Journal Homepage: - www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

Article DOI: 10.21474/IJAR01/19473
DOI URL: http://dx.doi.org/10.21474/IJAR01/19473

ISSN NO. 2320-5407

RESEARCH ARTICLE

EFFECT OF IROKO AND SAPELLI SAWDUST MIXTURE ON THERMAL PROPERTIES OF COMPRESSED EARTH BRICKS (CEB)

Hippolyte Nwandji Yankam[1], Elvis Mbou Tiaya[2] and Atahualpa Sosa-Lopez[3]

1. Department of Projects, Universidad Internacional Iberoamericana, Mexico.
2. Mechanics and Adapted Materials Laboratory (LAMMA), ENSET, University of Douala, Cameroon.
3. Universidad Autónoma de Campeche, Mexico.

……………………………………………………………………………………………………....

Manuscript Info

……………………….

Manuscript History
Received: 15 July 2024
Final Accepted: 17 August 2024
Published: September 2024

Key words:-
Earth Brick, Sawdust, Lime, Cement, Thermal Properties

Abstract

………………………………………………………………………

This study analyzes the effect of the mixture of Iroko and Sapelli sawdust on the thermal properties of compressed earth bricks(CEB). Various compositions were carried out for proportions of 15% sawdust consisting of the mixture of two wood species (Sapelli; Iroko) in various proportions. The earth+sawdust mixture was stabilized with 8% cement or slaked lime. The hot plate method were used to determine thermal properties of bricks.The presence of sawdust improves the thermal properties of earth bricks. On the other hand, these thermal properties do not systematically evolve in the same direction as the proportion of the species with the greatest density (Sapelli) in the sawdust mixture.

……………………………………………………………………………………………………....

Introduction:-

Cameroon, in its desire to reduce its housing deficit, has embarked on a social housing construction program. The sale of the first housing units built has only received the support of a section of the population due to its high cost price for the middle class. Furthermore, there are landlocked villages in Cameroon that do not have any quarries that can supply them with aggregates. The transport of aggregates from quarries to these landlocked villages makes construction high-cost (Nwandji and Atahualpa, 2022). In order to offer the population financially accessible constructions for people with an average income while promoting local materials, it is more than necessary to think about the development of high-performance, sustainable, economical and above all locally available materials. Earth in its natural state can be used as a building material with virtually no energy expenditure (Meukam, 2004). Among the plant fibers used in the production of Compressed earth brick(CEB), including hemp shiv (Laborel et al., 2015), date palm fibers (Taallah et al., 2014), coconut fibers (Djohore et al., 2018), is sawdust (Ouattara, 2013). Generally available in sawmills as a mixture of residues of several wood species with varied properties, the use of this, although promoting the recovery of waste from the wood industry, does not clearly allow us to know the effect of the different wood species present in the mixture on the properties of earth bricks. It is therefore interesting to know whether the thermal properties of earth bricks made from a sawdust mixture systematically evolve in the same direction as the proportion of the wood species with the greatest density (sapelli) in the mixture.

Corresponding Author:- Hippolyte Nwandji Yankam
Address**:-** Phd Student, Department of Projects,Universidad Internacional Iberoamericana, Mexico.

Materials:-

The earth
The site chosen for soil sampling is located in the city of Douala, coastal region of Cameroon, at the place called Pk18.

The wood
Iroko which is a class 2 wood(CIRAD, 2023) and Sapelli which belongs to class 3(CIRAD, 2024) are the two wood species used in our study. The wood was purchased in the locality of Logbaba and then transformed into sawdust by sawing.

Cement
The cement used is of type CEM II and class 42.5R. It was purchased from local suppliers in the city of Douala.

Lime
The lime used is of type CL90S. It was also purchased from local suppliers in the city of Douala.

Methods:-

Our approach consisted of:

1. Mix the previously dried and sieved laterite through a 3.15 mm mesh sieve, with 15% of the sawdust mixture (Sapelli+Iroko) in the proportions of the couple (%Sapelli; %Iroko) of (100%; 0%), (75%; 25%), (50%; 50%), (25%; 75%) and (0%; 100%);
2. Mix the previously dried and sieved laterite through a 3.15 mm mesh sieve, with 15% of the sawdust mixture (Sapelli + Iroko) in the proportions of the couple (%Sapelli; %Iroko) of (100%; 0%), (75%; 25%), (50%; 50%), (25%; 75%) and (0%; 100%) + 8% of binder (cement or lime);
3. Determine the optimum compaction water content for each composition;
4. Produce compressed earth bricks from these mortars. Then, using the asymmetric hot plane method test, we determined the thermal properties of the earth bricks obtained;
5. Highlight the results obtained for the different compositions of the earth bricks on the same graph or table in order to identify the impact of the presence of the different wood species in the sawdust mixture on the thermal properties of the earth bricks obtained.

The aim of the test was to evaluate the thermal properties of CEB, including thermal effusivity, volumetric heat and thermal conductivity. The bricks were produced under a compaction energy of 3.6 Mpa following the approach of Houben et al. (1996).

The test consisted, as illustrated in Figure 1, in heating one face of the CEB sample by means of a thermal resistance connected to a generator and in collecting, using a thermocouple, the evolution of the temperature of the heating resistance in contact with the CEB sample over time. During the time when the disturbance has not reached the other faces, it can be considered that the heat transfer at the center of the sample is unidirectional (Meukam, 2004).

Figure 1:- Thermal characterization of CEBby the asymmetric hot plane method.

Thermal Effusivity
The test temperatures Texp(t) were recorded using the acquisition module. From Ganou and al. (2021),

The variation of value between the experimental and simulated temperature obtained after modeling the test instrument was used to estimate the effusivity (Eff) and the volumetric heat (ρC_P). The pre-estimated value of thermal effusivity was obtained from the 1D numerical calculation of the slope δ (t) of the linear part of the experimental curve Texp(t) = $f(\sqrt{t})$.

Effusivity is obtained using equation 1 from Ganou's research (2021).

$$E_{ff(CEB)} = \frac{2\Phi}{\delta\sqrt{\pi}} - E_{ff(Po)} \qquad (1)$$

Where, $E_{ff(CEB)}$ represents the effusivity of CEB, Eff(Po) is the effusivity of polystyrene, δ is the slope of the linear part of the experimental curve $T(t) = f(\sqrt{t})$ and Φ is the heat flux produced by the heating element (Ganou, 2021).

Volumetric heat
The volumetric heat is estimated from equation 2from Ganou's research (2021).

$$\rho_s C_{p.s} = \frac{1}{e_s}\left(\frac{\Phi}{\beta} - \rho_{po} C_{p.po} e_{po} - \rho_h C_{p.h} e_h\right)$$)

Where,from Ganou's research (2021): e denotes the thickness (in m), C the specific heat (in J/kg/°K), ρ the apparent density (kg/m ^{3}); po is the symbol for polystyrene, h is the symbol for the hot plane, s is the symbol for the CEB sample and β is the slope of the linear part of the experimental curve T(t)=f(t).

Thermal conductivity
The thermal conductivity (λ) was derived from the effusivity and volumetric heat by equation 3.

$$\lambda = \frac{E^2}{\rho_s C_{p.s}} \qquad (3)$$

Result and Discussion:-
Table 1 presents the different compositions made in this study. The earthenware pellets made from these compositions had dimensions of 100×100×20 mm.

Table 1 Influence of sawdust on the thermal properties of non-binder-stabilized CEB.

Label	Compositions	Symbols
ECH1	earth+20.1% water	100% earth
ECH 2	earth+15% Iroko+17% water	C0(S0I100)15
ECH 3	land + 15% Sapelli + 22.8% water	C0(S100I0)15
ECH 10	earth +15% sawdust (75% Sapelli + 25% iroko) +16.5% water	C0(S75I25)15
ECH 13	land +15% sawdust (50% Sapelli+50%iroko)+20.4% water	C0(S50I50)15
ECH 16	earth +15% sawdust (25% Sapelli+75%iroko)+19.6% water	C0(S25I75)15
ECH 5	earth+8%lime+18%water	100% earth + 8% L
ECH 6	earth+15%Iroko+8%lime+22.4% water	L8(S0I100)15
ECH 8	earth+15% Sapelli +8%lime+18.4% water	L8(S100I0)15
ECH 11	earth +15%sawdust (75%Sapelli+25%iroko)+8%lime+20.5 water	L8(S75I25)15
ECH 14	earth +15% sawdust (50% Sapelli + 50% iroko) + 8% lime + 17.8% water	L8(S50I50)15
ECH 17	earth +15%sawdust (25%Sapelli+75%iroko)+8%lime+18% water	L8(S25I75)15

ECH 4	earth +8% cement + 19.1%	100% earth + 8% C
ECH 7	earth+15% Iroko+8% cement+15% water	C8(S0I100)15
ECH 9	earth+15% Sapelli +8%cement+20.1% water	C8(S100I0)15
ECH 12	earth +15% sawdust (75% Sapelli + 25% iroko) + 8% cement + 23% water	C8(S75I25)15
ECH 15	earth +15%sawdust (50%Sapelli+50%iroko)+8%cement +22% water	C8(S50I50)15

Case of compressed earth bricks not stabilized with binder.

Table 2 shows the values of thermal properties measured on non-binding stabilised earth bricks.

Table 2 Influence of sawdust on the thermal properties of non-binder-stabilized CEB.

Samples	Thermal conductivity (W/m K)	Thermal effusivity ($J/m^2 KS^{1/2}$)	Volumetric Heat ($J/m^3 K$)
Earth	0.796	1,001,770	1,260,180,892
Earth + 15% Iroko	0.335	775,700	1,872,811,463
Earth + 15% Sapelli	0.322	847,300	2,261,932,237
earth +15% sawdust (75% Sapelli+25%iroko)	0.269	775,530	2,260,012,472
earth +15% sawdust (50% Sapelli+50%iroko)	0.281	820,040	2,397,795,758
earth +15% sawdust (25% Sapelli+75%iroko)	0.289	743,690	2,053,954,878

It is observed that, compared to samples made only of earth, the presence of 15% of sawdust:

- Reduces thermal conductivity from 57.98% to 66.22%;
- Reduces thermal effusivity from 15.42% to 25.76%;
- Increases volumetric heat from 48.61% to 90.27%;

Similar results were obtained by Abessolo (2022).

Case of compressed earth bricks stabilized with lime.

The results of thermal characterization of lime-stabilized CEB are presented in Table 3.

Table 3:- Influence of sawdust on the thermal properties of lime-stabilized CEB.

for	Thermal conductivity (W/m K)	Thermal effusivity ($J/m^2 KS^{1/2}$)	Volumetric Heat ($J/m^3 K$)
earth+8%lime	0.920	1,008,640	1,106,557,642
earth+15%Iroko+8%lime	0.259	751,950	2,146,607,689
earth + 15% Sapelli + 8% lime	0.284	753,560	2,039,073,997
earth + 15% sawdust (75% Sapelli + 25% iroko) + 8% lime	0.275	777,300	2,251,870.179
earth +15% sawdust (50% Sapelli + 50% iroko) + 8% lime	0.315	678,240	1,461,634,777
earth + 15% sawdust (25% Sapelli + 75% iroko) + 8% lime	0.387	709,780	1,314,668,668

It is observed that, compared to samples made of earth + lime, the presence of 15% of sawdust:

- Reduces thermal conductivity from 57.96% to 71.82%;

- Reduces thermal effusivity from 22.94% to 32.76%;
- Increases volumetric heat from 18.81% to 103.50%;

Similar results were obtained by Abessolo (2022).

Case of compressed earth bricks stabilized with cement.
Table 4 shows the values of thermal properties measured on non-binding stabilised earth bricks.

Table 4:- Influence of sawdust on the thermal properties of cement-stabilized CEB.

Samples	Thermal conductivity (W/m K)	Thermal effusivity (J/m ^{2} KS $^{1/2}$)	Volumetric Heat (J/m ^{3} K)
earth +8% cement	0.859	1,013,840	1,202,166,873
earth+15% Iroko+8% cement	0.328	783,920	1,298,037,922
earth+15%Sapelli +8%cement	0.310	730,300	1,799,191,834
earth +15%sawdust (75%Sapelli+25%iroko)+8%cement	0.347	752,090	1,717,155,716
earth +15% sawdust (50% Sapelli + 50% iroko) + 8% cement	0.339	948,830	2,698,719,729
earth +15%sawdust (25%Sapelli+75%iroko)+8%cement	0.486	822,600	1,627,203,941

It is observed that, compared to samples made of earth + cement, the presence of 15% of sawdust:

- Reduces thermal conductivity from 43.36% to 63.88%;
- Reduces thermal effusivity from 22.80% to 82.16%;
- Increases volumetric heat from 4.47% to 63.72%;

Similar results were obtained byAbessolo (2022).

Effect of the proportion of Iroko in sawdust on the thermal effusivity of compressed earth bricks.
Figure 2 illustrates the effect of the proportion of Iroko in the sawdust mixture on the thermal effusivity of CEB. Among the CEB samples composed of Iroko and Sapelli mixture, the maximum thermal effusivity is observed for the lime- or cement-stabilized CEB whose proportion of Iroko in the sawdust is 25% and 50%, respectively. For the non-binder-stabilized CEB, the maximum thermal effusivity is observed in the sample whose proportion of Iroko in the sawdust is 50%.

The analysis of the shape of the curves shows that the thermal effusivity of the different samples does not systematically evolve in the same direction as the proportion of the wood species with the greatest density (Sapelli) in the mixture. This could be explained by the difference in humidity of the samples since humidity has an influence on the thermal properties of the constituents of the CEB.

Effect of the proportion of Iroko in sawdust on the volumetric heat of compressed earth bricks.
Figure 3 illustrates the effect of the proportion of Iroko in the sawdust mixture on the volumetric heat of CEB. Among the CEB samples composed of Iroko and Sapelli mixture, the maximum volumetric heat is observed for the lime- or cement-stabilized CEB whose proportion of Iroko in the sawdust is 25% and 50%, respectively. For the non-binder-stabilized CEB, the maximum volumetric heat is observed for the sample whose proportion of Iroko in the sawdust is 50%.

The analysis of the shape of the curves shows that the volumetric heat of the different samples does not systematically evolve in the same direction as the proportion of the wood species with the greatest density (Sapelli) in the mixture. This could be explained by the difference in humidity of the samples since humidity has an influence on the thermal properties of the constituents of the CEB.

Effect of the proportion of Iroko in sawdust on the thermal conductivity of compressed earth bricks.
Figure 4 illustrates the effect of the proportion of Iroko in the sawdust mixture on the thermal conductivity of CEB. Among the CEB samples composed of Iroko and Sapelli mixture, the maximum thermal conductivity is observed for CEB with 75% Iroko proportion in sawdust.

The analysis of the thermal conductivity of the different samples reveals that it does not systematically evolve in the same direction as the proportion of the wood species with the greatest density (Sapelli) in the mixture. This could be explained by the difference in humidity of the samples given that humidity has an influence on the thermal properties of the constituents of CEB.

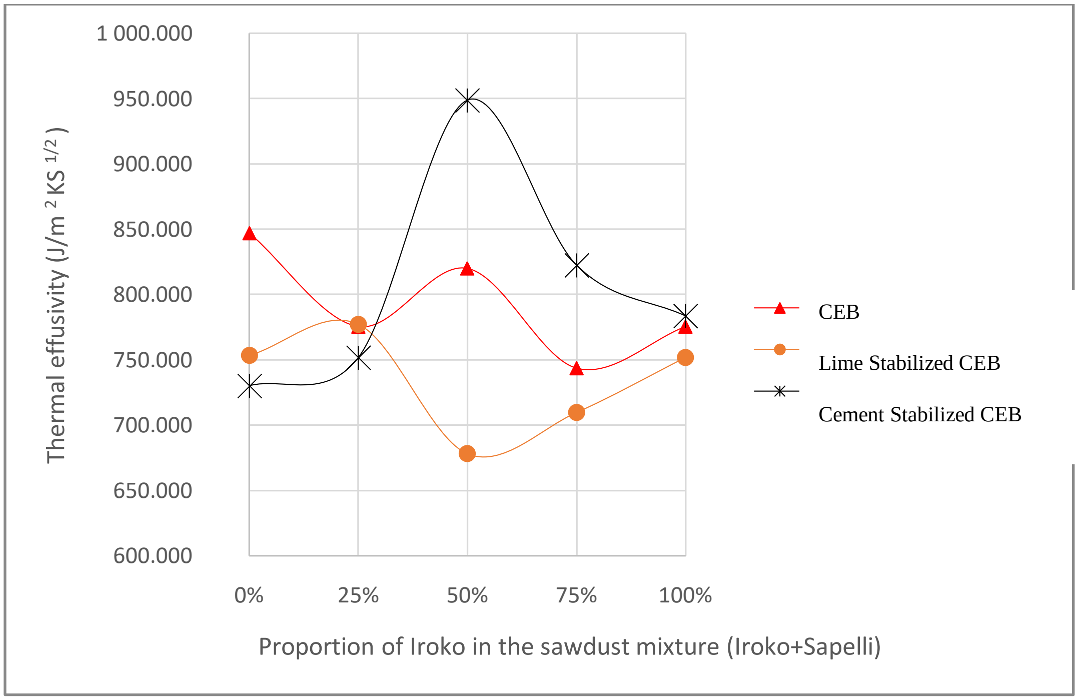

Figure 1curveof the thermal effusivity of CEB as a function of the proportion of Iroko in the sawdust mixture.

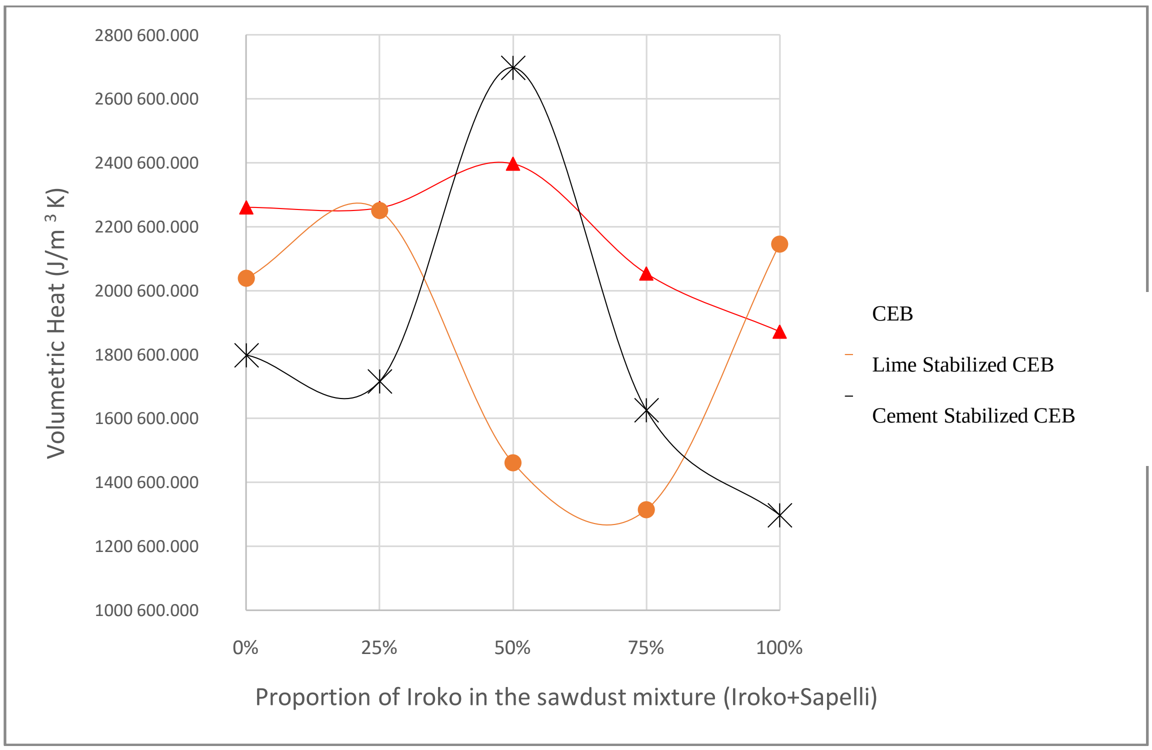

Figure 2 Curveof the evolution of the volumetric heat of CEB as a function of the proportion of Iroko in the sawdust mixture.

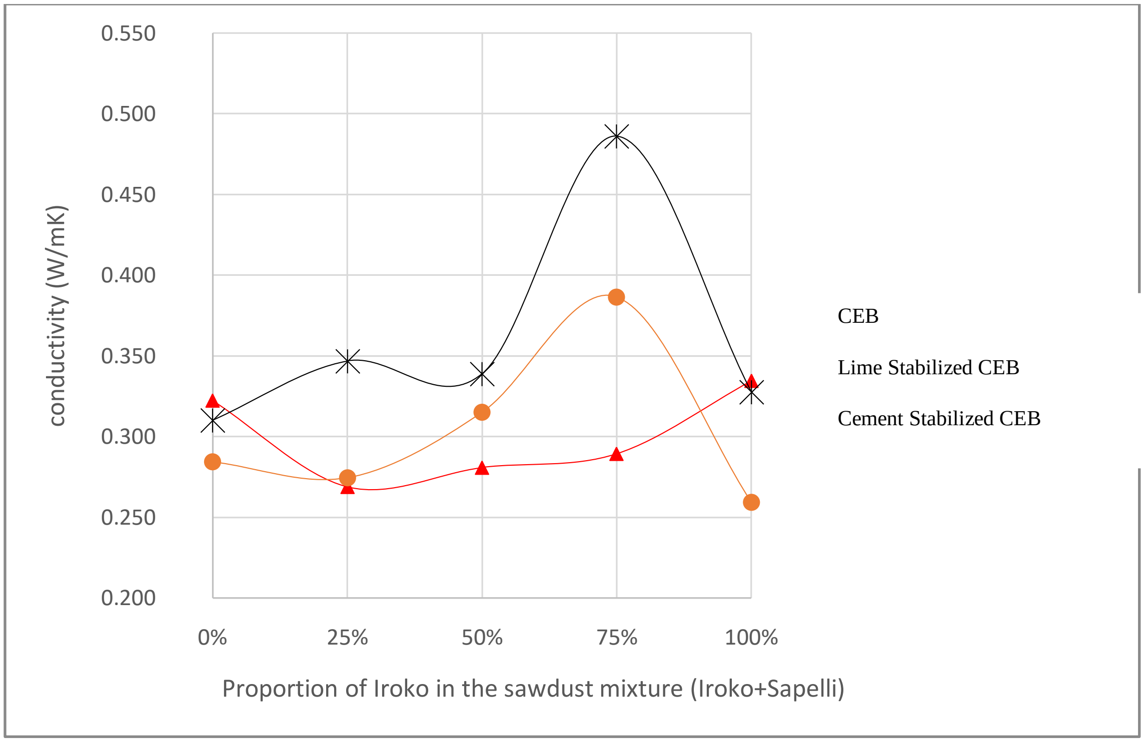

Figure 3 Curveof the evolution of the thermal conductivity of CEB as a function of the proportion of Iroko in the sawdust mixture.

Conclusion:-

This study was conducted to evaluate the effect of iroko and sapele mixture on the thermal properties of compressed earth bricks. The influence of wood species was observed on thermal effusivity, volumetric heat and thermal conductivity.

We observed that, compared to samples made only of soil, the addition of 15% of sawdust:
1. Reduces thermal conductivity from 57.98% to 66.22%;
2. Reduces thermal effusivity from 15.42% to 25.76%;
3. Increases volumetric heat from 48.61% to 90.27%;

Compared to samples made of earth +8% lime, the addition of 15% sawdust:
1. Reduces thermal conductivity from 57.96% to 71.82%;
2. Reduces thermal effusivity from 22.94% to 32.76%;
3. Increases volumetric heat from 18.81% to 103.50%;

Finally, compared to samples made of earth + 8% cement, the presence of 15% sawdust:
1. Reduces thermal conductivity from 43.36% to 63.88%;
2. Reduces thermal effusivity from 22.80% to 82.16%;
3. Increases volumetric heat from 4.47% to 63.72%;

Overall, these thermal properties do not systematically evolve in the same direction as the proportion of the species with the greatest density (Sapelli) in the sawdust mixture.

References:-

1. Abessolo, D. (2022). Formulation, élaboration et caractérisation expérimentale d'un composite à base de terre comprimée et de fibres de bambusa vulgaris [Thèse de doctorat]. Université de Douala.
2. Centre de coopération internationale en recherche agronomique pour le développement [CIRAD]. (2023). Fiches disponibles - Tropix 7 - Cirad. Tropix 7. Consulté le 23 juin 2024, à l'adresse https://tropix.cirad.fr/FichiersComplementaires/FR/Afrique/IROKO%202023.pdf
3. Centre de coopération internationale en recherche agronomique pour le développement [CIRAD]. (2024). Fiches disponibles - Tropix 7 - Cirad. Tropix 7. Consulté le 23 juin 2024, à l'adresse https://tropix.cirad.fr/FichiersComplementaires/FR/Afrique/SAPELLI%202024.pdf
4. Djohore, A. C., Djomo, A. S., Boffoue Moro, O., & Edjikémé, E. (2018). Effet de l'addition de fibres de coco traitées à la potasse sur les propriétés mécaniques des matériaux de construction à base d'argile – ciment. European Scientific Journal, 14(36). https://doi.org/10.19044/esj.2018.v14n36p104
5. Ganou, B. M. (2021). Construction en brique de terre comprimée et granulats biosourcés : une solution pour un habitat durable à Douala [Thèse de doctorat]. Cotutelle entre l'Université de Liège et l'Université de Douala.
6. Ganou Koungang, B. M., Tchamdjou Mbouendeu, O., D, N. N., Zhao, Z., Tchemou, G., Michel, F., Njeugna, E., Messan, A., & Courard, L. (2023). Experimental thermophysical dependent mechanical analysis of earth bricks with canarium schweinfurthii and cocos nucifera bio-aggregates - a case study in Cameroon. Cogent Engineering, 10(1). https://doi.org/10.1080/23311916.2022.2159159.
7. Houben, H., Rigassi, V., & Garnier, P. (1996). Compressed earth blocks : Production Equipment. CRATerre-EAG.
8. Laborel, P. A., Aubert, J. E., & Magniont, C. (2015). Influence de la teneur en Chenevotte sur les performances mécaniques et les propriétés hygrothermiques d'un Eco-Materiau à base de terre crue. Conférence Internationale Francophone NoMaD.
9. Meukam, P. (2004). Caractérisation de matériaux locaux en vue de l'isolation thermique de bâtiments [Thèse de doctorat]. Université de Yaoundé 1.
10. Nwandji, Y. H., & Atahualpa, S.-L. (2022). Evaluation of the suitability of a soil for the production of blocks of compressed earth. http://www.geovales.com/index.php/Journal/article/view/119
11. Ouattara, S. (2013). Recherche de briques légères : Conception et caractérisation de briques crues à base d'argile et de sciure de bois stabilisées au ciment Portland [Thèse de doctorat]. Université Felix Houphouet.
12. Taallah, B. (2014).) Etude du comportement physico-mecanique du bloc de terre comprimée avec fibres [Thèse de Doctorat]. Université Mohamed Khider - Biskra.