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The effect of Shea butter wastes on Physical Properties of Compressed Earth Bricks (CEB) and Cement Stabilized

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Abstract

The search for new types of low-cost, low-energy building materials has sparked renewed interest in recent years. It is with this in mind that a new category of compressed earth brick reinforced in agro-industrial wastes and likely to be "eco-sustainable" materials has been developed. This work aims to study the impact of the shea butter wastes rate on the thermal conductivity and Young's modulus of cement stabilized CEB. To do this, three clay materials noted F, K and Y have been characterized and used to produce CEB. The physico chemical characterization of these raw materials reveals that they consist mainly of kaolinite, quartz, iron compounds and micaceous phases. The geotechnical tests have revealed that the clay materials F and K belong to class A2 soils while Y class A3. Subsequently, earth bricks with different compositions in mass percentage of clay and shea butter wastes, stabilized with 5% of cement were made by compaction at 40 MPa. The thermal conductivity of the materials made, measured by the Hot Disk method, revealed a decrease in conductivity of 25% for formulations with clay F, 16% for formulations with clay K and 22% for formulations with clay Y, when shea butter wastes contents go from 0 to 10%. Likewise, a decrease in the density of the CEB was observed. Young's modulus results determined through ultrasound showed good rigidity when clay soil is substituted with shea butter wastes of up to 6% for formulations with F and Y and up to 8% for formulations with K. The strengthening of CEB stabilized with a small amount of cement to shea butter wastes improves their thermal insulation properties.

Keywords: Clays, Shea butter wastes, CEB, Thermal Conductivity, Young's Modulus

INTRODUCTION

Today the whole world is clamoring for sustainable development, Compressed Earth Bricks (CEB) are a very good alternative to cement blocks in the housing sector in sub-Saharan Africa. Clay presents itself as the ideal building material. Indeed, this material has many advantages, it is readily available and, requires very little energy to produce. In addition, this fully recyclable material has very interesting thermal, hygrometric and phonic properties. Thus, the utility bills regarding electricity consumption related to air conditioning and heating is reduced in earthen buildings (Allinson, D., & Hall, M., 2010), while improving the interior comfort of buildings.

Despite these numerous advantages, the diffusion of this construction technique remains limited because of the problems of mechanical strength, stiffness, and durability which this material suffers (Alam, I., Naseer, A., & Shah, A., 2015). Therefore, several studies have focused on improving the mechanical properties of CEB through the use of different techniques of stabilization. These include stabilization by the addition of mineral binders (cement, lime) which improves the mechanical strength and durability of CEB (Jayasinghe, C., and Kamaladasa, N., 2007) and also the use of organic additives and fibers (Chindaprasirt, P., & Pimraksa, K., 2008). The use of organic additives and fibers as a partial or total replacement of mineral stabilizers in addition to saving energy and reducing CO_2 emissions allows the improvement of CEB properties.

In addition, Côte d'Ivoire, a country whose economy is essentially based on agriculture, produces a wide variety of raw materials. However, hulls and/or plant residues from these materials are not sufficiently valued. The production of shea butter in the northern region of the country generates a significant amount of waste which is causing a real environmental problem. It has been shown that the sticky black residue, left after extraction of shea butter, can be used to fill the cracks in the walls and as waterproofing material (Van der Vossen, H.A.M & Kamilo, M., 2007). In order to maintain a cleaner environment, shea butter wastes could, therefore, be used in addition to cement to improve certain physical properties of bricks.

The main objective of the present work is to study the influence of shea butter wastes content on the thermal conductivity and Young's modulus of compressed earth bricks stabilized with cement.

MATERIALS AND METHODS

Materials

- The clay materials used in this study are three in number. The clay noted F and K are obtained from the central region of Côte d'Ivoire. The extraction sites are located around the following geographic coordinates: for F 08 ° 12'327 "N, 005 ° 07'078" W and for K 08 ° 09'030 "N, 005 ° 05'850" W. Y clay comes from the southern region of Côte d'Ivoire. The geographic coordinates of the sampling site are 08 ° 08'423 "N and 005 ° 06'125" W.
- Shea butter wastes noted (TK) are obtained from the shea butter preparation sites in the northern part of Côte d'Ivoire.
- The cement used for the mixtures is cement CEM I composed of 95% clinker and 5% gypsum. The chemical composition of the cement is presented in Table 1.

Table 1: Chemical composition of cement (% by mass of oxides)

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	TiO_2	MnO	P_2O_5	SrO	Na_2O	K_2O	SO_3	PF
19.62	5.49	3.08	64.27	0.97	0.54	0.05	0.14	0.12	0.26	0.94	3.97	0.42

Methods

The chemical analysis of the clay raw materials was carried out by ICP-AES plasma emission spectroscopy after dissolution by chemical means using a microwave.

X-ray diffractograms were obtained using a Bruker D8 ADVANCE device. The tests were carried out on unoriented powder preparations having a particle size of fewer than 100 µm in the range 2 ° <2θ <60 ° with a pitch of 0.01° and a counting time of 0.25 seconds per pitch.

The particle size distribution of the three clay raw materials was determined using the Mastersizer 2000 granulometer.

The specific surface of the clays was measured by the Brunauer Emmett and Teller (BET) method using the Micromeritics TriStar II. The measurements were carried out after degassing at 200°C for 16 hours on samples crushed and sieved at 100 µm.

The liquid limit (W_L) was determined by the Casagrande disk method and the plasticity limit (W_P) using the roller method. The plasticity index I_P is given by equation 1. The tests were carried out according to standard NF P 94-051.

$$I_P = W_L - W_P \quad (1)$$

The soil blue value (SBV) which characterizes the soil clay was determined by the methylene blue test according to standard NF P 94-068.

Organic matter contents were obtained by wet organic carbon determination using Mohr salt. The organic matter content is then deduced by equation 2.

$$\frac{\%MO}{\%C} = 1{,}7 \quad (2)$$

The porosity rate of the CEB was obtained by the ratio between the pore volume and the total volume of the material. The porosity rate is then given by equation 3.

$$\%P = \left[1 - \frac{\rho_S}{\rho_P}\right] \times 100 \quad (3)$$

Where ρs is the density calculated using the dimensions and mass of the material
ρ_P the theoretical density measured using the helium pycnometer.

The thermal conductivity of the CEB was determined by the Hot Disk method using a commercial device of the Hot Disk AB brand.

The Young's modulus of the stabilized CEB was determined by ultrasonic ultrasound.

Statistical analysis:

The X-ray diffractograms phase identification was performed using the International Center for Diffraction Data (ICDD) database using EVA software (Brukers AXS).

Formulation and production of CEB

Six different formulations of mass constituents (clay, shea butter wastes) stabilized with 5% cement were tested for the preparation of compressed earth bricks. This CEB are marked A_{95}-$_X TK_X C_5$ where A represents the clay used, TK the shea butter wastes and C the cement. The X is the quantity of shea butter wastes used as a partial replacement for the clay. The various components were homogenized and dry-mixed using a Controllable brand at a speed of 70 rpm for about 10 minutes.

RESULTS AND DISCUSSION

Characterization of raw materials

The results of the chemical analysis of clay are shown in Table 2. Silica (SiO_2) and aluminum oxide (Al_2O_3) is the major oxides present in the various samples. The SiO_2 /Al_2O_3 mass ratios are 3.37 for F; 2.48 for K and 3.24 for Y compared 1.18 for pure kaolinites (Lecomte-Nana, G., Bonnet, J.-P., & Soro, N., 2013). These high values suggested the presence of a large amount of free silica and clay minerals the type 2:1 (Jouenne, C.A., 2010). The iron oxide content is important in all samples mainly in clay K (15.67%). These three clay samples contain minor elements such as calcium, potassium, magnesium, sodium, and titanium.

Table 2: Chemical composition of clay raw materials (% by mass of oxides)

samples	SiO_2	Al_2O_3	Fe_2O_3	CaO	K_2O	MgO	Na_2O	TiO_2	SiO_2 / Al_2O_3
F	69.92	20.76	4.65	0.33	2.11	0.53	1.45	0.26	3.37
K	57.51	23.12	15.67	-	2.35	-	0.73	0.83	2.49
Y	66.61	20.57	9.27	0.05	1.23	0.18	0.57	1.52	3.24

According to the classification of lateritic soils as proposed by Lacroix (Lacroix, A., 1913) which takes into account iron oxide contents only, the K sample with a content of 15.67% in iron oxide can be called lateritic clay.

Figure 1 shows the diffractograms of the three samples. The indexation of the different peaks revealed the presence of kaolinite ($Si_2Al_2O_5$ (OH)4), quartz (SiO_2) and a micaceous phase in the three samples. The micaceous phase corresponds to muscovite in F and illite in samples K and Y. In addition to these main phases, F contains rutile (TiO_2), K of hematite and goethite, while Y contains rutile and goethite.

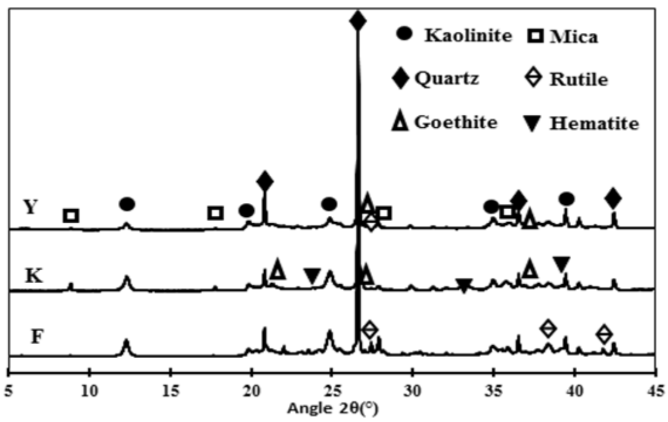

Figure 1: X-ray diffraction spectra of clay raw materials

The combined results of the chemical analysis and the XRD made it possible to evaluate the semi-quantitative mineralogical composition of the different clay materials using equation 4.

$$T(a) = \sum M_i \times P_i(a) \qquad (4)$$

Where T (a): content (oxide %) for the chemical element "a"; Mi: content (%) of mineral "i" in the subject matter and containing the element "i"; Pi (a): proportion of the element "a" in the mineral "i". The results are shown in Table 3.

Table 3: Semi-quantitative mineralogical compositions of the samples (% by mass)

Sample	Kaolinite	Quartz	Illite	Muscovite	Rutile	Hématite	Goethite
F	35.14	45.5	-	17.87	0.26	-	-
K	38.44	24.94	19.9	-	-	4.44	12.28
Y	41.9	42.41	10.65	-	1.52	-	4.25

Quartz, kaolinite, illite, and muscovite constitute the majority crystalline phases in the three clay raw materials.

The physical parameters of the samples are shown in Table 4. The plasticity index and the soil blue value SBV of F and K showed that these raw materials fall to class A2 (12 <I_P <25 and SBV <1.5) according to the Road Excavation Guide (REG) therefore suitable for the production of CEB in the raw state. Y fall to class A3 clay soil (I_P> 25 and SBV> 1.5), its use in the raw state for the production of CEB can cause shrinkage, cracking, weakening blocks. Prior treatment of this soil is therefore necessary. The densities measured for F and Y are identical and of the same order as those generally observed in kaolin and illites. The value 2.78 measured for K is in agreement with that measured in the laterites (2.5 to 3.7) (Maignien, R., 1958). The specific surface values of 18.32 $m^2.g^{-1}$ and 25.62 m^2/g for F and K respectively show that they are kaolinitic clays. In fact, clays of this type have a specific surface area that generally varies between 10 and 30.2 $m^2.g^{-1}$ (Guyot, J., 1969). The higher value of the area for Y is 41.61 $m^2.g^{-1}$ in addition to a large amount of iron oxide suggests the presence of fine particles (φ <80µm). The organic matter contents are less than 2% in F and Y which shows that they are geotechnically inorganic soils. The content for K is slightly above 2% but it remains geotechnically acceptable. These low levels of organic matter have an advantage for these raw materials because the organic matter will have a negligible role during stabilization.

Table 4: Physical parameters of clay raw materials

Samples	Liquid Limit W_L(%)	Limit of Plasticity W_P(%)	Plasticity Index I_P(%)	Blue Soil Value (g/100g)	Density	Specific Surface ($m^2.g^{-1}$)	Organic Matter (%)	Average Diameter d_{50}(µm)
F	44	21	23	1.35	2.64	18.32	0.9	35.15
K	39	22	17	0.5	2.78	25.62	2.83	17.47
Y	54	25	29	1.56	2.63	41.61	1.91	6.36

The particle size analysis curves of the clay raw materials (Figure 2) show similar patterns. They made it possible to evaluate for each clay sample the average diameters of the constitutive particles. These results show that the clay Y contains more fine particles than F and K which is in agreement with the specific surface of this clay.

The infrared spectrum of shea butter wastes (Figure 3**)** made it possible to identify the functional groups present in these raw materials. Thus, the vibration band of the OH bond around 3300 cm^{-1} and that of the C-H bond at 2853 cm^{-1} correspond to the polysaccharides. The band observed around 1730 cm^{-1} is due to C=O vibrations present in xylans and characteristic of hemicelluloses. The band around 1633 cm^{-1} corresponds to the water absorbed in the cellulose. The band at 1526 cm^{-1} is characteristic of the vibration of the C = C bonds present in the aromatic rings contained in the lignins. Finally, the vibrations of the C-O-C bonds around 1160 cm^{-1} and 1040 cm^{-1} are related to celluloses and hemicelluloses. These functions correspond to those generally encountered in the study of polysaccharides (Le Troedec, M., 2009).

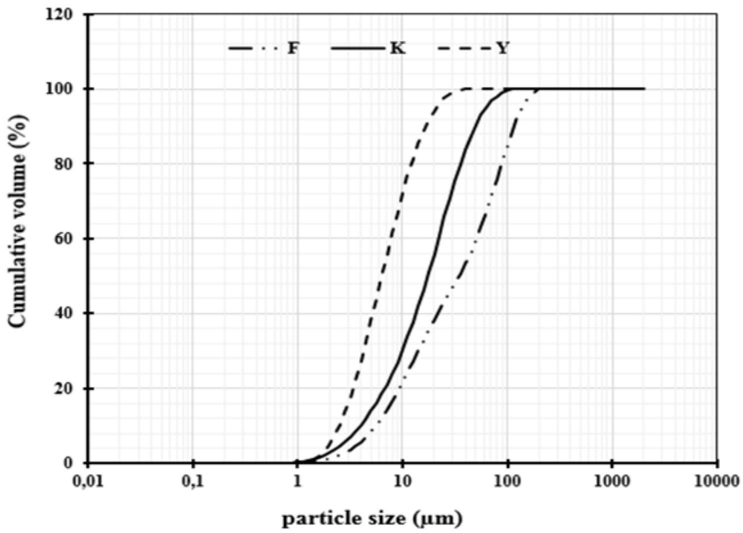

Figure 2: Distribution of Size of Samples

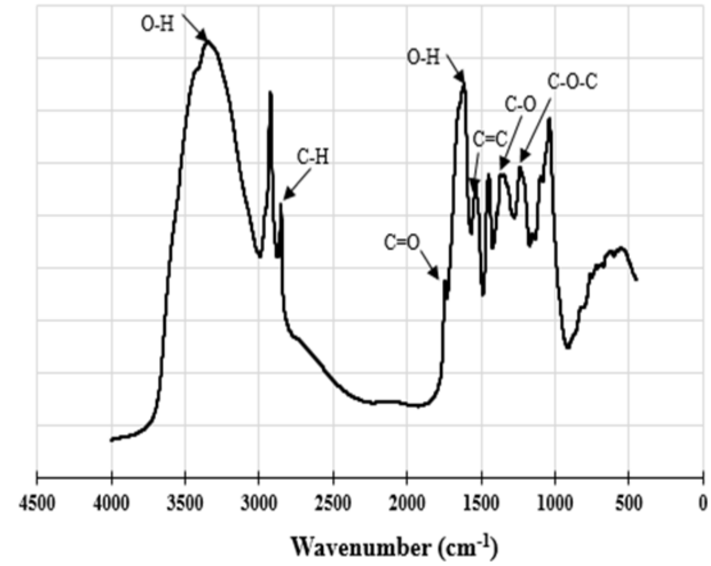

Figure 3: Infrared spectrum of shea butter wastes

Physical properties of CEB stabilized with cement and shea butter wastes

The different formulations of CEB studied given as a percentage weight of each constituent are presented in Table 5. The CEB were dried at 40 ° C for 7 days before the analyzes.

Table 5: Formulations and porosity of stabilized CEB

Samples	Clay A (%)	Shea wastes TK(%)	Cement C (%)	Rate of porosity		
				A=F	A=K	A=Y
A_{100}	100	-	-	32.33	30.41	30.99
$A_{93}TK_2C_5$	93	2	5	34.68	29.11	32.79
$A_{91}TK_4C_5$	91	4	5	33.79	29.79	31.93
$A_{89}TK_6C_5$	89	6	5	32.9	30.42	31.62
$A_{87}TK_8C_5$	87	8	5	32.98	31.24	31.17
$A_{85}TK_{10}C_5$	85	10	5	33.6	30.3	30.94

The influence of the proportion of shea butter wastes on the thermal conductivity and density of CEB was studied. Figure 4 shows the effects of shea butter wastes rate on the density of stabilized CEB. The results show a linear decrease in density from 2.64 to 2.44 for F, a decrease of about 8%, from 2.78 to 2.53 for K, a decrease of about 9% and a decrease of 2.63 to 2.44, a decrease of about 7%. Similarly, there is a slight increase in porosity (Table 5). These observations are in agreement with the results obtained by some authors who explained this decrease in density with an increase in the fiber content by a decrease in homogeneity, an improvement in the bonds and an increase in the porosity of the materials (Taallah, B., and Guettala, A., 2016). For others, it would be related to the low density of the fibers relative to the cement, which would lead to an increase in the volume of the compacted mixture thus inducing the reduction of the weight and the density of the materials (Ashour, T., Korjenic, A., and Korjenic, S., 2015).

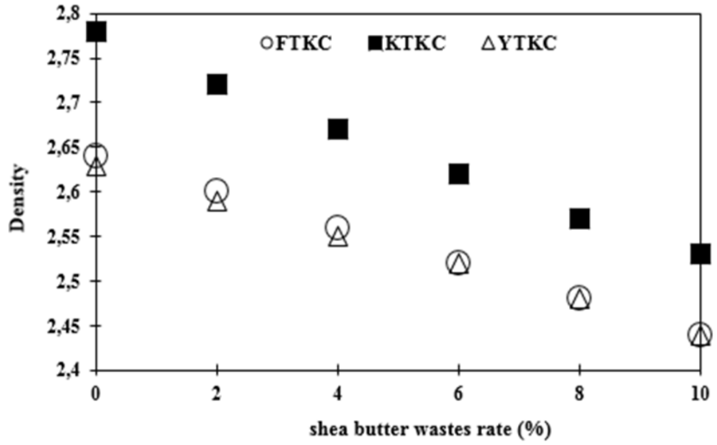

Figure 4: Variation in the density of the stabilized CEB based on the shea butter wastes proportion

The CEB developed with the K clay have densities higher than the densities of the bricks obtained with the Y and F clay. This difference could be explained by the higher content of iron oxides in the K clay compared to the other two clay F and Y.

Figure 5 shows the effect of the shea butter wastes content on the thermal conductivity and porosity of the CEB produced. The results showed a decrease in thermal conductivity with the increase in the content of shea butter wastes in the formulations studied. However, when the content of shea butter wastes in the formulations with K goes from 0 to 2%, an increase in the thermal conductivity of 0.77 to 0.85 $W.m^{-1}.K^{-1}$ is observed. This increase could be explained by the decrease in porosity (from 30.41 to 29.11%), due to the large amount of cementing phases resulting from the hydration of the cement. This has the consequence of increasing the rigidity of the structure of the material, thus inducing an improvement of the heat transfer in the material.

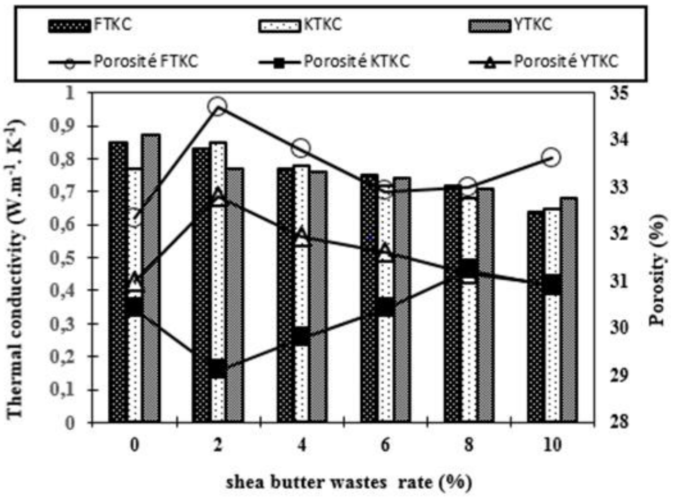

Figure 5: Variation of the thermal conductivity and porosity of the elaborated CEB based on the proportion of shea butter wastes

For the formulations with F, the conductivity decreases from 0.85 to 0.64 $W.m^{-1}.K^{-1}$, a decrease of 25%; for the formulations with K from 0.77 to 0.65 $W.m^{-1}.K^{-1}$, that is a drop of 16%, and finally for the formulations with Y from 0.87 to 0.68 $W.m^{-1}.K^{-1}$ corresponding to a decrease of 22%. An increase porosity up to 33.6% for F, 30.9% for K and 30.94% for Y is also observed. These values are of the same order of magnitude as those of compressed bricks stabilized with cement, sawdust and pozzolan, with average values ranging from 0.55 to 0.95 $W. m^{-1}.K^{-1}$ (Meukam, P., Jannot, Y., Noumowe, A., & Kofane, T.C., 2004). According to literature, the increase in the organic matter content results in the decrease of the thermal conductivity (Al-Oqla, F.M., and Sapuan, S., 2014; Benmansour, N., Agoudjil, B., Gherabli, A., Kareche, A., and Boudenne, A., 2014). This decrease in thermal conductivity can be explained on one hand by the creation of pores due to the presence of fibers or organic matter. On the other hand, it could be explained by the low thermal conductivity of the organic material compared to the clay matrix.

Figure 6 shows the evolution of the Young's modulus E based on the proportion of shea butter wastes in the CEB developed. The analysis of the results shows an increase in the stiffness of the CEB stabilized with 5% cement and 2% shea butter wastes in all clay used. The formulation with K has the best stiffness (11.6 GPa), followed by Y (7.4 GPa) and F (6.6 GPa). This improvement on the stiffness of the CEB could be attributed to the creation of bonds between the clay particles and the hydrates formed during the hydration of the cement. These hydrates consisting of hydrated calcium silicates and platelets of portlandin develop in both the clay-sand contact zones and in the clay matrix (Boffoue, M.O., Kouadio, K.C., Kouakou, C.H., 2015). The clay-cement and / or clay-sand-cement bonds generated thus make the CEB particles more consolidated and more resistant to mechanical stresses. However, for the proportion of shea butter wastes ranging from 4 to 10%, a gradual decrease of the module is observed. For the formulations with F and Y, the substitution rate of the clay soil with the shea butter wastes cannot exceed 6% because beyond this limit we have a decrease in rigidity compared to that of the non-stabilized CEB. For formulations with K and Y, 8% substitution can be achieved. This decrease in rigidity can be explained by the decrease in clay-cement and / or clay-sand-cement bonds due to the substitution of clay raw materials by shea butter wastes. The best stiffness depending on the degree of substitution obtained with K could be related to the higher density for this raw material.

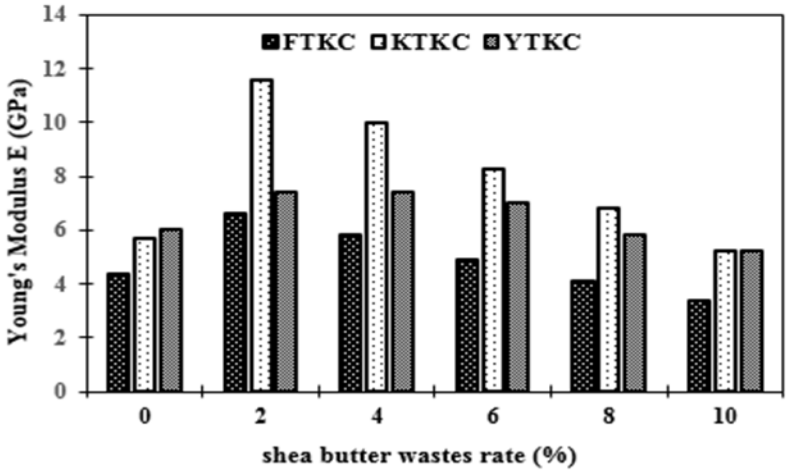

Figure 6: Variation of the Young's modulus of the elaborated CEB according to the proportion of shea butter wastes

Figure 7 shows the relationship between density and Young's modulus of the CEB stabilized with 5% cement and shea butter wastes. A positive correlation is observed between these two physical quantities. The correlation coefficients (r^2) of 0.99 for the formulations with F and K and 0.95 for the formulations with Y respectively show a very good correlation between the density and the Young's modulus. The stiffness of the CEB characterized by the Young's modulus increases with the density of the CEB.

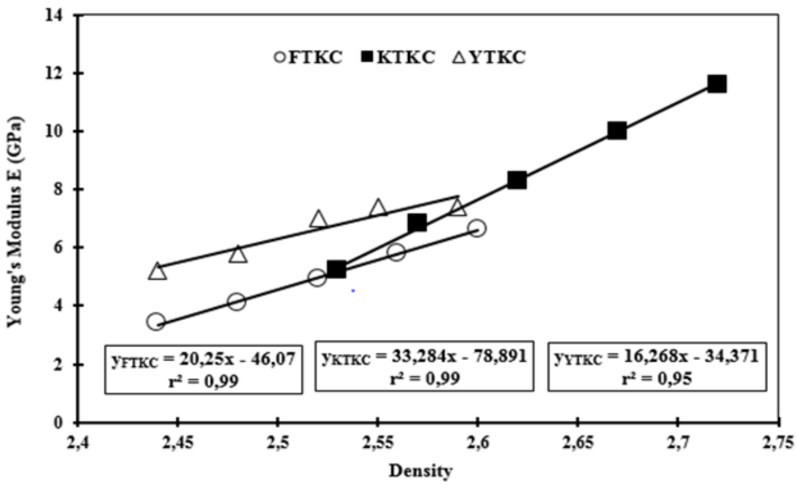

Figure 7: Correlation between the density and Young's modulus E of the elaborated CEB

CONCLUSION

The main objective of this work was to study the influence of shea butter wastes on some physical properties of Compressed Earth Brick (CEB) and stabilized with cement. To do this, three local clay raw materials consisting mainly of kaolinite, quartz and micaceous phases, shea butter wastes and cement were used. In the various formulations of CEB tested, the amount of cement is kept constant (5%) while that of shea butter wastes varies from 2 to 10% in substitution to the clay material. The results obtained showed the presence of pores due to shea butter wastes, which has the influence of reducing the density and the thermal conductivity of the elaborated CEB. A decrease in the thermal conductivity of 25% was observed for the formulations with the clay F against 16% for the formulations with the clay K and 22% for the formulations with the clay Y. The stabilized CEB also have a good rigidity related to the presence of cementing phases. Therefore, for the formulations with clay F and clay Y, a substitution rate of 6% of shea butter wastes is sufficient compared to 8% for the formulations with K in order to obtain acceptable physical property.

These different results showed that shea butter wastes offer CEB stabilized with little cement a good thermal insulation and also good rigidity property.

REFERENCES

Alam, I., Naseer, A., and Shah, A., 2015. Economical stabilization of clay for earth buildings construction in rainy and flood prone areas. *Construction and building materials, 77*, 154-159. https://doi.org/10.1016/j.conbuildmat.2014.12.046

Allinson, D., and Hall, M., 2010. Hygrothermal analysis of a stabilised rammed earth test building in the UK. *Energy and Buildings, 42*(6), 845-852. .https://doi.org/10.1016/j.enbuild.2009.12.005

Al-Oqla, F. M., and Sapuan, S., 2014. Natural fiber reinforced polymer composites in industrial applications: feasibility of date palm fibers for sustainable automotive industry. *Journal of Cleaner Production, 66*, 347-354. https://doi.org/10.1016/j.jclepro.2013.10.050

Ashour, T., Korjenic, A., and Korjenic, S., 2015. Equilibrium moisture content of earth bricks biocomposites stabilized with cement and gypsum. *Cement and Concrete Composites, 59*, 18-25. https://doi.org/10.1016/j.enbuild.2015.07.016

Benmansour, N., Agoudjil, B., Gherabli, A., Kareche, A., and Boudenne, A., 2014. Thermal and mechanical performance of natural mortar reinforced with date palm fibers for use as insulating materials in building. *Energy and Buildings, 81*, 98-104. https://doi.org/10.1016/j.enbuild.2014.05.032

Boffoue, M. O., Kouadio, K. C., Kouakou, C. H., Assande, A. A., Dauscher, A., Lenoir, B., and Emeruwa, E., 2015. Influence de la teneur en ciment sur les propriétés thermomécaniques des blocs d'argile comprimée et stabilisée. *Afrique Science: Revue Internationale des Sciences et Technologie, 11*(2), 35-43.

Chindaprasirt, P., and Pimraksa, K., 2008. A study of fly ash–lime granule unfired brick. *Powder Technology, 182*(1), 33-41. https://doi.org/10.1016/j.powtec.2007.05.001

Guyot, J., 1969. Mesure des surfaces spécifiques des argiles par adsorption. Paper presented at the Annales agronomiques.

Jayasinghe, C., and Kamaladasa, N., 2007. Compressive strength characteristics of cement stabilized rammed earth walls. *Construction and building materials, 21*(11), 1971-1976. https://doi.org/10.1016/j.conbuildmat.2006.05.049

Jouenne, C. A., 2010. Traité de céramiques et matériaux minéraux: Société de l'industrie minérale.

Lacroix, A., 1913. Les latérites de la Guinée et les produits d'altération qui leur sont associés (Vol. 10): Masson.

Lecomte-Nana, G., Bonnet, J.-P., and Soro, N., 2013. Influence of iron onto the structural reorganization process during the sintering of kaolins. *Journal of the European Ceramic Society, 33*(4), 661-668. https://doi.org/10.1016/j.jeurceramsoc.2012.10.024

Le Troedec, M., 2009. Caractérisation des interactions physico-chimiques dans un matériau composite à base de phyllosilicates, de chaux et de fibres cellulosiques. Thèse de doctorat, Université de Limoges, France.

Maignien, R. (1958). Le cuirassement des sols en Guinee. Mem. Serv. Carte Geol. Alsace-Lorraene(16), 240.

Meukam, P., Jannot, Y., Noumowe, A., & Kofane, T. (2004). Thermo physical characteristics of economical building materials. *Construction and Building Materials, 18*(6), 437-443. https://doi.org/10.1016/j.conbuildmat.2004.03.010

Taallah, B., and Guettala, A., 2016. The mechanical and physical properties of compressed earth block stabilized with lime and filled with untreated and alkali-treated date palm fibers. *Construction and Building Materials, 104*, 52-62. https://doi.org/10.1016/j.conbuildmat.2015.12.007

Van der Vossen, H.A.M and Kamilo, M., 2007. Ressources végétale de l'Afrique tropical 14. Oléagineux. [Tradcution de : Plant Ressources of Tropical Africa 14. Vegetable oils. Fondation PROTA, Wagenngen, Pays-bas / Backhyus Publishers, Leiden, Pays-Bas / CTA, Wageningen, Pays-Bas, GS (Editeurs), (), 261.