American Journal of Innovative Research and Applied Sciences ISSN 2429-5396 www.american-jiras.com

ORIGINAL ARTICLE

STABILIZATION OF COMPRESSED LATERITIC EARTH BLOCK USING RIVER SAND, EGG WHITE AND OX DUNG CENTERED

| LANTOVOLOLONA Jeanne Eliane Roger [1*] | ANDRIAMANAMPISOA Bina Flavie [1] | LAHADSON Stanislas Fulgence [2] | ANDRIAMASY Andry Malala [3] | RAKOTOARIMANGA Jeannot Victor [1] | and | RANDRIAMALALA Tiana Richard [4] |

[1.] University of Antananarivo | Faculty of Sciences | Department of Processes and Industrial Ecology | Antananarivo | Madagascar |
[2.] University of Antananarivo | Faculty of Sciences | Laboratoire de Chimie des Substances Naturelles et Chimie Organique Biologique (LCSN/COB)| Antananarivo | Madagascar
[3.] University of Vakinankaratra | Institut des Hautes Etudes en Science de la Société | Antsirabe | Madagascar |
[4.] Ministry of Public Works | Department of Researchs, Development and Materials | Laboratoire National des Travaux Publics et du Bâtiment (LNTPB) | Antananarivo | Madagascar |

| DOI: 10.5281/zenodo.14804565 | | Received January 26, 2025 | | Accepted February 01, 2025 | | Published February 05, 2025 | | ID Article | LANTOVOLOLONA-Ref4-2-20ajira260125 |

ABSTRACT

Background: Among other materials, earth is still mostly used in construction. **Objectives**: This purpose aimed to determine the usefulness of lateritic soil in confection of compressed earth block. **Methods**: Soil samples were collected from Ambatomirahavavy. Rectangular masonry mud-bricks and cylindrical compressed earth blocks CEB were made by mixing the soil sample with sand, ox dung and egg white in different ratios. Engineering and durability testing, which includes sieve analysis method, sand equivalent test, Proctor test, liquid and plastic limit tests were performed to characterise the soil sample, the soil based mixtures, the confectioned mud-bricks and CEBs. **Results**: A plasticity index of 17.3%, unit weight of 26.89 kN/m3, dry unit weight of 19.03 kN/m3, an optimum water content for compaction of 14.6% and a California Bearing Ratio of about 28% are found for the tested soil sample. Within 14.8% of water content, the dry density and the unit weight of the produced CEBs are 95.1 and 18.78 kN/m3, respectively. These values change to 11.4% for water content and 18.26 kN/m3 for unit weight, after the imbibition assay. High level of fine sand and low plastic index 14.1% are observed after addition of 33% of sand to the soil sample. The CEB control made with this mixture supports a maximum load of 7.25 kN and had a low compressive strength of 1.24 MPa. The addition of ox dung and egg white improves the resistance to compression. The mud-brick based on a similar mixture which has a Minimum Breaking Load of 26,8 kN, a high mechanical resistance for compression of 4.37 MPa and good flexural strength of 2.339 MPa exhibits 4.3 cm of abrasion loss at the end of the abrasive test and 10.32% of water absorption after the immersion assay. **Conclusion**: From these results, it is concluded that hard and resistant CEBs and masonry mud-bricks can be manufactured with the laterite earth from Ambatomirahavavy by taking advantage of its physical and mechanical characteristics. These findings contribute to valorize the lateritic soil of Ambatomirahavavy.
Keywords: *Compressed Earth Brick, Ox Dung, Egg White, Mechanical and Physical Characteristics.*

1.INTRODUCTION

Despite the advent of new materials, adobes and compressed earth bricks (CEB) remain the most popular and widespread building materials [1,2,3]. About 30% of the world's population uses them for their simplicity, low manufacturing cost, thermal and/or acoustic properties as well as for their extraction from the ground which is easy and without interference with the environment. However, the available literature suggests that red earth alone is not suitable for making good, durable bricks [1-3,4,5,6]. This led him to experiment with several mixtures in order to improve the physicochemical and mechanical properties of the bricks. The formation of laterites, which occurs by alteration of the parent rock (laterization), is specific to hot and humid tropical regions [4,5,6]. This natural material is used for the manufacture of bricks, among others [2-7]. A brick is a construction element generally rectangular in shape, made of sun-dried or kiln-fired earth [1,2].

Madagascar is an island with an abundant and available deposit of laterite. Mixed with ox dung and egg white, these materials were once frequently used to make walls. Currently known under the local name "Tambohon'ny Ntaolo", these walls, including that of “Ambohimanga rova”, have resisted centuries and it testifies its qualities.

The present study was performed to enhance the lateritic soil of Ambatomirahavavy. The main aim was to make hard and resistant compressed earth inspired by traditional Malagasy constructions, especially traditional walls. Thus, the secondary objectives that have been set include the characterization of the laterite earth from Ambatomirahavavy and mixtures based on this material as well as the preparation of CEB and its characterization.

2. MATERIALS AND METHODS

2.1 Materials

Laterite earth coded LS was obtained from Ambatomirahavavy worksite in the Analamanga region of Madagascar.

River sand of siliceous origin was collected on the RN 44 national road of Madagascar. It is fine blackish sand, 81.6 and 92% of the grains of which have a diameter of less than 2 mm and more than 0.2 mm, respectively. Its sand equivalent (SE) is 93% and its chemical composition is 89.67% SiO_2, 0.90% Al_2O_3, 0.91% Fe_2O_3, 5.96 CaO, 0.2% MgO, 0.05% SO^{3-}, 0.3% K_2O, 0.01% Na_2O and 0.019% Cl^-. The unit weight of its grains smaller than 4 mm is 26.75 kN/m^3.

Fresh ox dungs were obtained from Arivonimamo farms in the Itasy region of Madagascar. The dung was diluted to a viscous, fluid and homogeneous paste and then sieved (sieve less than 4 mm) to remove undesirable elements. Eggs were bought at the local market. The egg white was separated from the yolk and then an amount corresponding to the desired dosage was used. Other materials including cement (HOLCIM 42.5) were also required during this study. They were purchased from local trader.

2.2 Characterization of the laterite earth LS

All the used protocols were conducted according to the method reported by Mekhermeche A. and other with slight modifications, for this part of study [4,5,6]. The sieve and hydrometer analysis methods described in the NF P 18-560 standard were used to evaluate the grain-sizes of the sample. Later, grain-size distribution curves were constructed by plotting the size (in mm) on the abscissa (logarithmic scale) and the percentage passing to the y-axis (arithmetic scale). The mass of water content and the corresponding dry weight were used to calculate the water content ratio W (expressed in %). The Atterberg limits including liquid limit (LL) and plastic limit (PL) as well as the plasticity index (P_I) were assessed according to the method reported by Mekhermeche and other with slight modifications [4,5]. The liquid limit test was performed by using a Casagrande device. The equation (1) and the fine size particles obtained during the liquid limit test were considered for the plastic limit test. With P_h: wet mass and P_S: dry mass. The difference between the liquid limit and the plastic limit was used to calculate the plasticity index P_I. The unit weight γ_s (in kN/m^3) was determined using a pycnometer and by applying relation (2), with *a*: mass of the pycnometer, *b*: volume of the pycnometer, *c*: mass of the pycnometer + water + tested sample and *d*: mass of the pycnometer + tested sample. The sand equivalent (SE) values were determined by using the sand equivalent test described by Mekhermeche [4]. The equation (3) was applied. The optimum water content for compaction and the density of the moulded samples were studied through a modified PROCTOR assay [4,5]. Briefly, a total of 6000 g of sample in 5 layers were compacted (25 blows per layer) in moulds of about 2300 cm3. The sinking and the force corresponding to the 25 blows were determined using a 30 kN standardized hammer. Compacted and stabilized samples were air-dried for 96 hours, and then cured for 96 hours in an imbibition tank. After this time, its California Bearing Ratio (*I.CBR*) and dry density (*D.D*) were determined via a CBR assay after imbibition and by using relations (4) and (5).

$$PL = (P_h - P_s) \times 100 \qquad \textbf{(1)}$$

$$\gamma_s = \frac{d - a}{b - [c - d]} \times g \qquad \textbf{(2)}$$

$$SE = \frac{\text{sand reading height}}{\text{total height}} \times 100 \qquad \textbf{(3)}$$

$$I.CBR = \frac{reading\,value \times 20}{13{,}51} \qquad \textbf{(4)}$$

$$D.D = \frac{unit\ weight}{\gamma d\ opt} \quad \gamma\text{d opt} = 19.74\ kN/m^3 \qquad \textbf{(5)}$$

2.3 Characterization of LS based mixture

A mixture of LS with 33% of sand was made. The mixture was subjected to a sieve analysis as described earlier. Its Atterberg limits were studied and the corresponding plasticity index PI was deduced according to the previously reported procedure.

2.4 Preparation of CEB:

CEB types that differ in shape and ratio of ox dung, egg white, sand and LS were produced according to the method reported in literature with slight modifications [8,9,10]. The dry lateritic soil was sieved, and then kneaded to obtain a homogeneous mixture. Depending on the case, 2% or more water was added in fine droplets using a manual watering can and the soil was dry when too wet.

Five (5) types of cylindrical CEB noted from M1 to M5 and rectangular masonry mud-brick were prepared from different mixtures. CEB M1 (control) was made with LS and 33% of sand. CEB M2 was made with 95% of a mixture of 1817 g of moist soil (with a density of 2.26), 600 g of sand, 60 g of egg white, and 150 ml of water. CEB M3, which includes 18 g of cement, was prepared from a mixture of LS and 1% cement. The CEB M4 (LS + sand + ox dung) was made with 1719 g of mixture which includes 400 g of ox dung diluted in 830 cm^3 of water while the one coded

DOI: 10.5281/zenodo.14804565

M5 was made with 1713 g of mixture including 1726 g of LS, 600 g of sand, 400 g of ox dung and 60 g of egg white. Before moulding, each mixture was air-dried for 24 hours, and then appropriate water was added. The resulting material was put into a cylindrical mould where it is pressed at 60 kN for a few minutes using a manual press. The demoulding was carried out after a 24-hour rest period, and then the demoulded CEB was subjected to a cure. This cure consists of leaving the CEB in a cold room for 2 days and then in the open air for 5 days. The mud-bricks were prepared with 2400 g of soil (67%), 1180 g of sand (33%), 400 g of ox dung and 120 g of egg white. Eight hundred and thirty (830) cm^3 of water was used to dilute the ox dung and egg white before adding them to the mixture. The final mixture was put into a 22 × 10.5 × 6 cm^3 (length × width × height) rectangular mould and then compressed with an electric press. The bricks were then subjected to more than 7 days of cure.

2.5 Characterization of CEBs and the masonry mud-brick

Water absorption test was performed as previously described [10,11]. Successively, the dry CEB or mud-brick was weighed, put in water, then oven-dried at 105°C for 24 hours. After this period, the sample was weighed again, and then the water absorption A (in %) and the corresponding rate (in $g/cm^2.min$) were obtained by applying equations (6) and (7), respectively with m: mass of water absorbed by the product since the beginning of immersion (in g), S: surface area of the submerged section (in cm^2) and t: time elapsed since the beginning of immersion (in minutes) or with mw: mass of the absorbed water and mi: initial mass of the sample. The compressive strength test was executed using a TESTWELL machine and from equation (8), with *F*: maximum load supported by the specimen, *Sb*: average gross section of the specimen. Rectangular masonry mud-bricks with a mass of 2728 g and correction coefficients (α = 0.96 and β= 0.9) for the cubic CEB mould were considered. The flexural strength *S* (in MPa) of each sample was deduced from equation (9), with $3 \times F \times l$: Minimum Breaking Load, $2 \times d_1 \times d_2^2$: cross-sectional area. The test was conducted as described previously and value equal to 12.5 MPa was considered as medium [10,11]. The durability of the mud-brick was evaluated using the previously described abrasive test. Therefore, the brick was subjected to a mass of 1 kg and its surface was stroked for 1 minute by using a standardized abrasion tester.

$$A = \frac{m_w}{m_i} \times 100 \quad \textbf{(6)}$$

$$\alpha = \frac{m}{S \times t} \quad \textbf{(7)}$$

$$R_c = \frac{F}{S_b} \quad \textbf{(8)}$$

$$S = \frac{3 \times F \times l}{2 \times d_1 \times d_2^2} \quad \textbf{(9)}$$

2.6 Statistics

All the results were expressed as mean from replicate assays (n≥2) using Microsoft Office Excel 2010.

3. RESULTS

3.1 Characteristics of LS

The particle size distribution of LS is presented in Figure 1. The profile of this curve leads to recognize that of Sandy Clay Loam type. Its unit weight, which is 26.89 kN/m^3, is reminiscent of that of reddish Sandy Clay Silts. Its liquid limit (LL) is 43.1% while its plastic limit (PL) is equal to 25.8%. A plasticity index (P_I) of 17.3% can be deduced. This P_I value, which is between 15 and 40, indicates that it is a plastic soil.

Optimum water content (W_{opt}) of about 14.6% of the total mass allows a good compaction of 6000 g of this material and to obtain CEB with a unit weight of 19.03 kN/m^3 and a California Bearing Ratio (*I.CBR*) of about 28%. This *I.CBR* value, which is between 15 and 30, reflects a good resistance according to the quality standard of a laterite earth which is based on the CBR performance. Before imbibition, the density and unit weight of the tested CEBs are 95.1 and 18.78 kN/m^3, respectively with water content equal to 14.8%. After the imbibition assay, the water content *W* and the unit weight γ are, respectively, 11.4% and 18.26 kN/m^3.

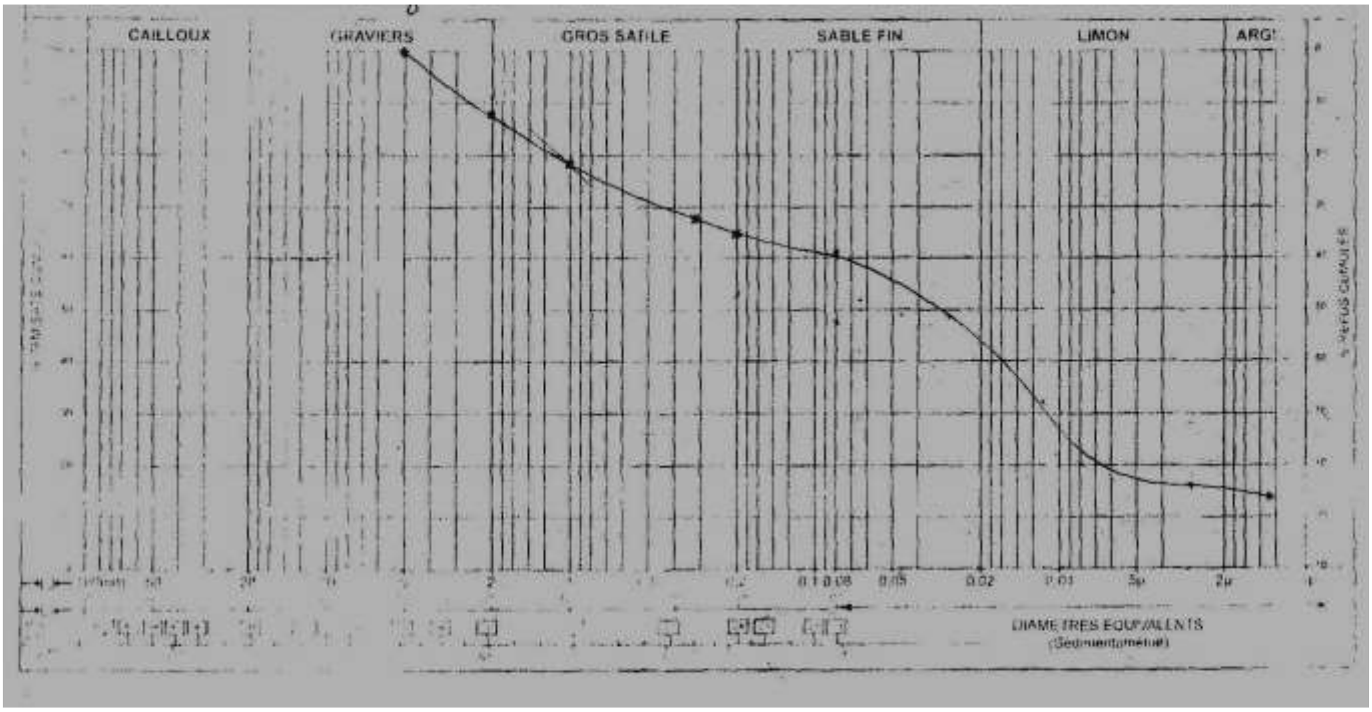

Figure 1 : Particle size distribution of the laterite earth from Ambatomirahavavy obtained by sieve and hydrometer analysis (Water content *W* of the sample = 9.9%).

3.2 Characteristic of the LS based mixture

The Particle size distribution of LS mixed with 33% of sand is shown in Figure 2. It provides a high level of fine sand. Its Atterberg limits, which are obtained with a sample with a water content *W* equal to 22.0%, are 36.1% for the liquid limit (*LL*) and 22% for the plasticity limit (*PL*). We retain a value of the P_I equal to 14.1%. This value, which is between 5 and 15%, indicates a non-plastic property. So, the addition of 33% of sand decreases the P_I from 17.3 to 14.1%.

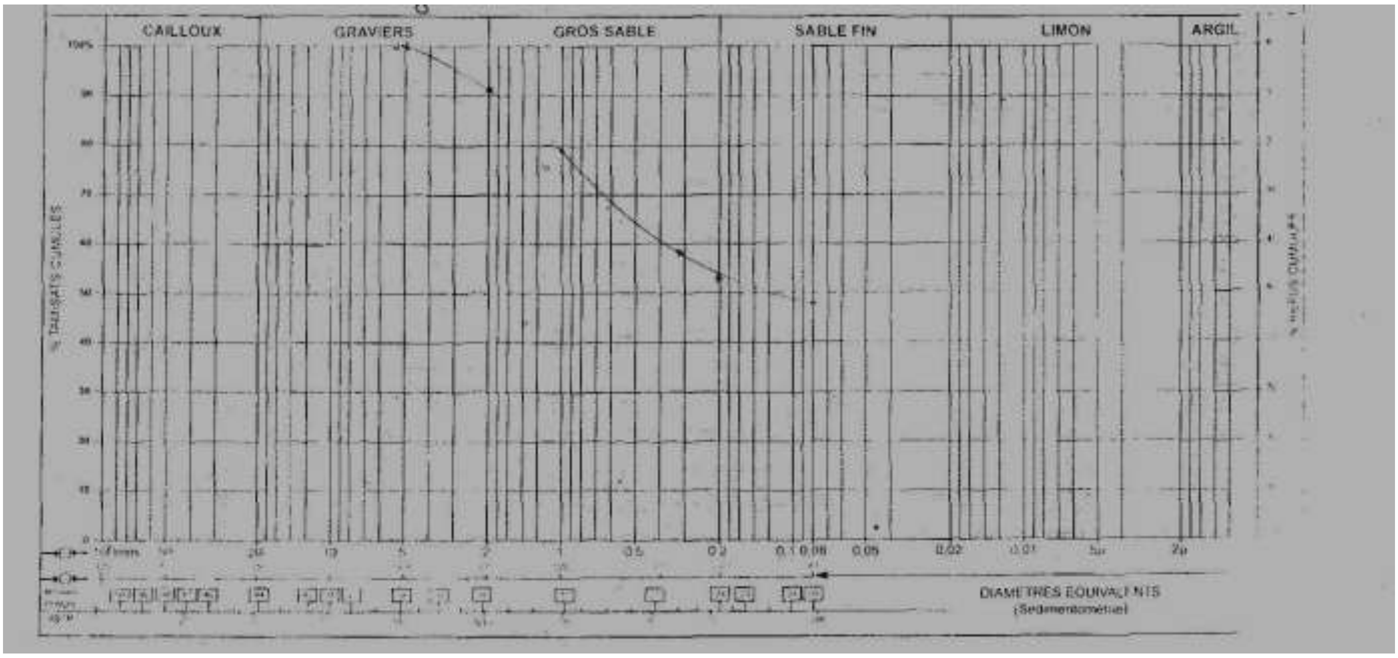

Figure 2 : Particle size distribution of the Ambatomirahavavy laterite earth mixed with 33% of sand. Values were obtained by sieve analysis (Water content W of the sample = 2.2%).

3.3 Physical and Mechanical Characteristics of CEBs

All the CEBs from M1 to M5 have a cylindrical shape with, an average of 8 cm in diameter, 16 cm in height, a section of 5024 mm^2 and a volume of 803.84 cm^3. The CEB coded M1 (LS + sand) which serves as a control has a mass of 1717 g, a density equal to 2.13 and a maximum supported load of 7.25 kN. The M2-coded CEB has a mass of 1727 g, a density of 2.14, and supports a maximum load of 17.5 kN. Table 1 reports the compressive strengths of each CEB.

DOI: 10.5281/zenodo.14804565

Based on these results, the compressive strength R_c is 1.24 MPa for the control CEB. This value, which is close to 1 MPa, allows us to deduce a low compressive strength. Apart the CEB M4 which has a moderated value, all the tested CEB have a higher resistance to compression. The CEB M5 shows the highest value.

The mud-bricks are rectangular with 22 × 10.5 × 6 cm (length × width × thickness). Each brick has a mass of 2730 g, 5939 mm^2 of section, 356.34 cm^3 of volume (section × height) and a Minimum Breaking Load of 26,8 kN. Its density is equal to 1.96 for a flexural strength *S* of 2.339 MPa and a compressive strength R_c of 4.37 MPa. This R_c value indicates that these masonry mud-bricks have a high mechanical strength for compression and good flexural strength. The studied mud-bricks exhibit 4.3 cm of abrasion loss at the end of the abrasive test. For an initial mass of 2720 g, the mud-brick reaches a mass of 2878 g after immersion. This allows us to deduce a mass of water P_{eau} equal to 158 g and water absorption of 10.32%.

Table 1: Compressive strengths of the laterite based CEBs (mean, *n*=2).

CEB Code	R_c with correction factors (in MPa)	Appreciation
M1 (témoin)	1,24	f
M2	3,07	F
M3	4,47	F
M4	2,80	m
M5	4,74	F

In duplicate (*n=2*); laterite + sand (M1); laterite + sand + egg white (M2); laterite + 1% cement (M3); laterite + sand + ox dung (M4); laterite + sand + ox dung + egg white (M5); Compressed Earth Brick (CEB), Compressive Strength (R_c), High Compressive Strength (*F*), Low Compressive Strength (*f*), Moderate Compressive Strength (*m*).

4. DISCUSSION

The objectives of this work were to make a hard and resistant compressed earth which is inspired by traditional Malagasy walls. Thus, earth sample from Ambatomirahavavy (LS) and mixtures based on this material were characterized by different methods, and then CEBs were prepared. The characteristics of the prepared CEBs were evaluated and the obtained data were used for the manufacture of masonry mud-brick.

According to the results obtained during its characterization, LS is a plastic soil of the reddish-brown Sandy Clay Loam type. Its CBR index indicates good resistance and the addition of river sand at 33% decreases its plasticity index (P_I) from 17.3 to 14.1%. Thus, this addition of sand switches its property from plastic to non-plastic considering the plasticity standard reported in the literature [4,5]. This reflects an improvement in the quality of the mixture for the manufacture of mud-brick. On the other hand, a relatively high amount of fine sand can be deduced by analysing the particle size distribution of this mixture and considering those of the used sand which have a diameter less than 2 mm (81.6%) and more than 0.2 mm (92%). It would mean that this mixture used alone is not conducive to the manufacture of CEB. This hypothesis is confirmed by the results obtained with the control CEB M1 which is made only with LS and sand. Indeed, it has the lowest compressive strength among the tested CEBs. Its value (1.24 MPa) is below that reported for the adobes of Madagascar (based on clay, sand and water) which is 2 to 5 MPa and those of CEBs described previously by other authors (< 2.4 MPa) [1,9, 15, 19]. Also, the results of the tests show that the additions of ox dung to the mixture of LS and sand increase its compressive strength. Ox dung would play a role as a binder and shrinkage and would act as an anti-crack. Indeed, similar finding is documented in the scientific literature and this would explain these results, at least in part Mahamat (2010) [12]. Since the maximum value is achieved with CEB M5, this implies that the addition of both ox dung and egg white provides the best compressive strength. Therefore, a similar mixture was chosen for the production of the mud-bricks. A good mechanical resistance to compression is found with the obtained bricks. Also, the sample has good flexural strength according to the standard for artisanal bricks. These facts are attributable to the binder and removal roles of the ox dung and the binding and fixing functions of the egg white. This could explain, at least in part, the high maximum supported load up to 26 kN. Indeed, the cohesion of the elements of soil that is measured by the flexural strength test depends on the quality and quantity of its fine-size grains or cementing agents [4,5]. In addition, the results show that these mud-bricks have water absorption of 10.32% and a low abrasion resistance. Under the same conditions, artisanal handmade brick should have a wear between 0 and 3.1 cm, we can deduce a low abrasion resistance for the sample tested. This reflects one of the weak points of earth construction, which is highly sensitive to moisture and water [1-12]. Thus, further studies are needed to improve these abrasion resistances and water absorption ratio.

5. CONCLUSION

From all the obtained results, we can conclude that the laterite earth from Ambatomirahavavy which is a reddish-brown plastic soil of the Sandy Clay Silt type is not conducive to the manufacture of CEB when used alone. The addition of sand changes the plasticity of the obtained mixture and makes it possible to produce masonry mud-bricks with low mechanical compressive strength. The addition of ox dung to the laterite and sand mixture improves its resistance to compression, but the best effect is obtained after adding egg white. In addition to good flexural strength, similar compressive strength is found with the masonry mud-brick which is made from the same mixture. However, the manufactured mud-bricks still has a low abrasion resistance.

This study allows the valorisation of the laterite earth from Ambatomirahavavy by taking into account its physical and mechanical characteristics in the manufacture of mud bricks which is inspired by the traditional Malagasy walls. The logical next step of this study would be to improve the use of ox dung in stabilized Compressed Earth Block, to study the thermal properties of the Compressed Earth Block with egg white and to design artisanal bricks that are more resistant to abrasion.

6. REFERENCES

1. **Rigassi V.** Bloc de terre comprimée : Manuel de production. 1st ed. Braunschweig: Friedrich Vieweg & Sohn; 1995.
2. **Richard PW.** L'adobe, une solution durable pour la construction d'habitations écologiques dans une zone à forte activité sismique comme le Chili [mémoire]. Sherbrooke: Université de Sherbrooke; 2010. Available from: https://savoirs.usherbrooke.ca/bitstream/handle/11143/7506/cufe_Wafer_Richard-Philippe_essai159.pdf?sequence=1&isAllowed=y
3. **P'Kla A.** Caractérisation en compression simple des Blocs de Terre Comprimée (BTC) : Application aux maçonneries « BTC Mortier de terre » [thèse de doctorat]. Lyon: Institut National des Sciences Appliquées de Lyon; 2002. Available from: https://theses.fr/2002ISAL0037
4. **Mekhermeche A.** Contribution à l'étude des propriétés mécaniques et thermiques des briques en terre en vue de leur utilisation dans la restauration des Ksour sahariennes [mémoire de magister]. Ouargla: Université de Ouargla; 2012. Available from: https://dspace.univ-ouargla.dz/jspui/bitstream/123456789/701/1/MEKHERMECHE_Abdessalam.pdf
5. **Elabbadi A.** Mécanisme de durcissement des briques en terre stabilisée à la chaux. Conditions de cure et choix des terres [thèse de doctorat]. Paris: Ecole Nationale Supérieure de Paris; 1986.
6. **Lawane A, Pantet AV, Vinai R, Thomassin JH.** Caractérisation des matériaux latéritiques pour une meilleure utilisation en Afrique. In : 20ème Congrès Français de Mécanique CFM; Aug 2011; Besançon, France. Available from: https://hal.science/hal-03422455v1
7. **Avliset I.** Matériaux de terre cuite. Technique de l'Ingénieur. 1994.
8. **Giovanni P.** La brique : fabrication et traditions constructives. Paris: Eyrolles; 2004. p. 196, 260. Available from: https://www.eyrolles.com/BTP/Livre/la-brique-9782212112122/
9. **Taallah B, Guettala A, Kriker A.** Mechanical properties and hygroscopicity behavior of compressed earth block filled by date palm fibers. *Constr Build Mater*. 2014;59:161–168. doi: 10.1016/j.conbuildmat.2014.02.058
10. **Ramiandrisoa AL, Ranaivoniarivo VG, Rakotoarivonizaka I, Andrianaivoravelona RR.** Etude du mécanisme de stabilisation des sols par des stabilisants naturels – cas du purin de bœuf. Recherches pour le développement, Série Sciences Technologiques. Centre d'Information et de Documentation Scientifique et Technique. 2021;6:361-378.
11. **Damodar SJ, Gupta MK.** Flexural strength – A measure to control quality of rigid concrete pavements. *Int J Sci Eng Res*. 2014;5(11):46-57. Available from: http://www.ijser.org
12. **Mahamat SI.** Etude comparative amélioration des briques en terre comprimée stabilisée par le ciment et la chaux [mémoire de master]. Ouagadougou: International Institute for Water and Environmental Engineering; 2010. Available from: https://fr.scribd.com/document/458314883/Memoire-Mahamat-Saleh

How to cite this article: LANTOVOLOLONA Jeanne Eliane Roger , ANDRIAMANAMPISOA Bina Flavie, LAHADSON Stanislas Fulgence, ANDRIAMASY Andry Malala, RANDRIAMALALA Tiana Richard and ANDRIAMIADAMANANA Christian. STABILIZATION OF COMPRESSED LATERITIC EARTH BLOCK USING RIVER SAND, EGG WHITE AND OX DUNG CENTERED. *Am. J. innov. res. appl. sci*. 2025; 20(2): 37-42. [**DOI**: 10.5281/zenodo.14804565]