile test results show a decrease in strength with the addition of Typha. In fact, it has a value of 0.28 MPa without Typha and drops to 0.14 MPa with 0.5% Typha; 0.12 MPa with 1% fiber and 0.14 MPa for 1.5% addition. Typha is found to cause BTC to lose more than 50% of its tensile strength.

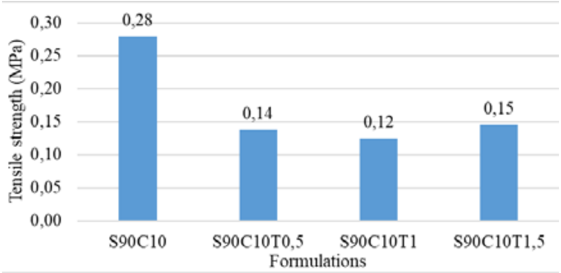

Figure 11. Effect of cement on the tensile strength of CEB.

The compressive strength of blocks without Typha is 4.36 MPa, which is well above the minimum strength of 2 MPa set by most standards. That of the Typha reinforced blocks goes from 1.26 MPa for 0.5% fiber and to 1.31 MPa for 1.5%. This gives a resistance loss of more than 68%.

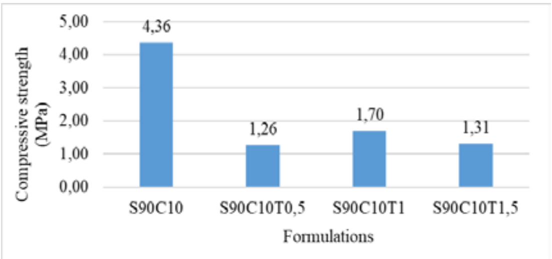

Figure 12. Effect of Typha on CEB compressive strength.

The results of the bending test show a decrease in strength as the amount of fiber increases. The resistance increases from 0.44 MPa with 0.5% Typha to 0.31 MPa for 1.5% addition. This gives a resistance loss of more than 57%.

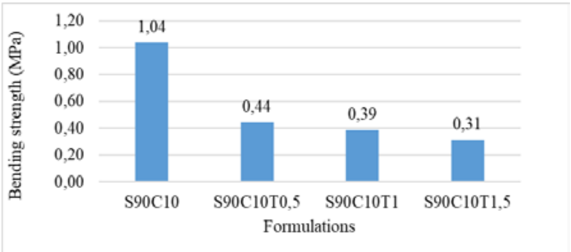

Figure 13. Effect of Typha on CEB bending strength.

These results show that the incorporation of Typha fibers reduces the mechanical characteristics of the blocks. Indeed, the cementitious matrix based on hydraulic binder corresponds to an assembly of solid phases, mainly hydrates. The entanglement of these hydrates ensures the cohesion of the materials, and gives this matrix the role of a real glue, at the origin of sometimes very high mechanical performance.

However, Typha being very porous, its incorporation into the cementitious matrix increases the proportion of voids and at the same time constitutes an obstacle to the deployment of chemical bonds and therefore reduces the resistance of the material.

The compressive strength values obtained remain modest overall because Houben and Guillaud, 1994 [10] recommended at least 2 MPa for blocks stabilized with cement. However, they may be sufficient for a one-storey building or a building with non-bearing walls.

Regarding the flexural strength, the addition of 0.5 and 1% of Typha complies with the American standard [11] which reports that the minimum value of the flexural strength 3 points must be greater than 0.34 MPa for a BTC to be suitable for use in construction.

In addition, the fibers are used for the purpose of preventing the propagation of cracks.

4. Conclusion

This work shows that reinforcing the blocks with Typha results in modest mechanical resistance. This means that these blocks can be used for certain ground-floor buildings, buildings with non-load-bearing walls or for separating walls. The incorporation of this fiber in earthen construction materials has a real interest because it participates in the transformation of Typha and thus reduces the nuisances linked to its development.

In perspective, a thermal characterization of the compressed and reinforced earth blocks of Typha will be carried out to evaluate the variation of the parameters according to the different formulations. As well as a treatment of Typha fibers is envisaged to reduce their mass absorption.

References

[1] Saad M. (2022). Potentiel des fibres végétales courtes dans l'amélioration du comportement mécaniques des mortiers. Thèse de doctorat de l'université de Toulouse.

[2] Harries K.A. (2016). Nonconventional and Vernacular Construction Materials: Characterisation, Properties and Applications. Elsevier Science 496p.

[3] Rahim M. et al (2014). Capacité tampon hydrique des bétons de chanvre et de lin expérimentation et application. Colloque International (CMMS14) UMMTO Tizi-Ouzou, Algérie 12 au 13 novembre 2014.

[4] Guerin L., International Labour Office (1985). Principes directeurs pour l'emploi de la terre crue. Bureau international du travail

[5] Ndiaye C.. (2018). Application des concepts d'Etat limite et d'Etat Critique à des Sols Tropicaux. Thèse de doctorat du diplôme de Docteur de l'université de Thiès.

[6] Calestreme A.. (2002). Synthèse bibliographique : Invasion de Typha australis dans le bassin du fleuve Sénégal. Diplôme d'Etudes Supérieures Spécialisées Productions Animales en régions chaudes. Université Montpellier II UFR Sciences.

[7] PNEEB/TYPHA. (2014). Capitalisation des résultats de recherches et expériences sur le typha. Document de capitalisation des expériences sur le Typha. Ministère de l'Environnement et du Développement durable de la République du Sénégal.

[8] Laibi A. B. (2019). Comportement hygro-thermo-mécanique de matériaux structuraux pour la construction associant des fibres de kénaf à des terres argileuses. Thèse de doctorat en Chimie de l'université de Caen Normandie.

[9] Page J.. (2017). Formulation et caractérisation d'un composite cimentaire biofibré pour des procédés de construction préfabriquée. Thèse de doctorat de l'université de Caen Normandie.

[10] Adam E. A., Agib A.R.A. (2001). Compressed Stabilised Earth Block Manufacture in Sudan. Paris: Graphoprint for the United Nations Educational, Scientific and Cultural Organization.

[11] Itulamya L. A. M. (2019). Valorisation des gisements argileux pour la fabrication des blocs de terre comprimée. Thèse de doctorat en Sciences de la Faculté des Sciences de l'université de Liège.