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Physico-Mechanical Characteristics of Earth Bricks Stabilized with Cement and Padouk Sawdust Residues

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Abstract

The objective of this work is to improve the physical and mechanical properties of stabilized earth blocks (BTC) used in construction in the Ndé department of Cameroon. To achieve this, two stabilizers, cement and sawdust, were used at varying percentages of 0%, 4%, 6%, and 8%. Physical characterization tests, including natural water content, specific weight, jar test, Protor, and Atterberg limits, were conducted. Additionally, mechanical tests, such as compression and three-point bending, were performed. The results show that as the amount of stabilizer increases, the density of BTC decreases. The samples with 8% sawdust have the highest density, while those without stabilizers have the lowest. Porosity decreases as sawdust and cement content increases, with smaller values observed in samples with 8% sawdust or cement. Our tests indicate that blocks stabilized with cement have slightly higher compressive strength than those stabilized with sawdust. However, the water absorption rate increases with higher sawdust content.

Keywords

Earth block, Cement, Sawdust, Physico-mechanical Characteristics, Bangante, West Cameroon

1. Introduction

The use of earth as a building material in its natural state has a long history [1]. However, the development of cement factories and concrete blocks has led to a decrease in its use in construction in developing countries over time [2]. Nowadays, efforts are being made to promote the use of this material in developed countries, especially for its thermal properties. This awareness campaign considers several aspects of earth material, including its social acceptance, hydro-mechanical behavior, acoustic properties, and thermal properties [3]-[7]. Earth has several advantages, including its widespread availability, ease of use, attractive appearance, and ability to maintain a comfortable temperature in both hot and cold seasons due to its thermal inertia. However, unstabilized earth has some disadvantages, such as low mechanical strength, susceptibility to cracking due to shrinkage, and high sensitivity to water.

The properties of raw earth depend on its physico-geotechnical characteristics, such as granulometric skeleton, plasticity, compressibility, and mineralogical composition [1] [8]. The vulnerability of raw earth to water is problematic for its mechanical performance and durability [9]. Soil composition may need to be modified if its intrinsic characteristics, such as particle size, plasticity, mineralogy, and compressive strength, do not meet certain requirements for use in construction [1]. To improve these characteristics, various methods are used, including compressing the matrix for densification, adding fibers and aggregates for matrix stability [10] [11] [12], and incorporating hydraulic, pozzolanic, or geopolymeric binders such as cement, lime, and pozzolana to ensure microstructural cohesion of the matrix [13] [14].

Cement is commonly used to stabilize sandy soils with low clay content (5% - 30%) and non-swelling clay mineralogy such as kaolinite. The cement can be used in mass fractions up to 8% of the soil mass [1] [15]. The hydration products, mainly hydrated calcium silicates and hydrated calcium aluminates, contribute to the cohesion of coarse sand and gravel particles and the densification of the matrix. This results in a reduction in porosity and water absorption, as well as an improvement in mechanical strength and durability [16] [17]. The addition of wood sawdust residues could improve the properties of CEBs. In Cameroon, there is a significant amount of unused sawdust. To promote sustainable development and the use of local natural resources, particularly in the construction industry, sawdust was used in this study to stabilize compressed earth blocks (CEBs). The study evaluated the impact of sawdust on the mechanical and hygroscopic properties of the CEBs.

2. Characterization of the Material

2.1. Earth Construction around the World

CEBs buildings can be found on all continents. The quality of these buildings depends on the formulation of their materials. Mechanical resistance, swelling, and shrinkage are among the common issues encountered. These problems can

(a) (b)

Figure 1. (a) Cracking of earth blocks, (b) Deterioration of earth blocks.

Figure 2. MIPROMALO headquarters in Yaoundé, Cameroon.

be aggravated by poor material study, characterization, or stabilization. **Figure 1** presents some problems of earth construction in particular cracking.

In Cameroon, the MIPROMALO (**Figure 2**) is responsible for promoting and disseminating the use of all local construction materials.

This research organization's focus guided the selection of materials studied in this work to produce BTC, including simple earth, earth and cement, and earth and sawdust.

2.2. Earth Material

Samples of earth were collected at depths of −30 cm and −50 cm to avoid the organic part of the soil. For our study, we used earth from the city of Bangangté, specifically from the entrance of the city in an area of production of raw adobe bricks (see **Figure 3**) and with the following geodetic coordinates: X = 518382.046, Y = 1050043.553, Z = 1401.82.

Figure 3. Sampling zone.

2.2.1. The Production and Value-Added Processing of Wood Sawdust in Cameroon

Cameroon is the third most significant African country in terms of the importance of its forest resources, with an area of over 55% covered by forest [18].

The forestry operation has a local processing capacity of 2.7 million m^3 of logs. The initial processing of wood before export is divided into sawing, peeling and slicing activities. All of these activities result in the production of sawdust, which is estimated to be 400,000 m^3. This production capacity is distributed across nearly 61 sawmills, 20% of which are located in the coastal region of Douala [18].

Regarding the fate of the sawdust, a small quantity is utilised in sawmills situated in peri-urban areas, operated by local residents, to power domestic ovens. The majority of the sawdust was incinerated in the vicinity of the sawmills. For sawmills installed in rural areas where firewood is not scarce, the vast majority of sawdust production is burned or dumped in pits set up near the sawmills. In light of the ongoing increase in demand and the importation of pellets from countries such as South Africa onto the European market, it is possible to develop the pellet sector in the short and medium term. This can be achieved by exploring alternative avenues for pellet utilisation in the construction materials industry [18].

Padouk

Figure 4 illustrates the type of Padauk wood found in the forest and its subsequent transformation into sawdust. The Padouk used in this study to produce wood shavings, scientifically known as *Pterocarpus soyauxii*, belongs to the Papilionaceae family (Leguminosae, Papilionoideae, Fabaceae) [19]. It is a highly durable wood that does not require preservation treatment, making it an environmentally friendly material of choice. It can be found in the equatorial forest of Nigeria to the Central African Republic, from the Democratic Republic of Congo to Angola. The sawdust used should be smaller than 1.6 mm in size and have a density of approximately 0.85 g/cm^3.

(a) (b)

Figure 4. (a) Padauk out of the forest; (b) Sawdust Padauk.

2.2.2. Cement

The first attempts at stabilising roads with cement were made in the United States in 1915. The use of cement in building construction was independently developed in Germany from 1920 onwards. In the United States, from 1935 onwards, the use of ground-cement increased significantly, with applications in road construction and the development of airfield runways. Since that time, cement stabilization has been employed in countless applications worldwide, both in public works and construction [1].

Cement is undoubtedly one of the most effective stabilisers for compressed earth blocks. The addition of cement before compression allows for the improvement of material characteristics, particularly in terms of water resistance. This is achieved through the irreversible bonds created between the largest particles. The cement will primarily affect the sand and gravel, acting in a manner similar to that of concrete or a sand-cement mortar. It is therefore inadvisable to use soils that are too clayey (>30%) [1]. In general, a minimum of 5% - 6% cement is required to achieve satisfactory results. The compressive strength is highly dependent on the dosage. An economically acceptable upper limit of 8% cement is often recommended [20].

The cement used is grey Portland cement with characteristics prescribed by the NF EN 197-1 standard for hydraulic binders. It is equivalent to CEM II-42.5 type cement. Its compressive strength is 42.5 MPa and its density is 1.44 g/cm^3.

This cement (**Figure 5**) contains clinker (70 - 79%), pozzolan (21% - 25%) and gypsum (≤ 5%). Its fineness is between 3900 and 4000 cm2/g. The mineral (**Table 1**) phases of CEM II 42.5 are: Alite, Belite, quartz, calcite, pyroxene and plagioclase. Pyroxene and plagioclase are residual crystalline phases of volcanic ash used as additives (Djobo *et al.* 2017; Jean Noël *et al.* 2020; Elie Kamseu *et al.* 2016; Leonelli *et al.* 2007). **Table 1** presents the main mineral phases found in the cement used.

Figure 5. CEM II 42.5 Portland cement powder.

Table 1. Chemical compositions of CEM II 42.5 cement.

Oxides (wt. %)	Fe_2O_3	SiO_2	CaO	MgO	CaO free	K_2O	SO_3	Na_2O	LOI
CEM II 42.5	4.65	19.3	65	0.98	1.8	0.9	2.01	0.2	0.45

3. Soil Characterization

3.1. Geotechnical Studies

3.1.1. Jar Test

Figure 6 represents the principle of the jar test. The sedimentation or jar test estimates the percentages of sand, clay, silt, and humus based on the thickness of each layer formed in the jar after settling. The soil texture can then be approximately determined using the soil texture triangle. Soil texture refers to the relative proportion of sand, silt, and clay particles in soil. Soil texture is often described by differentiating between heavy soils, which are rich in clay, and light soils, which are sandy or loamy. It is a major determinant of soil workability, water retention and drainage, as well as the level of organic matter and aggregation. The material's resistant elements include gravel and sand. Clays provide cohesion and control plasticity, as well as influencing the earth's reaction to humidity, which in turn affects shrinkage and swelling (Walker, 1995).

Figure 6. Principe Test Bocal.

3.1.2. Atterberg Limits

Some steps in determining the Atterberg limit are shown in Figure 7. Atterberg limits are conventional geotechnical characteristics of soil that mark the thresholds between the transition of soil from liquid state to plastic state (liquid limit, **Wl**) and the transition of soil from plastic state to solid state (plastic limit, **Wp**). These limits are expressed as the soil's water content at the considered transition state, expressed as a percentage of the mass of the raw material. The plasticity index is a measure of the quantity and type of soil present in a sample. It indicates the clay content of the sample [21]. These are used in specifications to control the compressibility properties and behaviour of soil mixtures. It is calculated using the equation (1) below:

$$\mathbf{Ip} = \mathbf{Wp} - \mathbf{Wl} \tag{1}$$

where **Ip** is the plasticity index, **Wp** is the plastic limit, and **Wl** is the liquid limit.

The determination of the Atterberg limits was carried out according to the NF P 94-051 standard [18] [19]. Knowing these limitations allows for quick prediction of a soil's construction possibilities.

(a) (b) (c)

Figure 7. (a) Wet sieving, (b) Plasticity test tare, (c) Drying ovens.

3.1.3. Water Content

The NBN EN 1097-5 standard describes a method for determining the total moisture content per unit of dry matter of an aggregate sample. Moisture can be found on the surface, inside the grains, or in pores accessible to water. The sample is weighed before and after drying at 110˚C. The percentage of water content is obtained by calculating the difference in mass between the wet and dry masses, expressed as a percentage of the dry mass [20].

To determine the wet mass, the sample is spread out on a tray and dried in a ventilated oven at 110˚C ± 5˚C until the mass of the contents changes by less than 0.1% between two successive weighings spaced at least 1 hour apart, at which point it is considered to have reached a constant mass. For fine aggregates, it is possible to mix the sample with a spatula during the drying process to facilitate water evaporation. However, the spatula must always be left in the container to avoid losing particles.

The water content (**W**) is calculated using the formula

$$\mathbf{W = Mass\ of\ water/Mass\ of\ soil} \quad (2),$$

where **Mass of water** = **Mass of soil** − **Mass of soil after drying**.

3.1.4. Proctor Trial

The objective of the Proctor test is to ascertain the water content to which soil must be compacted in order to achieve maximum dry density. A 15 kg sample, sieved using 5 mm aperture sieves, was taken and divided into five piles of 3 kg. The materials used in the Proctor test were as follows: the Proctor mould, a cylindrical metal tube with an internal diameter of 10.15 cm and a height of 11.7 cm; the standard lady, a cylindrical sheep 5.1 cm in diameter guided by a rod inside a sheath over a certain centimetre in length. The modified Proctor test requires a sheep weight of 2.49 kg and a drop height of 30.5 cm. It also calls for trowels and spatulas for mixing, a scale with a sensitivity of at least one gram and a maximum capacity of at least 20 kg, and a precision scale with an accuracy of 0.01 g. Additionally, the test requires tars and an oven with a temperature range of 105˚C. The Proctor test begins with sample preparation on the mixing table. The sample is first watered with approximately the requisite quantity of water for the first compaction stage. It is then mixed to achieve uniform humidification of the mass. The compaction process is carried out in five stages, with each layer approximately 2.5 cm thick receiving 55 blows. Once compaction is complete, the upper part of the mould is removed to weigh the specimen and obtain the precise weight of the sample, with an accuracy of one gram. This process is repeated on five identical samples, each having received a different quantity of water.

3.2. Production of Test Specimens

Test specimens are made using a standardized prismatic mould (**Figure 8(a)**) with dimensions of 16 × 4 × 4 cm^3 (NF P15-413 Standard). Compaction is carried out using a hydraulic press (**Figure 8(b)**) at a pressure of 10 MPa.

(a) (b)

Figure 8. (a) 16 × 4 × 4 mold, (b) Hydraulic press.

3.3. Formulation of Specimens

The blocks were manufactured at the Laboratory of Civil Engineering Technical Education of the University of Douala, following the Cameroonian standard NC 103. The mass of the dry specimens was kept constant during the experimental phase. We have formulations (**Table 2**) with and without stabilizer, using cement and Padouk sawdust stabilizers at rates of 4%, 6%, and 8% relative to the total dry mass of the test specimens.

Table 2. Mass composition of samples.

Désignation	Earth (%)	Water (%)	Sawdust (%)	Cement
B-Sr 0	90	10	0	0
B-Sr 2	88	10	2	0
B-Sr 4	86	10	4	0
B-Sr 6	84	10	6	0
B-Sr 8	82	10	8	0
B-Ci 2	88	10	0	2
B-Ci 4	86	10	0	4
B-Ci 6	84	10	0	6
B-Ci 8	82	10	0	8

4. Compression and Bending Tests

4.1. Compression Tests

The compression resistance of samples is determined by dividing the maximum load at axial compression failure by the cross-sectional area of the sample perpendicular to the direction of the compressive force. Compression tests aim to determine the behavior and response of a material under a compressive load by measuring fundamental variables such as stress and strain.

Compression tests were conducted on 16 × 4 × 4 cm^3 specimens. The compression strength is calculated using formula (3).

$$R_c = \frac{F}{Lxl} \quad (3).$$

With: R_c: Compressive strength of blocks in (MPa), F: Breaking force (N), L: Length of the specimen in cm, l: Width of the specimen in cm.

4.2. Density test

The blocks used have dimensions of 4 × 4 × 4 cm^3. The dry bulk density of the brick is determined using the formula below (expressed in kg/m^3):

$$\rho = \frac{M}{V} \quad (5)$$

M: the mass in kilograms and V: represents the volume in cubic meters.

4.3. Porosity Test

Dry the samples in an oven at a temperature of 105˚C ± 5˚C until a constant mass or dry mass (M_s) is obtained. After cooling, immerse them completely in water. Mass measurements were taken every 30 minutes after removing residual water with an absorbent cloth until the difference between two successive measurements was less than 0.2% or the saturated mass (M_{sa}) was reached [21]. The pore volume (V_p) is calculated as the difference between the final saturated mass and the initial dry mass, divided by the density of water (ρ_{eau}). The apparent porosity (P) was determined by dividing the pore volume by the total volume (V_t) of the specimen [21].

$$V_p = \frac{M_{sa-M_s}}{\rho_{eau}} \tag{6}$$

$$\rho = \frac{V_p}{V_t} \tag{7}$$

4.4. Water Absorption Test

The water absorption test determines the amount of water absorbed by capillarity. The test involves measuring the increase in mass of the specimen placed in a container with a constant water level. Prior to the absorption test, the specimens were dried in an oven at 105˚C for 24 hours. The mass of the completely dry specimen (M_s) was then recorded. The test tube was finally immersed in water for 24 hours and its soaked mass (M_t) was measured [22]. The absorption percentage is calculated using the following formula:

$$A_{bs} = \frac{M_t - M_s}{M_s} \times 100 \tag{8}$$

5. Results and Discussion

5.1. Geotechnical Classification

5.1.1. Soil Nature and Acidity

We collected three soil samples from the study area, spaced an average of 30 metres apart, and passed them through a 5 mm sieve. The pH of a material has an impact on its properties [23] [24]. If the pH is below 6, soil pre-treatment is necessary. **Table 3** shows the results of the jar test.

Table 3. Nature of the soil with the texture triangle and pH.

Samples	n % gravel 5 > Φ > 2 mm	Sand 2 > Φ > 0.02 mm	% stringers 0.02 > Φ > 0.002 mm	% clay Φ ≤ 0.002	pH
Earth 1	1.2	55	24.8	19	7.80
Earth 2	1.8	56	24.2	18	7.90
Earth 3	2	57	21.5	19.5	7.50
Nature	Sandy Loams	Sandy Loams	Sandy Loams	Sandy Loams	

The texture triangle in Figure 9 helped us determine the type of soil under study. Based on our three samples, we conclude that the soil is sandy loam. Ideally, the soil should contain between 0% and 40% gravel, 25% and 80% sand, 10% and 25% silt, and between 8% and 30% clay [25]. Our analysis confirms that the soil is suitable for making earth blocks.

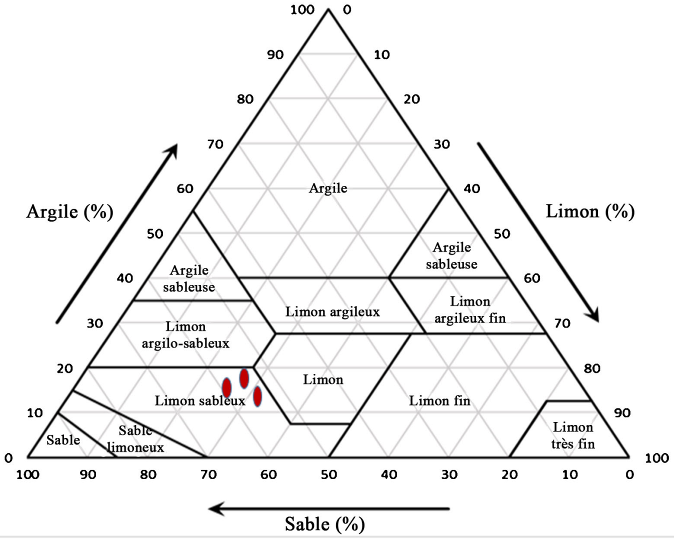

Figure 9. Texture triangle.

5.1.2. Atterberg Limits, Water Content, Plasticity and Cohesive State

Atterberg limits are expressed in terms of liquidity limits (**Wl**), plasticity limits (**Wp**) and plasticity index (**Ip**). Their determination is necessary, because it represents a very important index for the classification of soils and also allows a better understanding of their behavior.

1) The Atterberg limits vary according to the cement content

Figure 10 illustrates the variation in the Atterberg limits as a function of cement content. The results demonstrate that the addition of cement to the base soil leads to a reduction in the plasticity index (from 15.9% to 11.28%), an increase in the liquidity limit (from 44.6% to 49.5%) and the plasticity limit (28.7% to 38.22%). This variation can be attributed to the hydration of the cement.

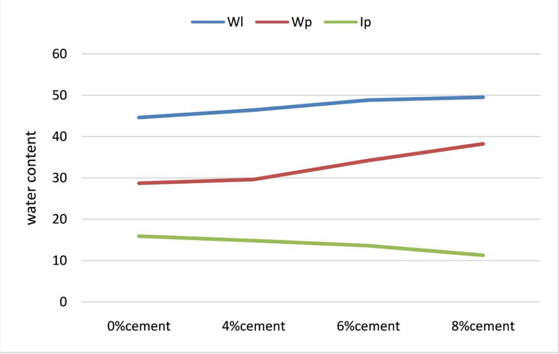

Figure 10. The Atterberg limits vary according to the cement content.

2) The Atterberg limits vary according to the sawdust content.

Table 4 presents the results of the Atterberg limits when we use sawdust as a stabilizer.

Table 4. The Atterberg limits, nature of the soil and corrosive state are dependent on the sawdust content.

Sample	Ll	Ip	Types of soil with stabilizer	Degree of plasticity	Cohesive state
CEBs 0% Sr	46.6	15.9	Low plastic stringers	Low plastic soil	strongly cohesive
CEBs 4% Sr	38.4	14.8	Low plastic clay	Plastic floor	Moderately Cohesive
CEBs 6% Sr	34.8	13.92	Low plastic clay	Plastic floor	Moderately Cohesive
CEBs 8% Sr	34.5	12.28	Low plastic clay	Plastic floor	Moderately Cohesive

5.1.3. Proctor Essay

The test enables the optimal compaction characteristics of a material to be determined. It is important to note that this test determines the water content (W) that gives the maximum dry density of a material for a given compaction energy.

1) Base soil and earth/Cement

Figure 11 illustrates the evolution of density as a function of water content. Figure 11 Proctor demonstrates a curve that allows for the determination of the optimal water content corresponding to the maximum dry density of the earth. Furthermore, the optimal water content of cement-stabilised earth is presented. The results demonstrate that the introduction of cement into the base soil results in a gradual decline in the maximum dry density, with a maximum compaction density of 19.7 KN/m^3 reducing to 18.35 KN/m^3. As the sawdust content increases from 0% to 8%, however, a slight increase in water content from 12% to 13.5% is observed when dry density drops slightly.

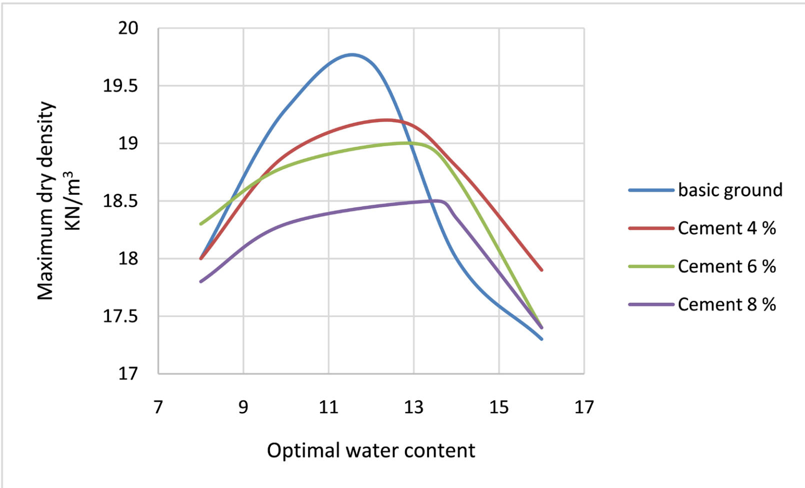

Figure 11. Proctor curve of base soil and soil + cement.

2) Base soil and earth/Sawdust

Figure 12 shows the variation in dry density as a function of water content. This is done with sawdust as a stabilizer. The results demonstrate that the introduction of sawdust into the base soil results in a gradual decline in the maximum dry density, reaching a maximum compaction density of 19.7 KN/m^3, which then reduces to 17.8 KN/m^3. As the sawdust content increases from 0% to 8%, however, a slight decrease in dry density is accompanied by an increase in water content from 12% to 13.5%. This reduction is due to the density of padauk, the original species of our sawdust, which is lower than that of the base soil.

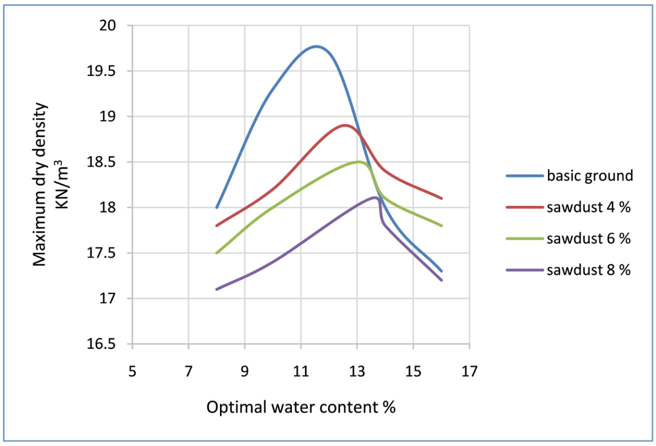

Figure 12. Proctor curve of base soil and soil + sawdust.

5.1.4. Density

Solid density is an important property of construction materials used to control quality from raw powders to final products. Geometric and skeletal densities allow researchers and producers to calculate the open porosity of a solid and hardened sample, which provides critical properties such as strength, temperature tolerance, and transformability. Figure 13 shows the evolution of density for different samples.

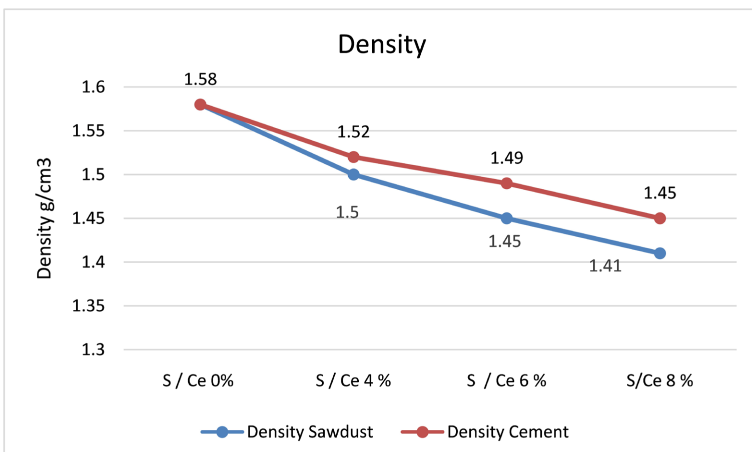

Figure 13. CEBs density variation with cement and sawdust content.

The addition of stabilizers to CEBs results in a decrease in density. At 0% sawdust, the density is 1.58 g/cm^3, while at 8% sawdust, it is 1.41 g/cm^3. As the percentage of sawdust increases, the density of BTC decreases further. As the percentage of sawdust increases, the density of CEBs decreases further. These values are lower than those of terracotta (1.8 - 2.0 g/cm^3) and rammed earth (1.7 g/cm^3) [26]. The reason for this phenomenon is the gradual decrease in the volume of the earth in the prepared BTC. Its density is estimated to be 1.64 g/cm^3, which is higher than that of cement (1.44 g/cm^3) and sawdust (0.85 g/cm^3).

5.1.5. Porosity

Figure 14 illustrates the effect of stabilizers on porosity.

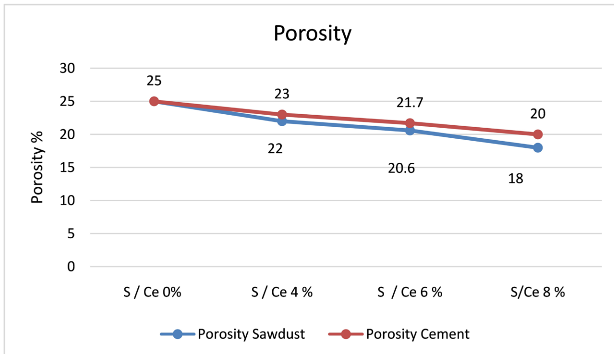

Figure 14. Shows how porosity changes with stabilizer content.

CEBs with stabilizers, such as cement or sawdust, have lower porosity compared to those without stabilizers (25% porosity).

The reduction in porosity can be attributed to the smaller size of cement particles, which can infiltrate the pores more easily. For instance, CEBs with 8% cement have a porosity of 18%.

The porosity of CEBs stabilized with sawdust is reduced due to the smaller diameter of the sawdust particles passing through a 1.6 mm sieve, which facilitates infiltration between the voids. Compression also contributes to the reduction of voids. When using sawdust as a stabilizer, the porosity decreases from 25% to a minimum of 20% with 8% sawdust.

5.1.6. Absorption

Figure 15 shows the curve representing the variation in absorption of the different formulations.

The absorption capacity generally increases by 17% to 20% when sawdust residue is added. This is due to the absorption capacity of agricultural residues. [27] demonstrated that the absorption capacity increases with the addition of fibers, depending on their length.

However, when cement is added, the absorption rate decreases. The total absorption value ranges from 17% for blocks without cement stabilizer to 12% for blocks containing 8% cement. This can be attributed to cement's ability to fill voids, reduce porosity between soil particles, and decrease infiltration. According to [28], the addition of cement also reduces the absorption capacity of earth blocks.

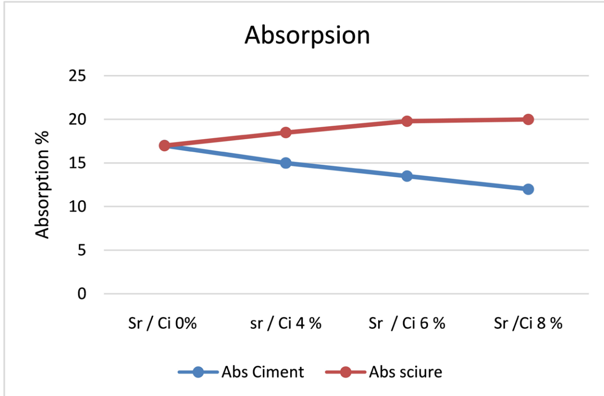

Figure 15. Absorption.

5.1.7. Compressive Strength

The resistance of CEBs in compression is shown in **Figure 16**.

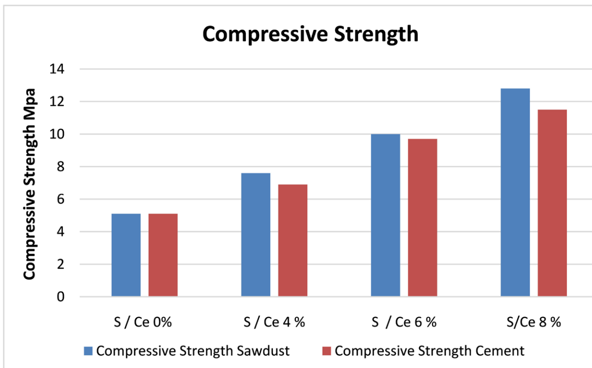

Figure 16. Compressive strength.

Figure 17 shows the variation in stress as a function of displacement during the compression test. The compressive strength increases as stabilizers are added. Specifically, the strength increases from 5.1 MPa with 0% stabilizer to 12.8 MPa with 8% cement, and from 5.2 MPa with 0% sawdust to 11.5 MPa with 8% sawdust.

The increase in strength for cement is due to infiltration and void reduction caused by the stabilizer and the compressive force. The results confirm previous findings by [29] [30] that adding cement increases compressive strength.

Additionally, introducing fibers to sawdust improves its compressive strength. Other studies have shown that stabilizing with plant fibers also increases compressive strength of CEBs, as reported by [31] [32] for low sawdust rates.

The curve of the evolution of the stresses as a function of the displacement also demonstrates that the compressive resistance increases with the stabiliser rate.

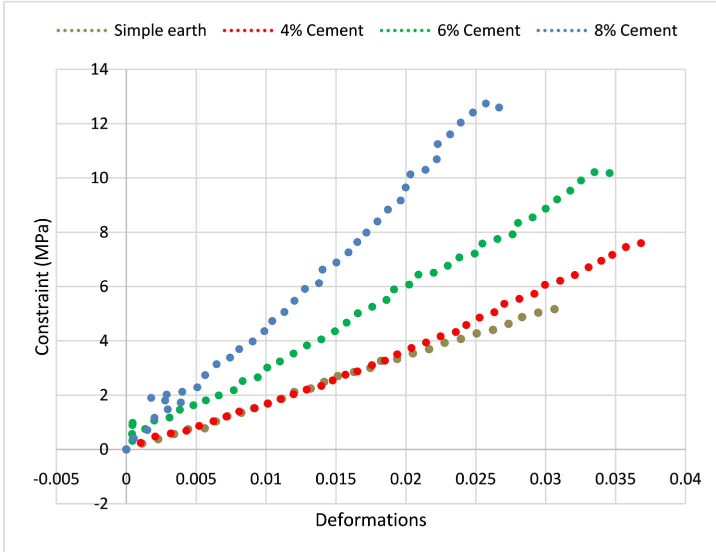

Figure 17. Stress/displacement curve.

6. Conclusions

The aim of this study was to investigate the behaviour of earth blocks used in construction in the Ndé department of West Cameroon. The blocks were produced by stabilising soil with cement and sawdust, resulting in a compressive force of 10 MPa. Test pieces were manufactured using a 5 mm diameter sieve to remove large grains. We sifted our sawdust samples through a 1.6 mm sieve to stabilize them. We manufactured test pieces without stabilizer, with an average mass of 1250 g per sample, and then with stabilization at 4%, 6%, and 8% earth mass using sawdust or cement as a stabilizer. The results showed that the use of sawdust or cement as a stabilizer improved the mechanical and hygroscopic properties of earth blocks. The compressive strength without stabilizer was 5.1 MPa. The compressive strength of the material reaches a maximum of 12.8 MPa at 8% cement and 11.7 MPa at 8% sawdust. The density of the material decreases from 1.58 g/cm^3 without stabilizer to 1.45 g/cm^3 with 8% cement and 1.41 g/cm^3 with 8% sawdust. The porosity of the material also decreases from 25% without stabilizer to 18% with 8% cement and 20% with 8% sawdust. Using cement as a stabilizer reduces absorption from 17% to 12%, compared to 20% with 8% sawdust.

Our tests indicate that blocks stabilized with cement have slightly higher compressive strength than those stabilized with sawdust. However, the bending strength and water absorption rate increase with higher sawdust content.

Data Availability

The data supporting the results of the study are contained in this paper.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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