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Thermal Characterization of a Block of Compressed Earth, Stabilized with Cement and Reinforced with Typha Fibers

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Abstract

The use of raw earth materials makes it possible to naturally regulate humidity and improve thermal comfort inside homes. This is why, in recent years, we have seen a renewed interest in these so-called traditional materials, but especially in compressed earth blocks. 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 and improve the thermal insulation of buildings. This article deals with the influence of crushed Typha on the thermal behavior of CEB based on laterite and stabilized with cement. Several formulations based on Laterite, Typha (between 0.5 and 1.5%) and cement (10%) were made and CEB made with a Cinva-Ram type press. The thermal characteristics were obtained from an asymmetrical heating plane. The thermal conductivity and thermal effusivity values show that Typha provides better thermal insulation while maintaining good absorption inertia for the CEB.

Article Info

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Keywords

Laterite, cement, Typha, CEB, thermal conductivity, thermal effusivity.

Introduction

In Senegal as everywhere in the world, global warming, the depletion of fossil resources, pollution with greenhouse gases and the economic crisis are encouraging construction players in general and those in materials in particular to turn to local and biosourced products. The construction sector is responsible for more than 36% of total energy consumption and alone emits 39% of greenhouse gas emissions (Saad, 2022).

The cement industry alone causes between 5 to 7% of CO2 emissions globally (Harries, 2016). In addition, a lot of waste is generated by this sector. This is the reason why in recent years we have seen a renewed interest in our country, for these so-called traditional materials but especially for compressed earth blocks (CEB). Thus, several works (TER stations, schools, hotels, villas, etc.) are built in Senegal with this product to essentially reduce environmental impacts and improve the thermal comfort of buildings.

The incorporation of Typha into the material can improve thermal comfort and combat the proliferation of this plant which has become invasive in the River Valley. The use of aggregates from vegetable plants in the manufacture of construction materials can help to effectively reduce greenhouse gas emissions thanks to their ability to capture CO2 (Rahim *et al.*, 2014). This study attempts to find the impact of the addition of Typha aggregate on the thermal characteristics of CEB based on cement-stabilized laterite. 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 thermal conductivity and thermal effusivity values are determined by an asymmetric hotplate device on samples cut with a chainsaw from blocks of different formulations, produced with a Cinva-Ram type manual press.

Equipment and materials

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 (Guerin, 1985).

Thermal test device

The device used is an asymmetrical hot plane (Figure 2), composed of a surface probe powered by a direct current generator. A thermocouple placed under the probe makes it possible to measure the temperature at the center of it.

The sample with a section of 10 cm x 10 cm and a thickness of 2 cm is placed above the probe. The sample, probe and thermocouple assembly is placed between two blocks of 5.9 cm thick polystyrene foam.

The exterior surface of each polystyrene foam block is in contact with the surface of a 4 cm thick aluminum block in order to obtain a constant temperature on this surface (Figure 3).

The samples are cut with a chainsaw from BTCs measuring 29.5 x 14 x 8 cm3 (Figure 4).

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 5). It is chosen on the basis of its availability and abundance in the region.

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 6).

It contains the following percentages (Table 1):

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 7) show that the laterite of Sindia is a low plastic clay.

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

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).

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

Typha Australis

Typha australis (Figure 9) 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 (Calestreme, 2002). 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 (PNEEB/TYPHA, 2014).

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

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 11). 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 12). This hydrophone character also observed for Kenaf fibers (Laibi, 2019) and flax straw (Page, 2017) is due to the porosity and the presence of hemicellulose in these plants.

Formulation of the samples

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

For each composition, 3 blocks of 29.5 x 14 x 8 cm3 were prepared and three test pieces with a section of 10 x10 cm2 and a thickness of 2 cm cut with a chainsaw to determine the thermal properties. After the tests, an average value was retained.

Results and Discussion

The results of the thermal conductivity tests are illustrated by Figures 14 and 15 and those of thermal diffusivity by Figures 16 and 17.

They show that the introduction of Typha into BTCs based on laterite stabilized with cement makes it possible to improve the thermal insulation properties, in fact, λ increases from 0.378 W.m-1. K-1 for 10% cement without Typha at 0.223 W.m-1. K-1 for 10 % cement and 1.5 % Typha (Figure 14).

Thus, it is noted that for 1.5% Typha, the thermal conductivity decreases by more than 40% compared to CEB without fibers (figure 15).

Thermal effusivity decreases depending on the quantity of Typha added. Precisely, it goes from 641.83 J. K-1.m-2. s- 1/2 for 0.5 % Typha at 442 J. K-1.m-2. s-1/2 for 1.5 %.

Figure 17 shows that for 1.5 % Typha, the thermal effusivity decreases by almost 30 % compared to CEB without fibers.

The reduction in thermal conductivity and thermal effusivity as a function of the quantity of Typha added is justified by the porosity of Typha which reduces the density of the blocks. The higher the density of a material, the more thermal conductivity and its thermal effusivity increase. The relatively high thermal effusivity values show that these materials have good absorption inertia.

These results show that the incorporation of Typha fibers into blocks can reduce energy consumption in habitats and prevent the proliferation of Typha and thus reduce the nuisance linked to its development. In perspective, treatment of Typha fibers is planned to reduce their mass absorption.

Table.1 Soil granularity

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

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**

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

	MBV
Laterite of Sindia	**2.2**

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.

Fig.1 Manual press

Fig.2 Device of the asymetrical hot plan

Fig.3 Schema of the experimental asymmetrical hot plate device (Bodian, 1987).

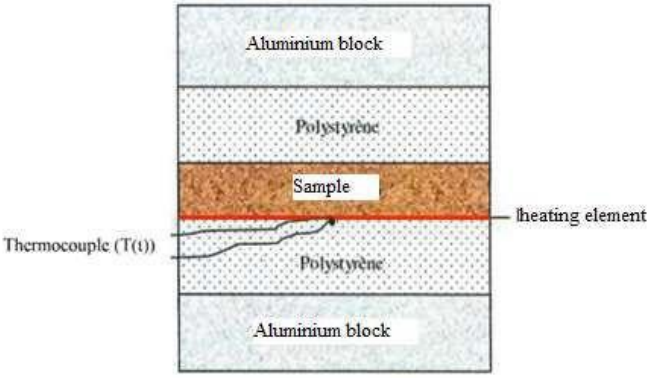


Fig.4 Cutting test specimens with a chainsaw

Fig.5 Location of the lateritic quarry of Sindia (Ndiaye, 2018).

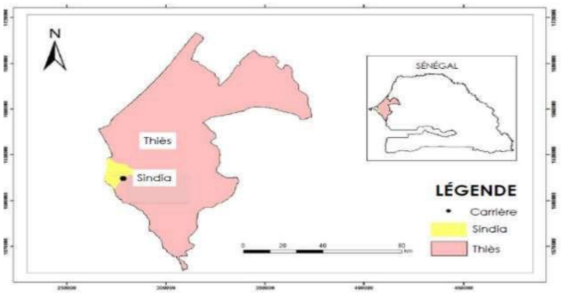


Fig.6 Curve of the total granulometric test of the laterite of Sindia in the spindle (AFNOR, 2001).

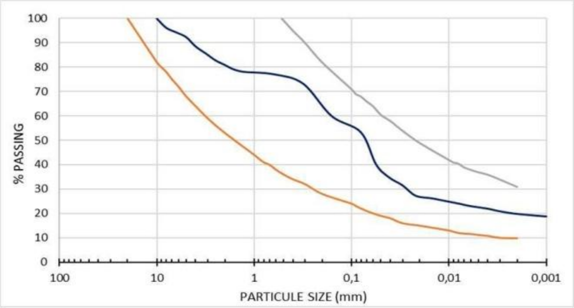


Fig.7 Classification of Sindia laterite on the Casagrande diagram of fine.

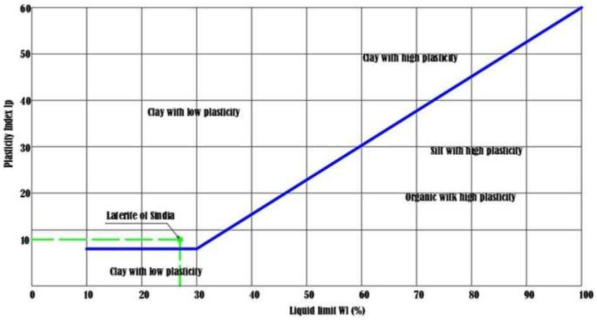


Fig.8 Representation of soil plasticity in the spindle of the soil plasticity diagram (AFNOR, 2001).

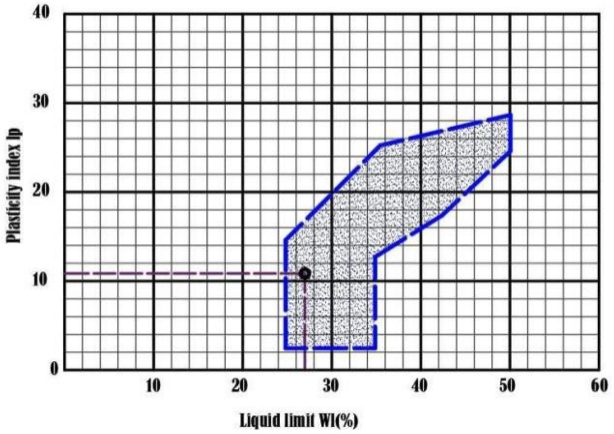


Fig.9 Typha plants

Fig.10 Crushed typha

Fig.11 Particle size test of crushed Typha

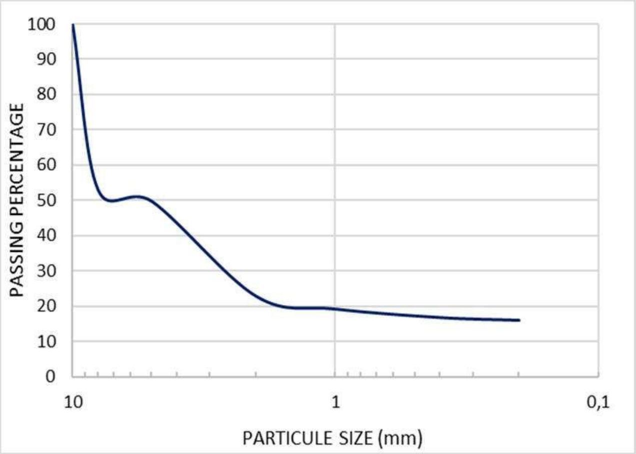


Fig.12 Curve of massive absorption of water by immersion of crushed Typha as a function of time.

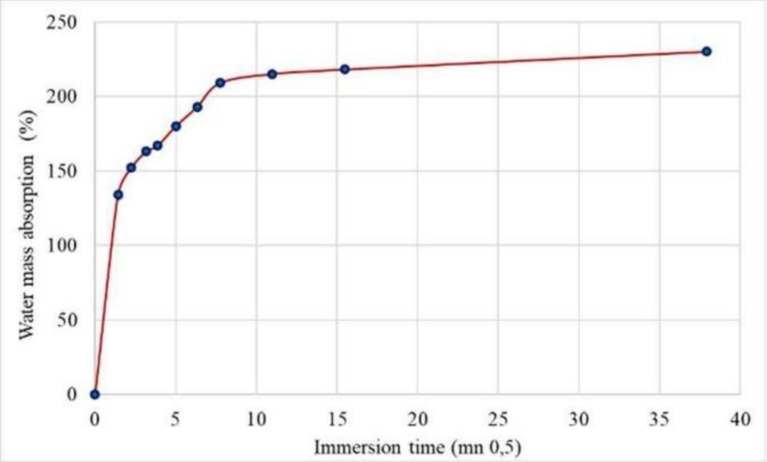


Fig.13 CEB

Fig.14 Effect of Typha on the thermal conductivity of CEB

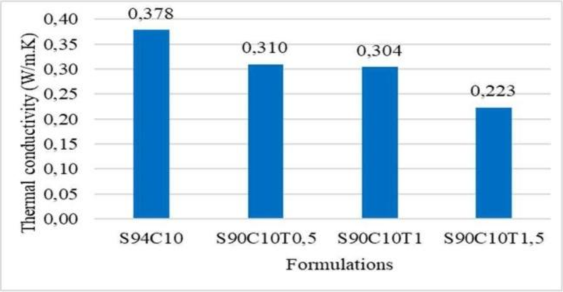


Fig.15 Decrease in thermal conductivity depending on the percentage of Typha

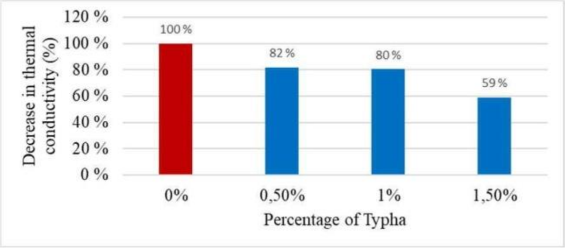


Fig.16 Effect of Typha on the thermal effusivity of CEB

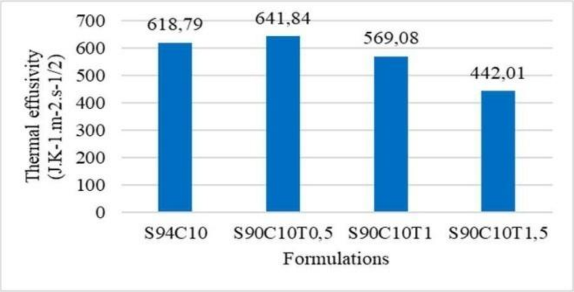
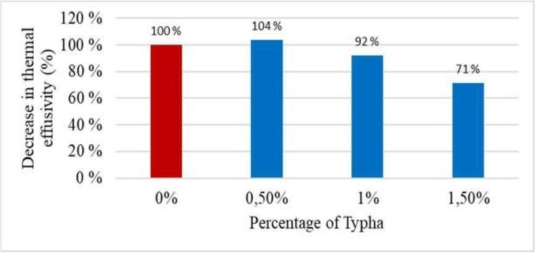


Fig.17 Decrease in thermal effusivity depending on the percentage of Typha



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