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RESEARCH ARTICLE

INFLUENCE OF SAWDUST MIXTURE ON THE MECHANICAL PROPERTIES OF COMPRESSED EARTH BRICKS (CEB): CASE STUDY OF IROKO AND SAPELLIWOOD SPECIES

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Abstract

This paper aims to evaluate the influence of the Iroko and Sapelli sawdust mixture on the compressed earth block's (CEB) mechanical characteristics. For 15% sawdust, different compositions were tested using different ratios of a mixture of two wood species (Iroko and Sapelli). The earth+15% sawdust mixture was stabilized with 8% slaked lime. The mechanical properties studied were: dry compressive strength, wet compressive strength and abrasion coefficient. The results showed that the studied properties vary with the composition of the sawdust mixture. However, these mechanical characteristics do not consistently change in the same way as the percentage of the species in the sawdust mixture that have the best mechanical qualities (Sapelli).Apart from the sample made of earth + 15% Sapelli + 8% lime, all lime-stabilized samples can be used according to standard NF XP 13-901 (2001) for the production of CEB under a pressure of 3.6 Mpa with regard to their average strengh in dry compression (greater than 2 Mpa).

Introduction:-

Among the dozen existing earth construction techniques, the most common are: adobe, rammed earth, earth-straw, cob, compressed blocks and cob (Houben et al., 1996).

Of the above-mentioned earth construction techniques, compressed earth bricks are the most recent. Compressed earth bricks (CEB) have only appeared very recently. Around 1950, the first manual press by Colombian engineer Raul Ramirez (CINVA Center in Bogota), with its 300 to 800 bricks per day, conquered the international market with its simplicity and lightness. After several improvements, the technique took off in the context of low-cost housing programs in Africa and Latin America (Terra Award, 2015).

However, the adoption of CEB has not yet been fully achieved, due to the lack of knowledge of some of its ecological properties, but above all due to certain inadequacies both in terms of mechanics (compressive strength, tensile strength) and durability, in particular its poor resistance to humidity (Cherif et al, 2021). Houben et al. (1996), the NF XP P 13-901 standard (2001) as well as CRATERRE (1989), cited by BIT (2002) have defined reference zones of soils usable for the production of CEBs. Although the boundaries of the zones are not rigorous

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(Nwandji and Atahualpa, 2022), engineers use stabilization techniques to improve the properties of CEBs. The United Nations Centre for Human Settlements (1992), cited by Oussama (2018), defines soil stabilization as the modification of the properties of an earth-water-air system by appropriate processes in order to obtain permanent properties compatible with a desired achievement. Indeed, stabilization aims to improve the properties of an earth brick irreversibly through mechanical, physical, chemical or even mixed processes, in particular its load-bearing strength, its sensitivity to water and its durability (Meukam, 2004). Physical stabilization aims to act on the texture of the soil by modifying the properties of the soils by correcting the granularity or by incorporating fibers into soils rich in clay. The mixture obtained by incorporating other materials leads to a modification of the plasticity of the base material by adding sand (to reduce plasticity) or by adding fines to increase its cohesion (Ouarda, 2016). Among the fibers and other plant residues studied by some authors as means of stabilizing CEB, we note sawdust and palm kernel ash (Adetoro and Adekanmi, 2015), coconut fibers (Enokela and Alada, 2012), sugarcane molasses (Malanda et al., 2017) as well as bamboo fibers (Abessolo, 2022).

Although it encourages the recovery of waste from the wood industry, the use of this, which is typically available in sawmills as a mixture of residues of several wood species with varied properties, does not clearly allow us to know how the various wood species present in the mixture affect the properties of earth bricks. (Nwandjiand Atahualpa, 2024). Consequently, it is intriguing to determine whether the mechanical characteristics of earth bricks composed of a sawdust mixture systematically change in tandem with the mixture's percentage of the wood species with the highest employment class (sapelli). The purpose of this paper is to assess how the combination of sapelli and iroko sawdust affects the mechanical characteristics of compressed earth blocks (CEB).

Method:-

Our approach consisted of:

1. Sieve the soil through a 3,15 mm mesh sieve, then determine its particle size and its Atterberg limits using standardized test;
2. Add 15% of the sawdust combination (Sapelli + Iroko) in the following proportions: (0%; 100%), (25%; 75%), (50%; 50%), (75%; 25%), and (100%; 0%) plus 0% or 8% of lime to the previously dried and sieved laterite using a 3.15 mm mesh sieve;
3. For every composition, find the ideal compaction water content.;
4. Produce compressed earth bricks measuring 4×4×4 cm3 and 4×4×16 cm3 from these mortars;
5. Subject the CEBs to a 14-day cure followed by 14 days of drying for CEBs not stabilized with lime and 42 days for CEBs stabilized with slaked lime; (vi) Subject the 4×4×4 cm3 samples to the compression test and the 4×4×16 cm3 sample to the wear test.

The aim of the test was to evaluate the mechanical properties of CEB, including dried compressive strengh, wet compressive strengh and abrasion coefficient. The bricks were made using the method of Houben et al. (1996) with a compaction energy of 3.6 Mpa.

The following properties were determined on the basis of the standardized tests: abrasion coefficient, dry and wet compressive strengths.

Three samples of each formulation were made for the determination of compressive strengths while one sample of each formulation was made for the wear test.

Granulometric analysis

The granulometric analysis was carried out by sieving according to the NF P 94-056 (1996) standard for the soil fraction greater than 80µm while for the fine soil fraction, it was carried out by sedimentation according to the NF P 94-057 (1992) standard.

Plasticity

The plasticity index (PI) was determined by the difference between the liquid limit (Wl) and the plasticity limit Wp: PI = Wl-Wp.

The liquid limit (Wl) and the plastic limit (Wp) were determined by laboratory tests according to standard NF P 94-051 (1993) on a soil sample previously sieved through a 400 µm square mesh sieve.

Abrasion resistance

The test consisted of, according to the NF XP 13-901(2001) standard, as illustrated in Figure 1, fixing a 3 kg mass to the wire brush, then weighing the CEB sample and then brushing the CEB samples for one minute at a rate of one back and forth per second over a width of 25 mm ± 2 mm. After one minute, the brushed surface is cleaned using a brush and the sample is weighed again and the brushed surface measured. The abrasion coefficient is obtained by the expression (1):

$$Ca = \frac{(P0 - P1)}{S} \quad (1)$$

where

- P0 is the initial mass of the brick in grams;
- P1 is the mass in grams of the brick after brushing.
- S is the brushed area.

Figure 1 illustrates the progress of this test.

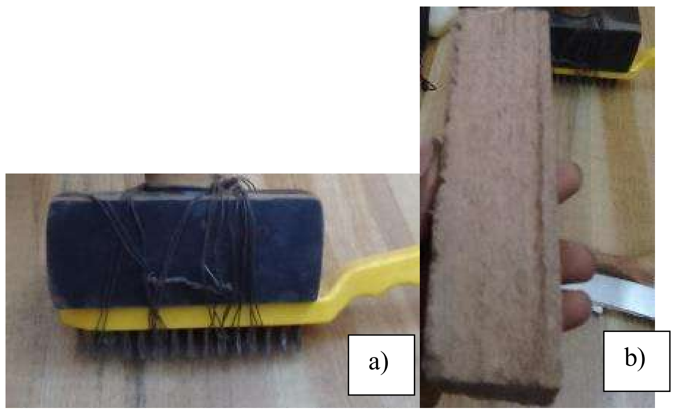

Figure 1:- Wear test of a CEB sample (a= wire brush and b= brushed surface of the sample).

Compressive strength

The dry compressive strength was determined on the 4×4×4 cm3 blocks after a 14-day cure followed by 42 days of drying for the lime-stabilized samples, while drying lasted 14 days for the other samples. The wet compressive strength was determined on the different blocks after 2 h of immersion in water and storage in waterproof plastics for 2 days. Figure 2 illustrates the preparation of samples for wet compression testing and figure 3 illustrates the progress of this test.

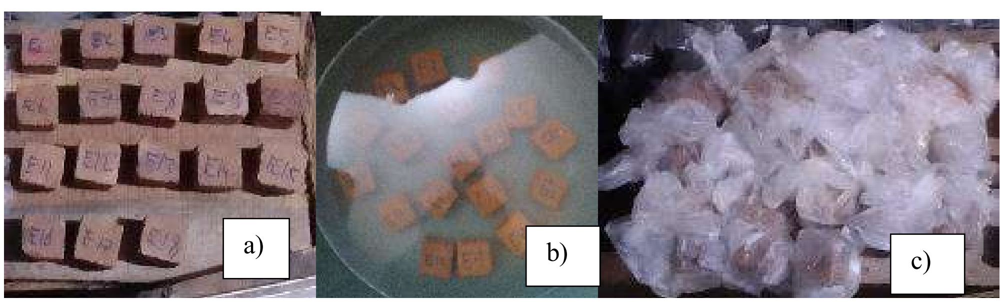

Figure 2:- Preparation of samples for wet compression testing.

Figure 3:- Crushing a sample in the press.

Compressive strength is determined by the formula (2):

$$Rc = \frac{F}{S} \quad (2)$$

where:

- Rc is the compressive strength in Mpa;
- F is the breaking load, expressed in N;
- S is the cross-sectional area of the specimen in mm².

Materials:-

Soil

The location chosen for soil sampling is Pk18 in the coastal Cameroonian city of Douala. Figure 4 illustrates the location of the sampling site.

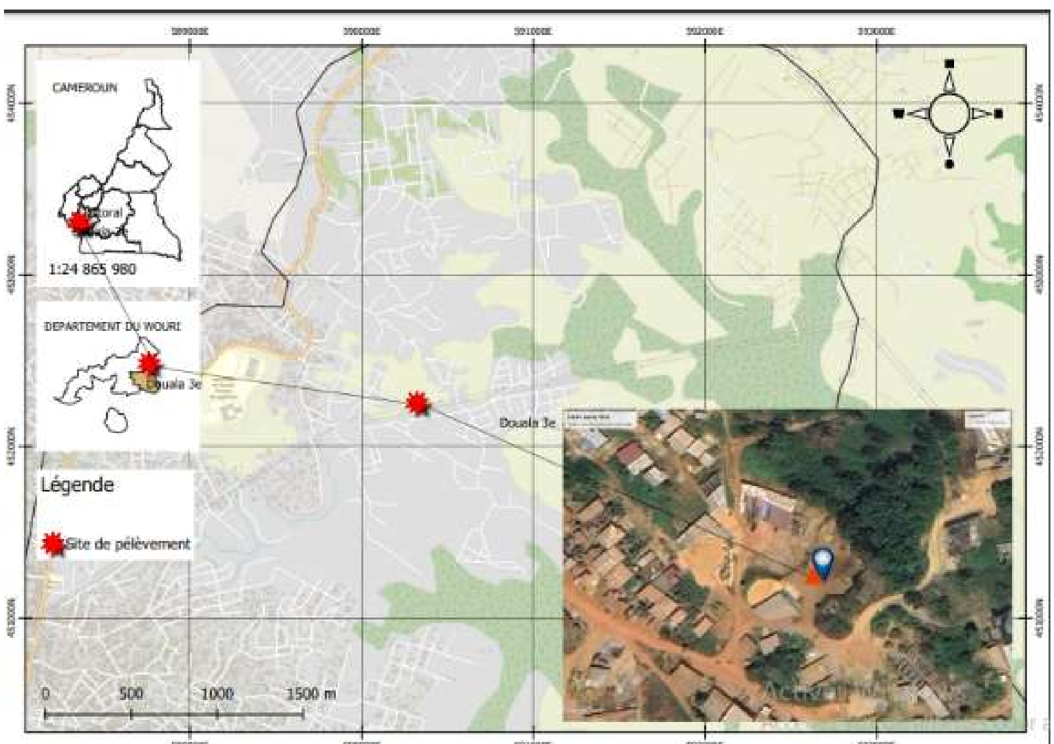

Figure 4:- Location of the sampling point.

Binders

CL90S is the type of lime used. It was acquired from a Douala-based supplier.

Wood
The two wood species used in our study are Sapelli, which is classified as class 3 (CIRAD, 2024), and Iroko, which is classified as class 2 (CIRAD, 2023). The wood was bought from the Logbaba neighborhood and then sawed into sawdust.

Results and Discussion:-

Analysis of the granularity of the soil studied
The insertion of the granulometric curve of the soil sample studied in the reference zone defined by the standard NF XP P 13-901 (2001) is presented in figure 5. A significant proportion of silt and clay relative to the reference spindle.

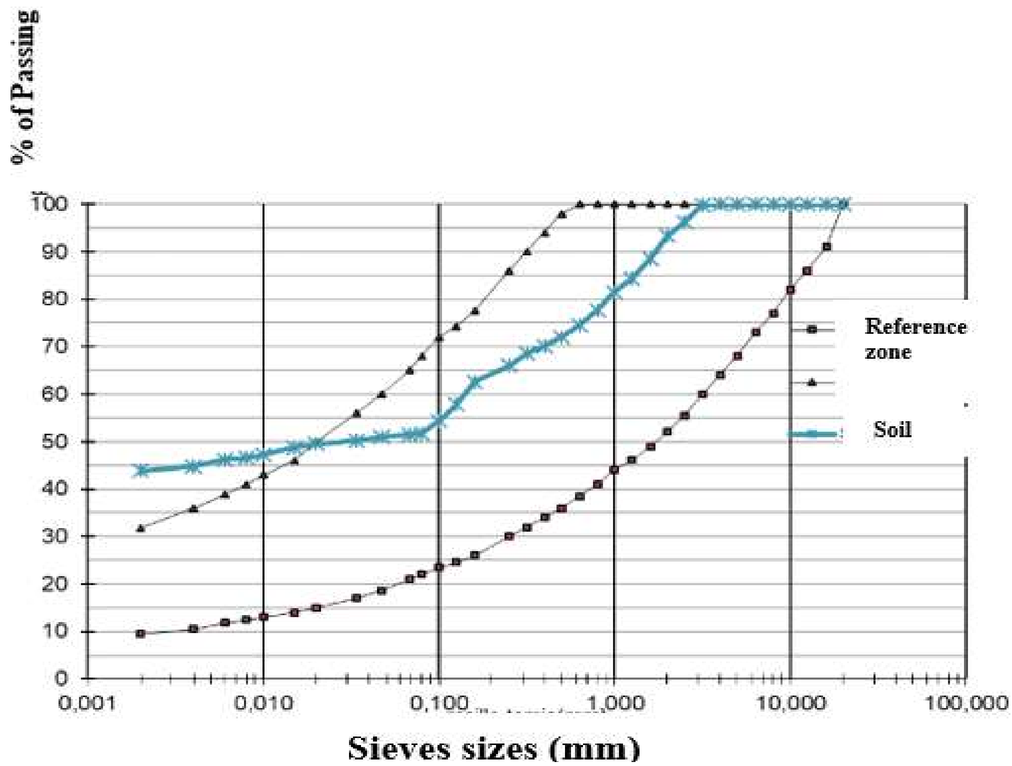

Figure 5:- Superposition of the soil granulometric curve on the reference zone of the NF XP P 13-901 (2001) standard.

The granulometric composition of the soil sample studied is as follows:
- Clay: 43.75%;
- Silt: 5.75%;
- Sands: 43.77%;
- Gravel: 6.73%.

Compared to the spindle recommended by Houben, Rigassi and Garnier (1996), we observe for this soil sample:
- A silt deficit;
- A high proportion of clay.

Analysis of soil plasticity
By introducing the coordinate point (Wl; IP) of the soil studied, i.e. (34.94%; 12.54%) in the reference graph of the NF XP P 13-901 (2001) standard, we observe, as illustrated in figure 6, that this point is located almost at the limit of the reference zone.

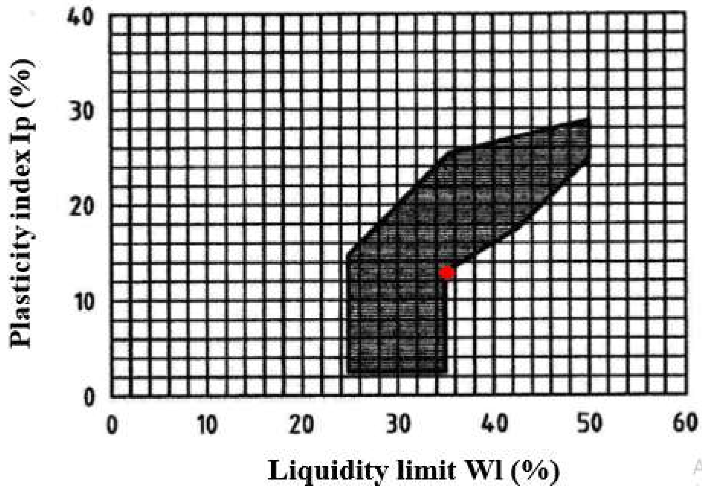

Figure 6:- Superposition of the Atterberg limits of the ground on the reference zone of the NF XP P 13-901 (2001) standard.

Classification of soil according to its suitability for CEB production.
The classification of this soil was carried out according to the NF XP P 13-901 (2001) standard, taking into account the couple (Ip; T0.08) corresponding to the plasticity index and the percentage passing through the 80 µm mesh sieve . Figure 7 shows that the insertion of the couple (12.54; 51.69) in the graph from the NF XP P 13-901 (2001) standard, reveals that our soil is class A2, i.e. a material usable for the production of CEB but having too many fines.

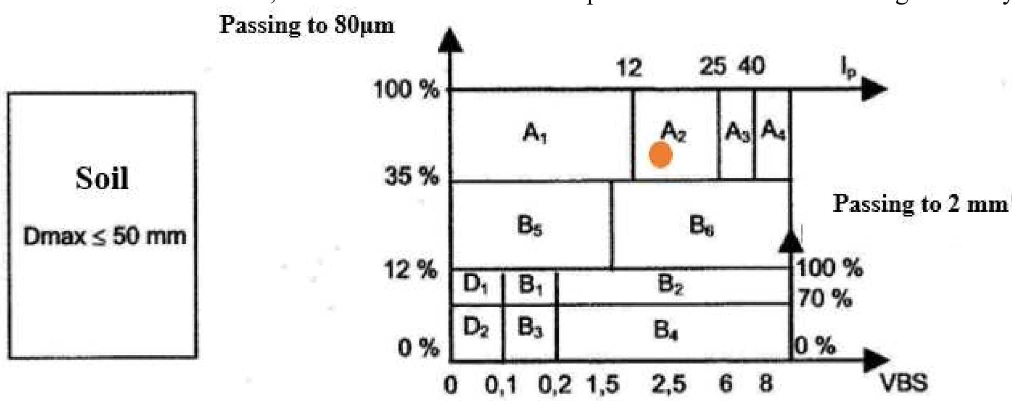

Figure 7:-Soil classification in relation to standard NF XP P 13-901(2001).

Although this soil can be used for the production of CEB, its improvement can be done by correcting its granulometry or by chemical stabilization. Figure 8 of BIT (2002), with regard to the fine fraction of the soil as well as its plasticity index, presents lime as the chemical stabilizer that could be the most suitable.

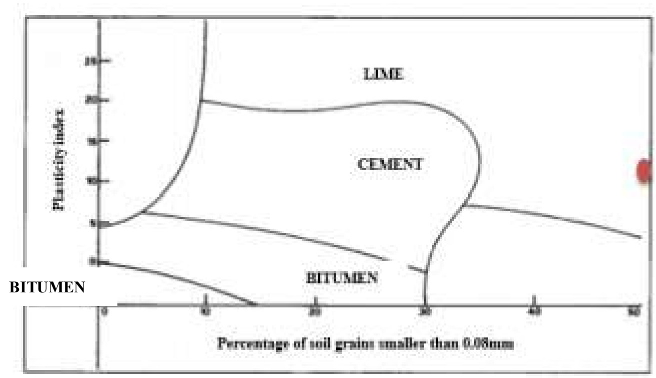

Figure 8:-Identification of the most suitable chemical stabilizer for stabilizing the soil studied.

Influence of the mixture of Sapelli and Iroko wood sawdust on dry compressive strength

Figure 9 illustrates the influence of the proportion of Iroko in the sawdust mixture on the dry compressive strength of CEB. It can be seen that the dry compressive strength does not consistently change in the same way as the percentage of the species in the sawdust mixture that have the best mechanical qualities (Sapelli).

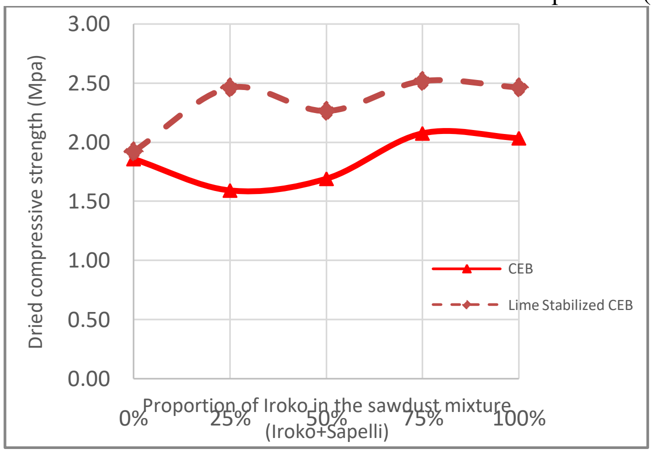

Figure 9:- Curve showing the evolution of dry compressive strength according to the amount of Iroko in the mixture of sawdust..

Figure 10 illustrates the influence of sawdust addition on dry compressive strength.

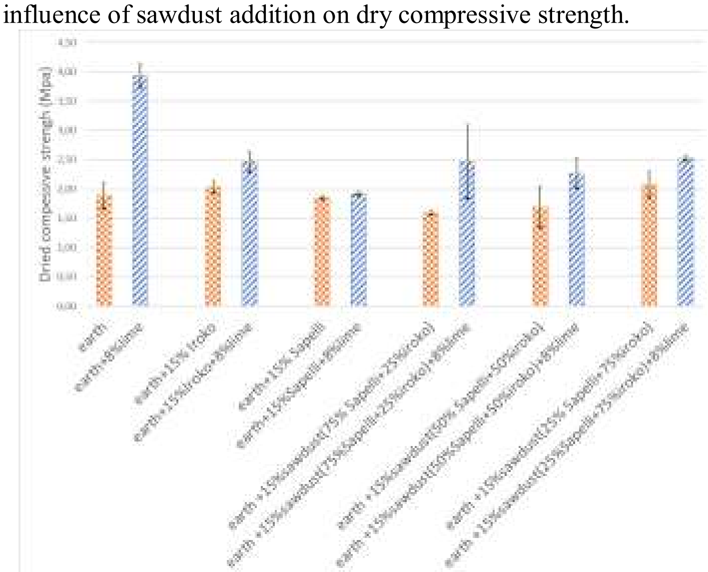

Figure 10:- Influence of the addition of sawdust on dry compressive strength.

We observed that the addition of 15% sawdust causes a variation in dry compressive strength of:

- -15.84% to 9.68% compared to mortar made from earth;
- -51.09% to -36% compared to mortar made from earth + lime.

On the other hand, apart from the sample made of earth + 15% Sapelli + 8% lime, all lime-stabilized samples can be used according to standard NF XP 13-901 (2001) for the production of CEB under a pressure of 3.6 Mpa with regard to their average resistance in dry compression (greater than 2 Mpa).

Influence of the mixture of Sapelli sawdust and Iroko wood on the resistance to wet compression
Figure 11 illustrates the effect of the proportion of Iroko in the sawdust mixture on the wet compressive strength of CEB.

It is observed that the resistance to wet compression does not consistently change in the same way as the sawdust mixture's percentage of the wood species with the best mechanical qualities (Sapelli).

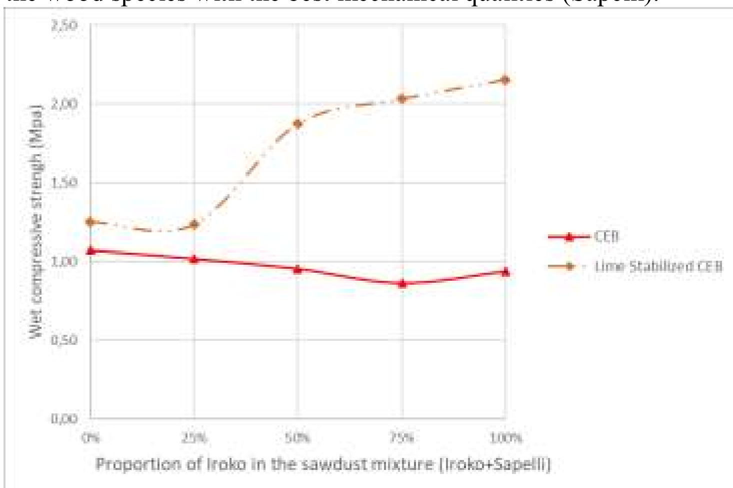

Figure 11:- Curve showing the evolution of wet compressive strength according to the amount of Iroko in the mixture of sawdust.

Figure 12 illustrates the influence of sawdust addition on the wet compressive strength of CEBs.

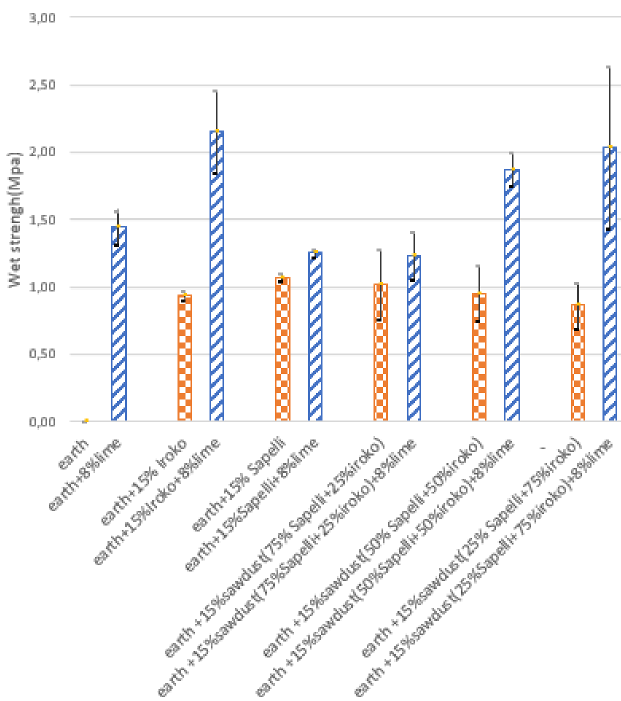

Figure 12:- Influence of the addition of sawdust on the wet compressive strength of CEB.

Unstabilised CEBs with no sawdust dissolved in water in less than an hour, making it impossible to measure their wet compressive strength. The addition of sawdust increased the stability of CEBs immersed in water (Nwandji and Atahualpa, 2024). For lime-stabilised CEBs, we found that the addition of 15% sawdust caused a change in wet compressive strength of -14.45% to 49.57% compared to the soil + lime CEB sample.

On the other hand, all lime-stabilized samples have sufficient resistance (greater than 1 Mpa) according to the NF XP 13-901 (2001) standard for use in humid environments. However, their physical and hygroscopic properties must be checked before confirming their suitability for use in humid environments.

Influence of the mixture of Sapelli and Iroko wood sawdust on abrasion resistance
Figure 13 shows how the amount of Iroko in the sawdust mixture affects CEB's ability to withstand abrasion. It has been noted that the percentage of the wood species with the best mechanical qualities (Sapelli) in the sawdust mixture does not consistently change in the same direction as the abrasion resistance.

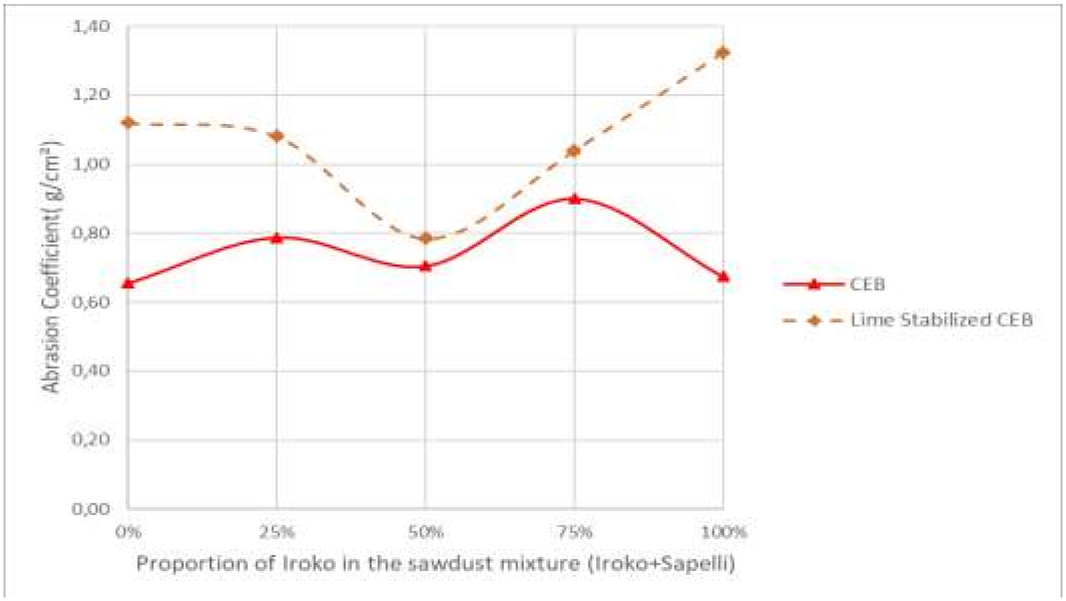

Figure 13:-Curve showing the evolution of the abrasion resistance of CEB according to the amount of Iroko in the mixture of sawdust.

Figure 14 illustrates the influence of sawdust addition on the abrasion resistance of CEB.

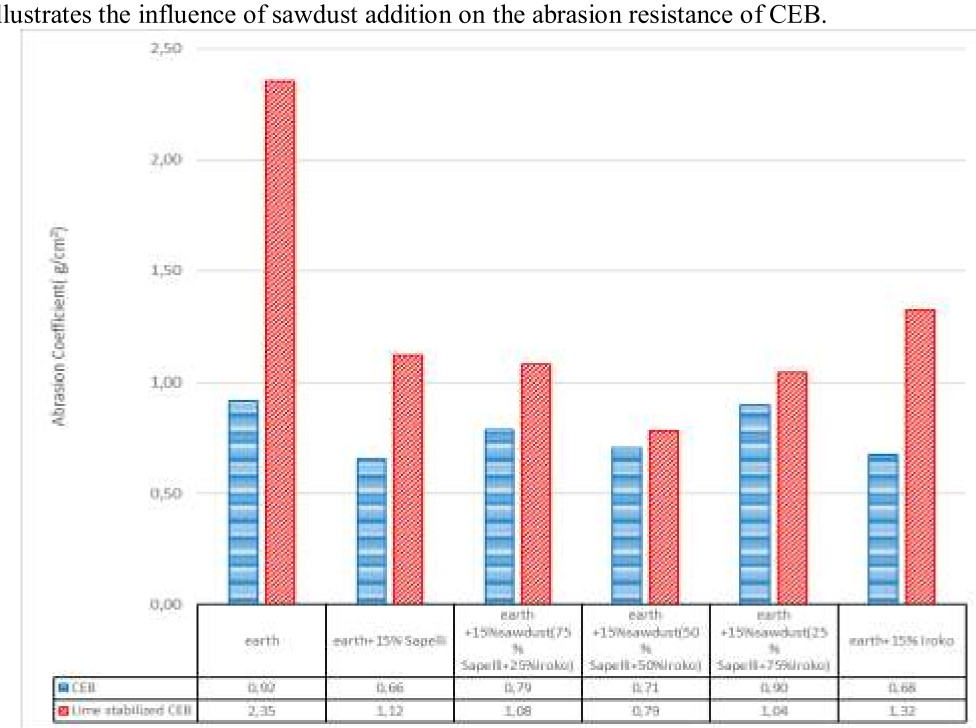

Figure 14:-Influence of the addition of sawdust on abrasion resistance.

We observed that the addition of 15% sawdust causes a reduction in abrasion resistance of:

- 1.89% to 28.53% compared to mortar made from earth;
- 43.69% to 66.60% compared to mortar made from earth + lime.

On the other hand, only the sample composed of earth +8% lime has sufficient characteristics according to standard NF XP 13-901(2001) for use in an environment subject to the risk of abrasion.

Conclusion:-

The purpose of this study was to assess how the combination of iroko and sappelli affected the mechanical characteristics of compressed earth bricks. Wood species were found to have an impact on the abrasion coefficient, wet compressive strength, and dried compressive strength.

We observed that, compared to samples made only of soil, the addition of 15% of sawdust:

- A variation of -15.84% to 9.68% in dry compressive strength;
- Unstabilized CEBs with lime and no sawdust dissolved in water in less than an hour, which does not allow the measurement of their wet compressive strength. The addition of sawdust increases the stability of CEBs immersed in water (Nwandji, Mbou and Atahualpa, 2024);
- A reduction of 1.89% to 28.53% in abrasion resistance.

Compared to samples made of earth +8% lime, the addition of 15% sawdust:

- Reduces dry compressive strength from -36% to 51.09%;
- Causes a variation in wet compressive strength from -14.45% to 49.57%;
- Reduces abrasion resistance from 43.69% to 66.60%.

In general, these mechanical characteristics do not consistently change in the same way as the percentage of the species in the sawdust mixture that have the best mechanical qualities (Sapelli). Apart from the sample made of earth + 15% Sapelli + 8% lime, all lime-stabilized samples can be used according to standard NF XP 13-901 (2001) for the production of CEB under a pressure of 3.6 Mpa with regard to their average resistance in dry compression (greater than 2 Mpa).

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