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RESEARCH

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# Predictive modeling of lime-stabilized soil performance in compressed earth brick applications

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## Abstract

This research aims to analyze lateritic soils from the southern region of Cameroon for the production of compressed earth bricks. The study involves sixteen (16) soil samples gathered from four key locations: Mebae-Ndong, Mevae, Akak-Essatolo, and Enongal. The results show that the samples had specific gravity values ranging from 1.92 to 2.38, and particle size analysis allows us to identify these soils as sandy clay soils. These soils are predominantly very plastic silty soils and very plastic organic soils, according to Atterberg limits. The proctor tests show that the soils have bell-shaped textures, which are typical of CEB-producing soils. The best compaction of these soils occurs when the water content is between 14.5 and 20.5%. These are fine clay soils of subgroups A-7-5, according to the HRB classification. The compressive strength of lime-stabilized bricks after 28 days was measured at 3.37 MPa for Akak-Essatolo, 4.62 MPa for Mevae, 3.66 MPa for Enongal, and 5.31 MPa for Mebae-Ndong. In terms of flexural strength, the values were 0.23 MPa (Akak-Essatolo), 0.22 MPa (Mevae), 0.24 MPa (Enongal), and 0.55 MPa (Mebae-Ndong). The integration of lime stabilization and predictive analytics offers a novel pathway for optimizing CEB production in tropical regions, with implications for sustainable housing and infrastructure development.

**Keywords** Lime stabilization, Statistical analysis, Compressed earth bricks, Regression modeling

## 1 Introduction

Compressed earth bricks (CEBs), particularly when fired, are widely recognized for their affordability, accessibility, and thermal and acoustic insulation properties [1]. However, their production often requires energy-intensive processes or stabilizing agents such as ordinary Portland cement (OPC), lime, or sodium silicates [2], with OPC alone contributing approximately 8% of global CO<sub>2</sub> emissions. In response to housing challenges in developing nations, recent efforts have focused on converting locally available raw



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materials into building products through innovative technologies [3–5]. This shift aims to reduce costs and environmental impact by moving away from globally standardized components toward earth-derived materials [6–11].

Lateritic soils, formed through tropical weathering processes, are abundant and cost-effective, making them suitable for infrastructure and housing applications [12–20]. In Cameroon, laterite covers about 70% of the land surface, especially in the equatorial zone [19, 21, 22], and is commonly used for traditional mud bricks. Its advantages include low energy processing, natural aesthetics, and strong thermal properties [23]. Yet, for CEB production, lateritic soils must meet strict geotechnical standards to ensure mechanical strength and durability [24–28].

Stabilization of lateritic soils is essential to enhance strength, load-bearing capacity, and resistance to environmental stressors, as outlined by ASTM standards [29]– [30]. Understanding mechanical behavior is key to developing effective stabilization methods [31]. Prior studies have explored various additives as recycled polyethylene [32], geopolymers [33], straw fibers [34], liquid polymers [35], bone ash [36], and lime [37], demonstrating diverse strategies for improving soil performance.

Despite awareness of structural risks, construction professionals often lack sufficient technical data to guide material selection. This study addresses that gap by characterizing lateritic soils from Ebolowa, Cameroon, through physical, chemical, mineralogical, and mechanical analyses. Lime-stabilized CEBs are produced and evaluated, and a predictive model is developed to estimate brick strength. These findings aim to improve material specifications, reduce design costs, and support sustainable construction planning.

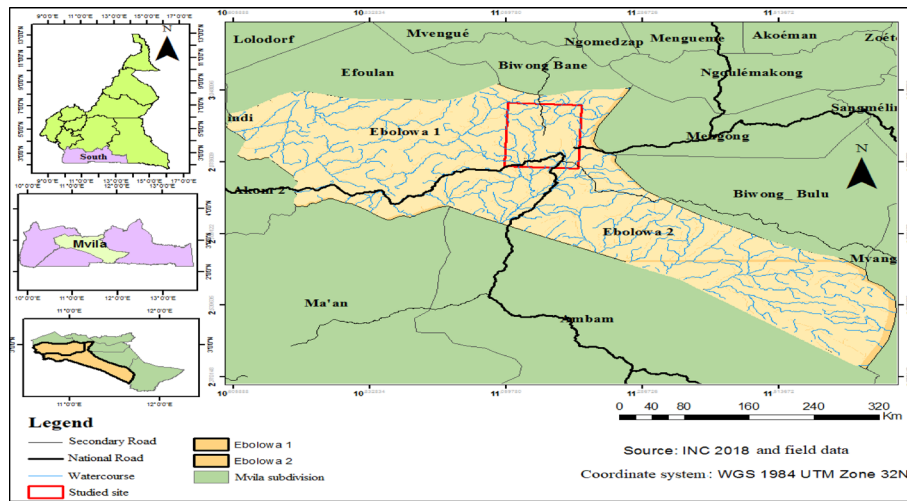
## 2 Geographical context

The research area is located in Ebolowa, Cameroon's South region, characterized by its rich lateritic soil deposits and its growing economic development, which contrasts sharply with a persistent lack of infrastructure, making it a compelling site for analyzing territorial development dynamics. It is also the capital of the Mvila Division. The city of Ebolowa is bordered to the south by the city of Ambam, to the north by the city of Mengong, to the west by the city of Biwong-Bané, and to the east by the city of Mvangan (Fig. 1).

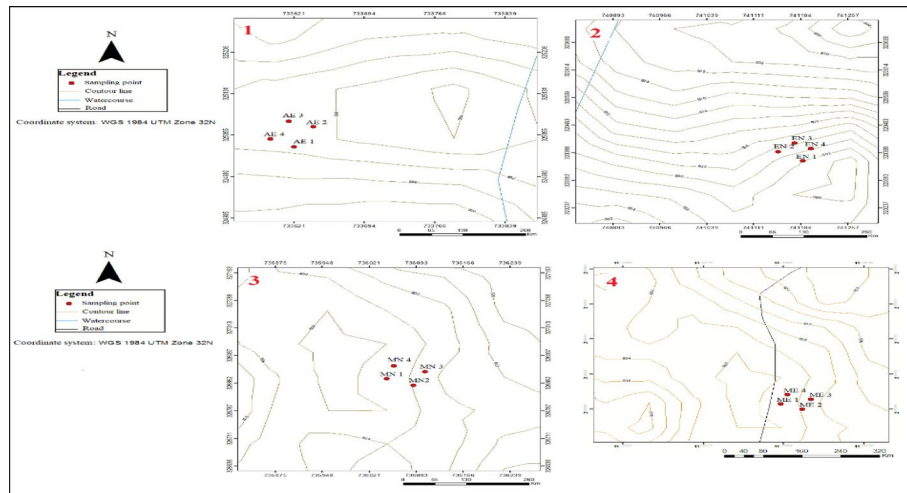
## 3 Sampling method

The study employed a grid-based sampling method, as illustrated in the sampling maps for each site (Fig. 2). We used a systematic sampling approach, ensuring spatial coverage across each location. Sixteen soil samples were collected; four from each of the four sites (Mebae-Ndong, Mevae, Akak-Essatolo, and Enongal). Replicates were gathered within each site to account for intra-site variability and improve the reliability of the geotechnical and mineralogical analyses. The four sites were selected based on their representative lateritic soil profiles, distinct lithological characteristics, and geographical relevance within the Ebolowa region.

The analyzed soil profiles predominantly consist of lateritic gravel formations. Sample specimens display a characteristic color gradient spanning reddish-brown, ochre brown, and Belgian brown hues (Fig. 3), with collection procedures standardized at a mean depth of 1.2 m below surface level.



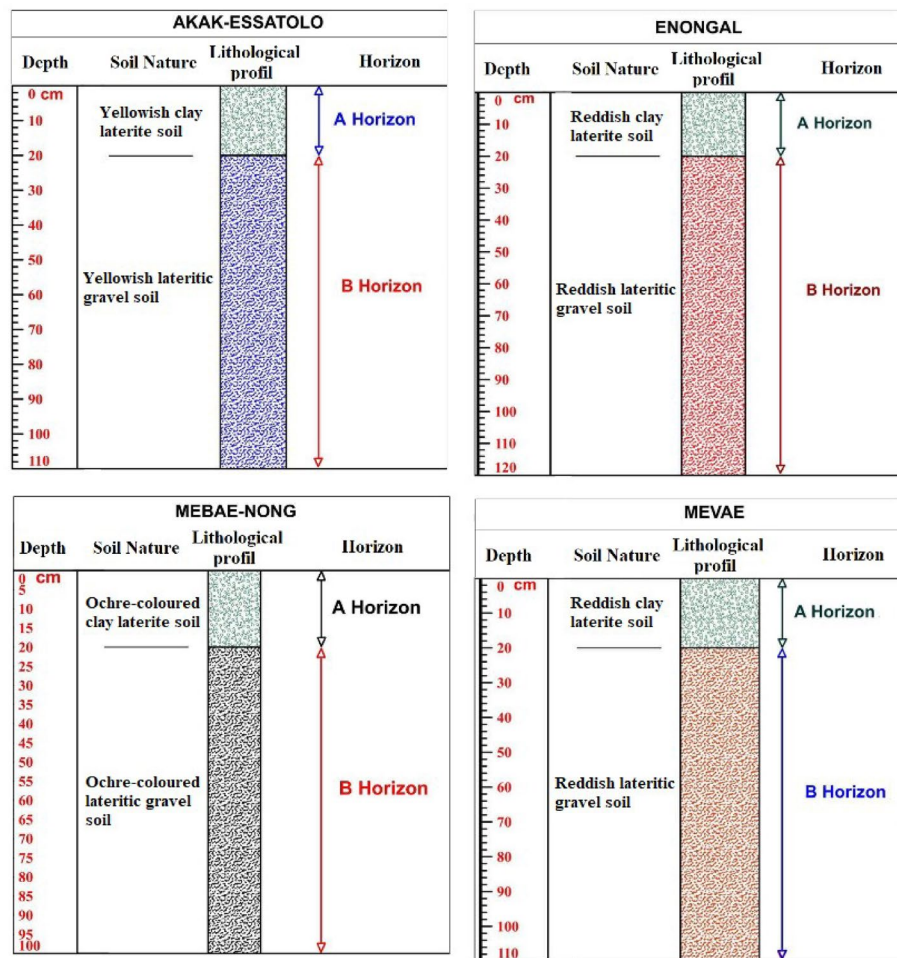
**Fig. 1** Location of the study site



**Fig. 2** Sample map of (1) Akak-Essatolo, (2) Enongal, (3) Mebae-Ndong, and (4) Mevae soil

The sampling wells were described during the fieldwork and it appears that these sampling wells are characterized by two main soil horizons. It is observed from the surface:

- The surface layer (A horizon) comprises a thin clay-rich lateritic stratum measuring several centimeters in thickness. Distinct color variations characterize the different sampling locations: Mevae soils display reddish ochre tones, Enongal soils exhibit true red coloration, Mebae-Ndong soils show ochre pigmentation, while Akak-Essatolo soils present yellowish hues.
- The lateritic gravel layer (B horizon) immediately underlies the surface A horizon, exhibiting consistent coloration with the overlying stratum. Profile measurements reveal its vertical extent spans 20–110 cm depth in the Mevae, Mebae-Ndong, and Akak-Essatolo sampling sites while extending slightly deeper (20–120 cm) at the Enongal location. Textural analysis identifies this horizon as a composite matrix of clay-sand-gravel particles.



**Fig. 3** Lithological profile of the sampling wells

#### 4 Experimentation method

X-ray diffraction (XRD) analysis was conducted using a Bruker-AXS D8 Advance diffractometer equipped with a LynxEye position-sensitive detector array to determine the mineralogical composition of ground samples with particle sizes below 100  $\mu\text{m}$ . Complementary elemental characterization was performed via parallel X-ray fluorescence (XRF) techniques, combining conventional wavelength-dispersive XRF spectrometry with a high-performance Niton XL3t980 handheld XRF analyzer, enabling precise chemical composition profiling of the samples.

Comprehensive geotechnical evaluation was implemented at the certified material testing facilities of MIPROMALO and LABOGENIE (Cameroon), adhering strictly to standardized French testing protocols: hygroscopic water content determination (NF P 94 – 050 [38]), specific gravity assessment (NF P 94 – 054 [39]), combined dry sieve granulometry (NF P 94 – 056 [40]) and sedimentation analysis (NF P 94 – 057 [41]) for complete particle size distribution, methylene blue adsorption capacity (NF P 94 – 068 [42]), modified Proctor compaction characteristics (NF P 94 – 093 [43]), organic matter content quantification (XP P 94 – 047 [44]), and Atterberg limit determination (NF P 94 – 051 [45]).

Prismatic test specimens (nominal dimensions  $4 \times 4 \times 16 \text{ cm}^3$ ) were fabricated through a rigorously controlled manufacturing sequence: (i) representative field sampling employing standardized soil collection protocols, (ii) systematic laboratory preparation involving oven-drying at  $105 \text{ }^\circ\text{C}$ , mechanical crushing to  $< 2 \text{ mm}$  particle size, precision sieving, and optimized water content adjustment, (iii) high-pressure hydraulic compaction at controlled strain rates, (iv) careful demolding procedures, and (v) ambient air-drying under regulated environmental conditions. Following prescribed curing intervals (7, 14, 21, and 28 days) under controlled humidity and temperature, mechanical performance evaluation was conducted through standardized compressive strength (NF P 94–420 [46]) and three-point flexural strength (NF P 94–422 [47]) testing protocols.

A comprehensive statistical evaluation of the CEB mechanical properties was conducted using XLSTAT 2014 integrated with Microsoft Excel. This analysis involved correlation testing between key parameters to develop predictive models of brick behavior. After that, a multiple linear regression model was employed to predict compressive and flexural strengths based on geotechnical parameters. Model performance was evaluated using  $R^2$  as key metric. Linear regression was selected due to its interpretability and suitability for continuous outcome variables.

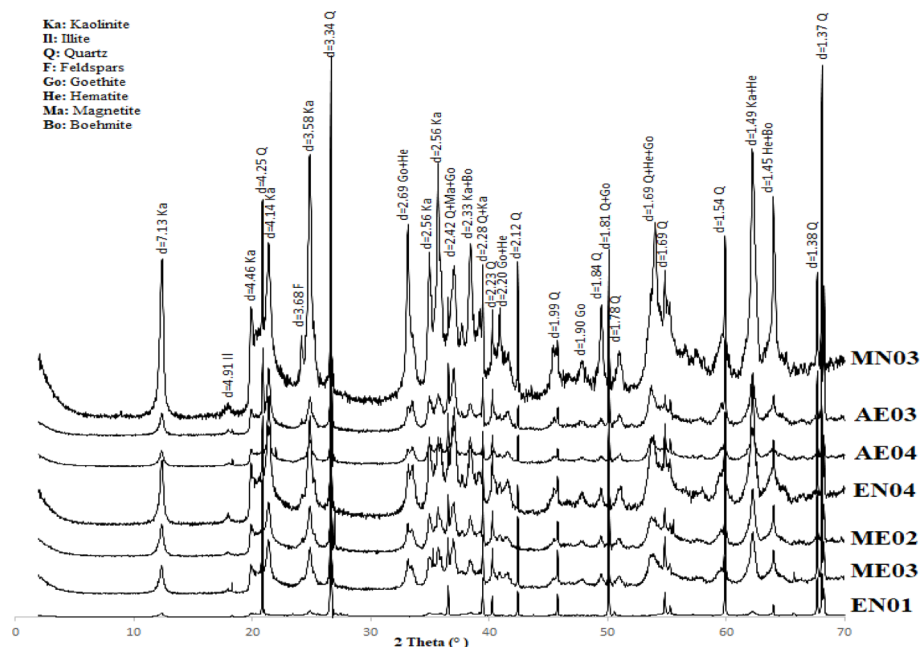
## 5 Results and discussions

### 5.1 Mineralogical and chemical parameters

#### 5.1.1 Mineralogy

The mineralogical characterization of the samples revealed the distinct mineral phases present in the material composition. These crystalline constituents are identified in the X-ray diffraction patterns shown in Fig. 4.

The X-ray diffraction patterns indicate the presence of both clay minerals (dominantly kaolinite and illite) and non-clay mineral phases including quartz, feldspar, goethite, hematite, magnetite, and boehmite. This mineralogical assemblage is characteristic of



**Fig. 4** Diffractogram of the studied soil samples

ferrallitic lateritic formations [15, 48]. Illite occurrence suggests derivation from the local metamorphic basement rocks [49], while the significant kaolinite content enhances the material's workability and plasticity [50]. The observed mineral composition renders these soils particularly suitable for ceramic and earthen brick production. The substantial presence of iron oxides (hematite, goethite, magnetite) and aluminum hydroxides (gibbsite, boehmite) directly results from lateritic weathering processes that concentrate these secondary minerals [15, 48]. Specifically, iron predominantly occurs as goethite ( $\alpha$ -FeOOH) and hematite ( $\text{Fe}_2\text{O}_3$ ), while aluminum manifests primarily as boehmite ( $\gamma$ -AlO(OH)) within the soil matrix.

### 5.1.2 Chemical composition

Table 1 contains the results of the geochemical tests

X-ray fluorescence spectrometry quantifies the oxide composition, revealing  $\text{Fe}_2\text{O}_3$  concentrations (23.63–30.48 wt%) that corroborate hematite prevalence across all lithological samples. The coupled  $\text{Al}_2\text{O}_3/\text{SiO}_2$  ranges (31.18–40.63 wt% respectively) reflect the characteristic kaolinite-muscovite-hematite assemblage [15], with the elevated alumina-silica ratio (0.77–1.30) confirming both the material's refractory potential and kaolinitic dominance. Trace element analysis shows  $\text{Na}_2\text{O}$  (0.1–0.14 wt%) and  $\text{K}_2\text{O}$  (0.15–0.33 wt%) concentrations below the threshold for smectite ( $\text{Na}_2\text{O} > 0.5$  wt%) and illite ( $\text{K}_2\text{O} > 1.0$  wt%) formation, effectively excluding montmorillonite in Mevae and Akak-Essatolo lithologies and demonstrating negligible illite crystallinity. These geochemical signatures collectively validate the XRD mineralogical interpretation while constraining the phyllosilicate population to kaolinite-group minerals.

## 5.2 Physical parameters

### 5.2.1 Natural water content

The measured water contents, presented in Table 1, range from 12.25% to 25.02% across all samples. These elevated moisture levels can be attributed to both seasonal influences and mineralogical composition: (1) sampling occurred during April's peak rainfall period, and (2) the predominance of kaolinitic clays in the soil matrix enhances water retention capacity [51]. This dual mechanism is particularly evident in the Mebae-Ndong and Akak-Essatolo specimens, which exhibited the highest moisture values.

### 5.2.2 Specific gravity

The specific gravity measurements presented in Table 1 demonstrate limited spatial variation, ranging from 1.92 to 2.38 across all sampling sites, with Mebae-Ndong specimens exhibiting the lowest values. These results align with typical lateritic soil characteristics (2.5–3.6) as documented by Bohi [13] for Ivorian laterites. Maignian [52] attributes such density variations to compositional differences, where lower values correlate with alumina enrichment while higher densities reflect iron oxide predominance. Notably, the measured specific gravities approximate that of quartz (2.6), corroborating the X-ray diffraction and chemical analyses that identify quartz as the dominant mineral phase in these materials.



### 5.2.3 Organic matter

Table 1 summarizes the organic matter content of stabilized samples, demonstrating a consistent range of 3.12–4.99% throughout the study area. These values reflect the characteristic organic composition of the region's lateritic soils. Organic matter concentrations typically vary between 3% and 4%. The standard XP P 94 – 047 [44] defines weakly organic soils as those with organic matter levels ranging from 2 to 6%. The presence of organic materials in soils, in variable degrees, can impede the earth brick manufacturing process. Indeed, Elevated organic content may induce progressive material degradation through corrosion and softening mechanisms, potentially compromising the stabilization efficacy [53].

### 5.2.4 Atterberg limits

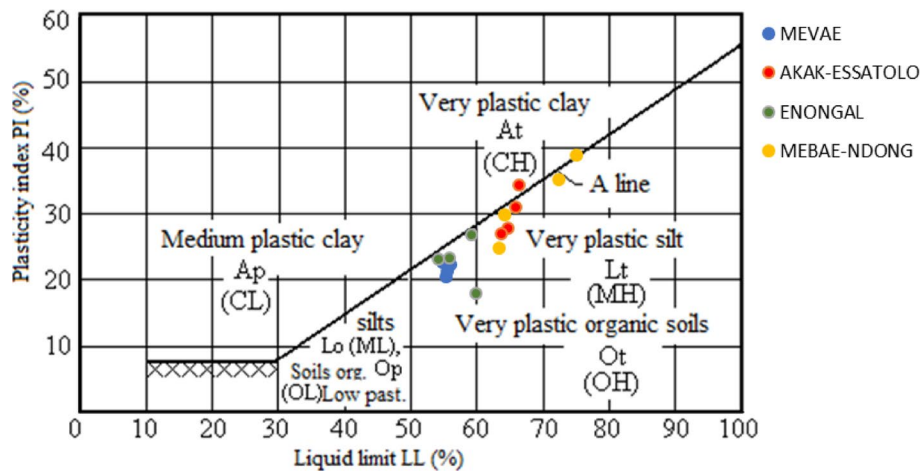
The results of these tests enabled the establishment of the plasticity parameters that govern the consistency state of the analyzed lateritic soils. The standardized testing protocol enabled quantitative determination of key consistency limits, including (1) liquid limit (WL), (2) plastic limit (WP), and (3) derived plasticity index (PI), with complete results presented in Table 1. The samples collected from the four sites demonstrate a wide range of variability. The maximum value of liquidity limitations is 74.7%, while the average value is 61.41. On the other hand, the plasticity limits provide a maximum of 41.6% and an average of 34.65%. The plasticity indices show a maximum value of 39.1%. These measured values are significantly higher than the optimal values advised by Morel [54] for CEB buildings (WL 54 to 72.1, WP 30.7 to 41.6, PI 18.1 to 39.1). Mebae-Ndong has the greatest plasticity indices on the site, followed by Akak-Essatolo, Enongal, and Mevae. The results of this research are projected and reviewed using Casagrande's plasticity chart (Fig. 5).

The plasticity characteristics diagram indicates that the investigated soils predominantly classify as highly plastic silts and organic clays. Such material properties preclude their direct use in compressed earth brick production meeting NC 102–115 specifications [55]. However, lime amendment has been demonstrated to significantly enhance the geotechnical performance of high-liquid-limit soils [56, 57]. While soils exhibiting plasticity indices (PI)  $\geq 10\%$  present manufacturing challenges, particularly extrusion-induced cracking from variable water content during processing [58, 59], this same plasticity range (15–25% PI) renders them particularly suitable for lime-stabilized compressed earth brick fabrication when properly engineered [60].

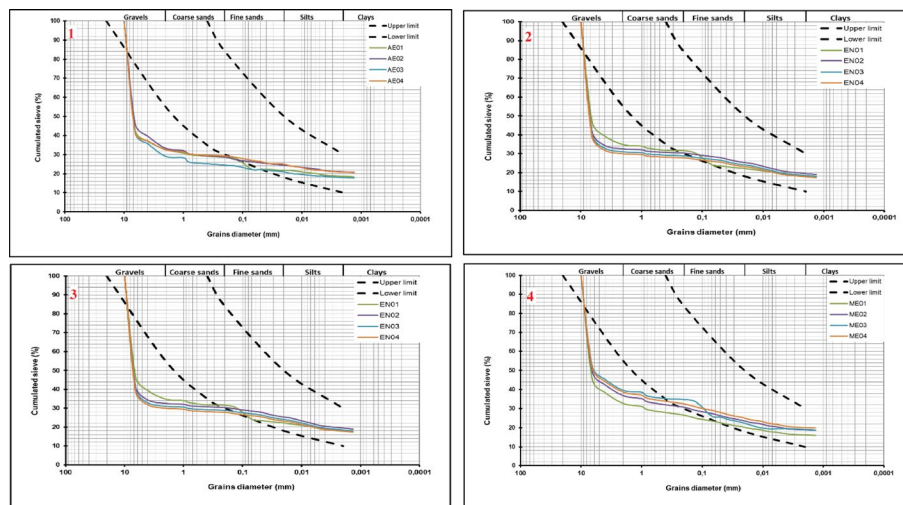
### 5.2.5 Grain size distribution

The granulometric distribution of the investigated material (Akak-Essatolo, Enongal, Mebae-Ndong, and Mevae soils) is presented in Fig. 6, with particle size curves developed following NC-102 standards.

Granulometric analysis of the particle size distribution curves (Fig. 6) indicates the studied soils consist primarily of lateritic gravels, as evidenced by the pronounced slopes in the gravel fraction compared to the relatively flat clay portions, with sample MN02 being the sole exception. These curves reveal significant heterogeneity in particle sizes, with coarse fractions dominating the sieve analysis while fine fractions prevailed in sedimentometry measurements. Such granulometric characteristics directly influence soil plasticity [61] and workability, where elevated clay mineral content can substantially



**Fig. 5** Atterberg limits of the vaiuous samples projected on the Casagrande plasticity chart



**Fig. 6** Grain size distribution of (1) Akak-Essatolo, (2) Enongal, (3) Mebae-Ndong, and (4) Mevae soils

increase water absorption capacity. Furthermore, the particle size distribution critically affects key engineering properties including the mechanical strength and durability of compressed earth bricks [62].

As shown in Table 1, the grading curves of the four soil samples fall outside the normative envelope for stabilized earth block production [55], likely due to the natural variability of lateritic soils in the Ebolowa region. Standard recommendations require clay contents between 8% and 30%, as excessive clay can lead to shrinkage cracking during drying [59] and hinder the kinetics of lime stabilization. The observed clay deficiencies in these soils therefore justify the use of stabilization techniques, such as lime treatment, to enhance their performance in compressed earth brick manufacturing [58].

### 5.2.6 Methylene blue

The methylene blue adsorption test quantified the Soil Blue Value (SBV) for all specimens, revealing values ranging from 0.93 to 1.60 g/100 g (mean = 1.26 g/100 g) as presented in Table 1. These SBV measurements provide critical insight into clay mineralogy,

with the mean value indicating a sandy loam classification according to NF P94-068 standards [63]. This characterization reflects the dominant soil texture throughout the study area. s.

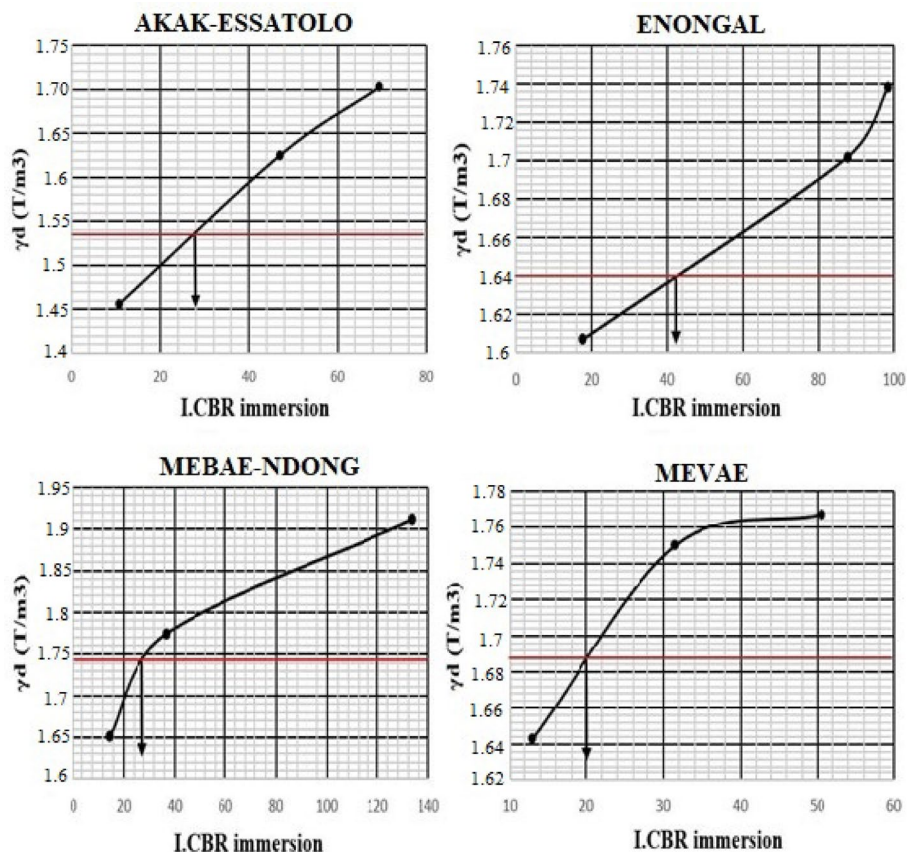
### 5.2.7 Compaction parameters

The results from the modified Proctor test on Akak-Essatolo, Enongal, Mebae-Ndong, and Mevae soil are shown in Table 1 and illustrated in Fig. 7.

The modified Proctor compaction tests revealed optimal dry densities ( $\gamma_d$ ) ranging from 1.62 t/m<sup>3</sup> (Akak-Essatolo) to 1.83 t/m<sup>3</sup> (Mebae-Ndong), with a mean value of 1.73 t/m<sup>3</sup>, while the corresponding optimum moisture contents (W<sub>opm</sub>) varied between 14.5% (Mebae-Ndong) and 20.5% (Akak-Essatolo). Site-specific analysis (Fig. 7) yielded the following compaction characteristics:

- Mevae soils:  $\gamma_d = 1.76$  t/m<sup>3</sup> at W<sub>opm</sub> = 19%.
- Akak-Essatolo soils:  $\gamma_d = 1.62$  t/m<sup>3</sup> at W<sub>opm</sub> = 20.5%.
- Enongal soils:  $\gamma_d = 1.73$  t/m<sup>3</sup> at W<sub>opm</sub> = 16%.
- Mebae-Ndong soils:  $\gamma_d = 1.83$  t/m<sup>3</sup> at W<sub>opm</sub> = 14.5%.

These results align with the recommended range (1.30–1.80 t/m<sup>3</sup>) for compressed earth brick (CEB) production [64]. The W<sub>opm</sub> ensures optimal grain lubrication and particle rearrangement, maximizing density and mechanical strength. Excess moisture fills voids, reducing compressibility, while insufficient moisture hinders compaction efficiency.



**Fig. 7** Modified proctor results of Akak-Essatolo, Enongal, Mebae-Ndong, and Mevae soils

### 5.3 Mechanical parameter

#### 5.3.1 Californian bearing ratio (CBR)

The results of the Californian Bearing Ratio test conducted on of Akak-Essatolo, Enongal, Mebae-Ndong, and Mevae soils are plotted in Fig. 8, and the CBR ( $I_{CBR}$ ) index is recorded in Table 1.

The measured California Bearing Ratio (CBR) values range from 20 to 43 across all samples. Based on the bearing capacity classification system [65], these average CBR values confirm the soils' suitability for subgrade and base course applications in T1S4 construction projects. Furthermore, CBR testing provides valuable insight into soil gradation characteristics, as lower CBR values typically correlate with finer-grained soil compositions.

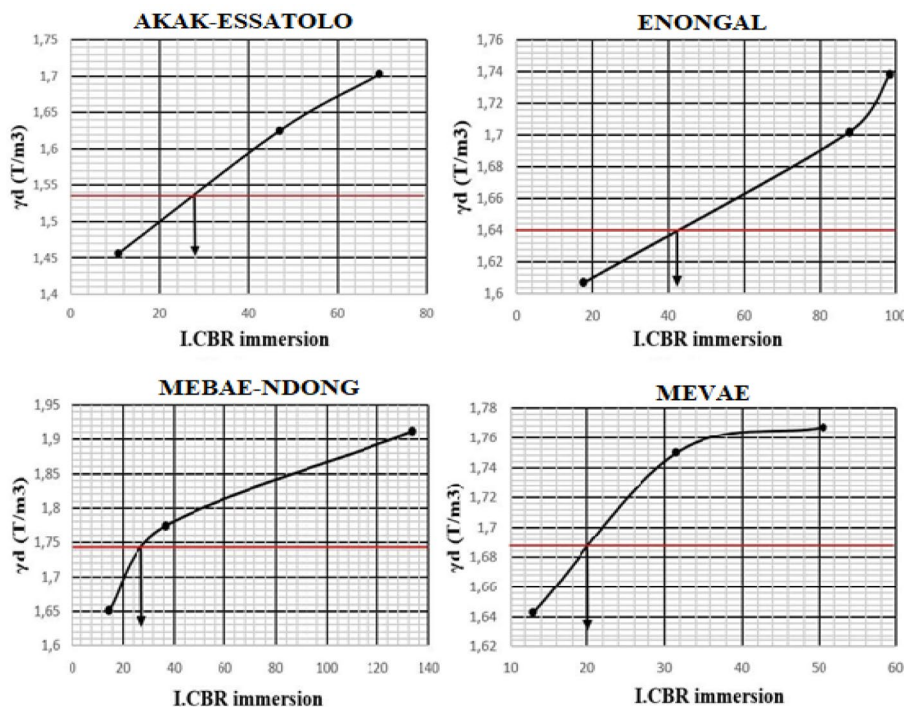
#### 5.3.2 Highway research board classification

Based on the Highway Research Board (HRB) classification system, the combined analysis of particle size distribution and plasticity characteristics enabled comprehensive soil classification. The granulometric test results, when correlated with Atterberg limits data, permitted definitive categorization of the investigated materials according to standard HRB protocols. Thus, based on this classification, the tested soils are clayey and fall into HRB class A-7-5. The group indices calculated for the soils of Mevae, Akak-Essatolo, Enongal, and Mebae-Ndong are 0, 18, 2, and 17.

### 5.4 Properties of compressed earth bricks (CEB)

#### 5.4.1 Physical properties

**5.4.1.1 Water absorption** The water absorption capacity significantly impacts the compressive strength and long-term durability of compressed earth bricks (CEBs), exhibiting

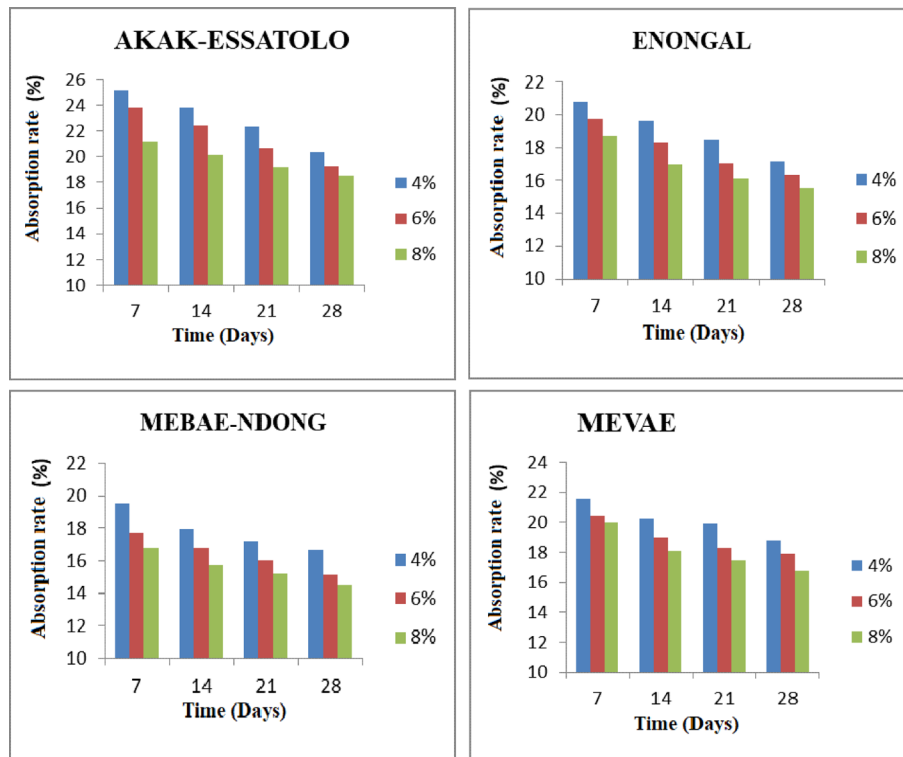


**Fig. 8** CBR results of the studied soils (Akak-Essatolo, Enongal, Mebae-Ndong, and Mevae)

direct correlations with both clay and lime content. Figure 9 presents the water absorption test results, demonstrating these critical material relationships.

The results reveal that as the stabilization rate increases, the absorption rate decreases. At 0%, the specimens fully disintegrate upon immersion. As a result, when the CEB is immersed in water, soil cohesiveness is entirely disrupted. Winterkorn [66] found that stabilization with lime improves the hydric characteristics of CEBs by forming a matrix that binds the particles. Lime will consequently work mostly on the sandy parts. This is why the Akak-Essatolo specimen, which has the sandiest soils in the study area, shows higher absorption rates. Indeed, the NC 102–115 [55] standard specifies absorption rates of less than 15%. The absorption rate obtained by stabilizing the material with lime ranges from 14.45% to 25.54%, and these values tend to decrease over time. The absorption values in stabilized bricks stay extremely close to the limit value specified by the NC 102–115 [55] standard. These results reveal that lime has the effect of increasing the cohesiveness of the material (the samples do not disintegrate by immersion), but does not allow us to acquire suitable results from the point of view of the NC-102 standard in terms of the material's water absorption rates.

**5.4.1.2 Bulk density** Dry density serves as a key indicator of compaction quality, with measured values being directly influenced by compaction energy, material properties, and molding water content. These interdependent factors collectively determine the resulting mechanical performance of stabilized CEBs, as evidenced by the 28-day curing data presented in Table 2.



**Fig. 9** Absorption rate of CEB with lime stabilization

**Table 2** Bulk density results of lime stabilized CEB

Studied site	Lime rate (%)	Bulk density (g/cm <sup>3</sup> )
ME	0%	2.35
AE		2.38
EN		2.40
MN		2.42
ME	4%	2.29
AE		2.32
EN		2.39
MN		2.40
ME	6%	2.25
AE		2.30
EN		2.37
MN		2.38
ME	8%	2.30
AE		2.39
EN		2.39
MN		2.41

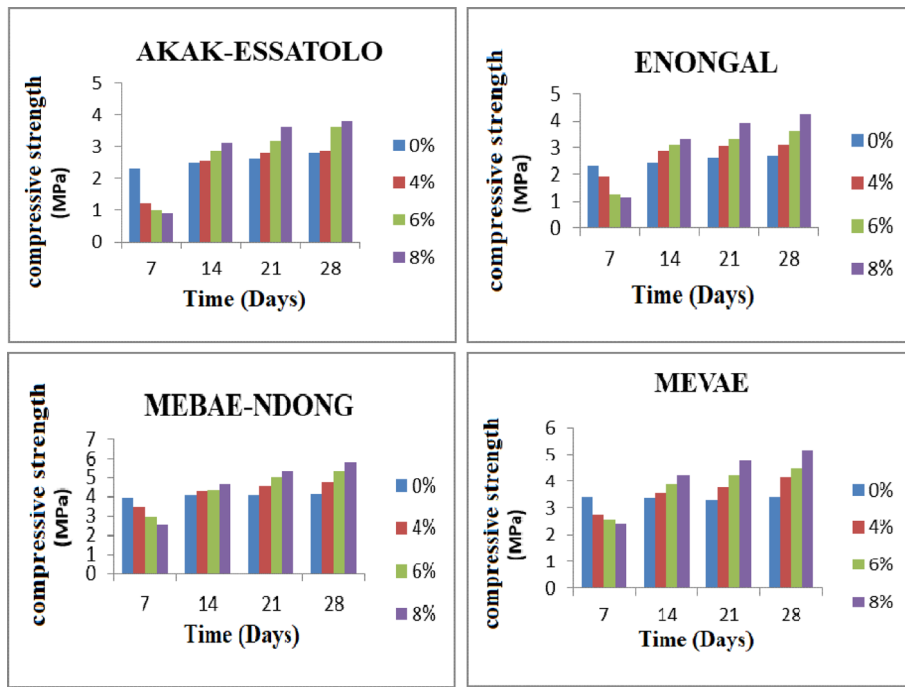
In general, the specimens' bulk densities range between 2.25 and 2.42 g/cm<sup>3</sup>. The values obtained for unstabilized specimens range from 2.35 to 2.42, while lime-stabilized specimens range from 2.25 to 2.41 g/cm<sup>3</sup>. NC 102–115 [55] recommends that compressed earth bricks have a bulk density of 1.5 to 2 g/cm<sup>3</sup>. The samples from the research area are generally above this range, with lime concentrations ranging from 0 to 8%. This implies that the compaction was successful. Furthermore, when the bricks are stabilized with lime, they show a modest rise in bulk densities. This demonstrates that the addition of lime in quantities of 4 to 8% has a densifying impact on the earth-brick specimens.

#### 5.4.2 Mechanical properties

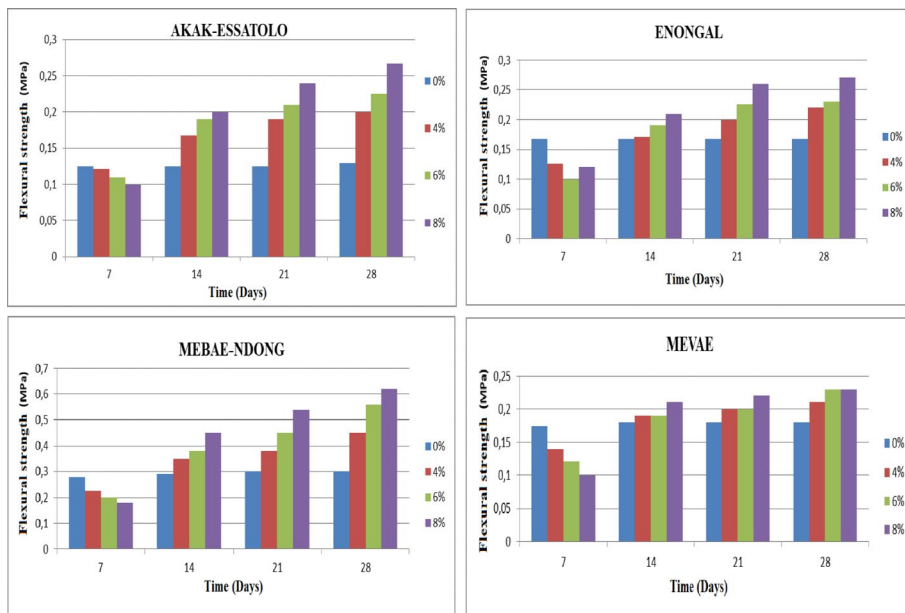
**5.4.2.1 Compressive strength** The results of the compressive strength test performed on the lime stabilized specimens at 7, 14, 21, and 28 curing days are shown in Fig. 10.

The experimental results indicate that unstabilized lateritic bricks meet the NC 102–115 [55] standard requirements for non-stabilized earth bricks, exhibiting compressive strengths above 2 MPa after 14 days of curing. The introduction of lime stabilization significantly improves mechanical performance, demonstrating a clear positive relationship between lime content and compressive strength development. Strength progression over time varies by location, with Mevae specimens increasing from 2.3 MPa at 7 days to 5.1 MPa at 28 days, Akak-Essatolo from 2.3 to 3.8 MPa, Enongal from 2.3 to 4.2 MPa, and Mebae-Ndong showing the highest strength development from 3.93 to 5.81 MPa over the same period. These findings corroborate Morel's [54] research on the strengthening effects of lime in lateritic soils while highlighting significant regional variations in performance, with Mebae-Ndong achieving the highest ultimate strength and Akak-Essatolo the lowest among the tested samples. The time-dependent strength enhancement observed across all sites underscores the importance of adequate curing periods for optimal performance of stabilized earth bricks.

**5.4.2.2 Flexural strength** The results of the flexural strength test carried out on the lime stabilized brick specimens at 7, 14, 21, and 28 days are presented in Fig. 11.



**Fig. 10** Compressive strength of lime stabilized CEBs

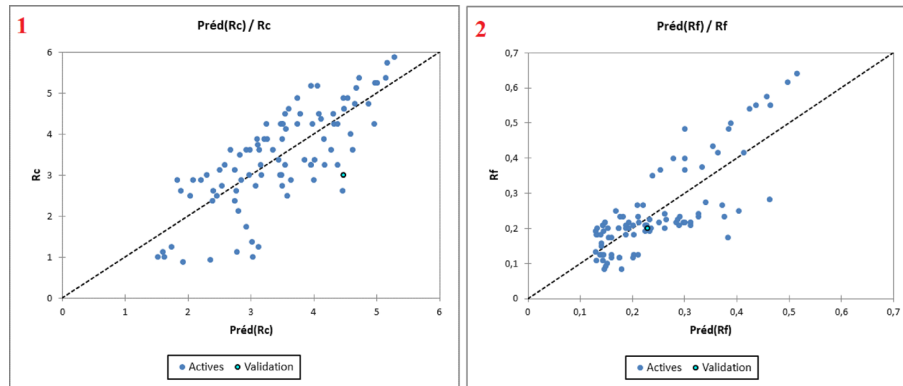


**Fig. 11** Flexural strength of lime stabilized CEB

In general, the flexural and compressive strengths rise as the proportion of lime increases. Flexural strengths vary globally from 0.16 to 0.44 MPa. The changes in the flexural strength of the bricks after 7, 14, 21, and 28 curing days indicate that the flexural strength of each earth brick rises with time. It has also been discovered that the rising proportion of lime included in the earth blocks increases the flexural and compressive strength. The measured values are of the same order of magnitude as those of previous studies conducted by Sajanthan et al. [67] who stabilized the bricks with cement.

**Table 3** Matrice de correlation (Pearson)

Variables	time	stab	Rc	Rf	Abs
Time	1	-0.0176	<b>0.6811</b>	<b>0.5059</b>	<b>-0.4886</b>
Stab	-0.0176	1	0.1565	0.1396	<b>-0.4099</b>
Rc	<b>0.6811</b>	0.1565	1	<b>0.8026</b>	<b>-0.7350</b>
Rf	<b>0.5059</b>	0.1396	<b>0.8026</b>	1	<b>-0.6909</b>
Abs	<b>-0.4886</b>	<b>-0.4099</b>	<b>-0.7350</b>	<b>-0.6909</b>	1



**Fig. 12** Model for predicting (1) Compressive strength, and (2) Flexural strength

**5.4.3 Statistical analysis of the mechanical parameters of CEB**

The correlation matrix (Table 3) indicates strong positive relationships between compressive and flexural strength ( $r=0.8$ ), and moderate positive correlations between curing time and both compressive ( $r=0.68$ ) and flexural strength ( $r=0.50$ ). Significant inverse relationships were observed for water absorption with compressive ( $r=-0.73$ ) and flexural strength ( $r=-0.70$ ). Weaker negative correlations emerged between absorption and curing time ( $r=-0.48$ ), and absorption and lime content ( $r=-0.41$ ). These results demonstrate that while mechanical strength parameters show positive covariation with curing time, they exhibit inverse proportionality with water absorption characteristics.

The parameters of CEB were subjected to linear and nonlinear regression modeling, and the models developed are as follows:

- The first model is a non-linear modeling of the compressive strength as a function of the lime content and water absorption: The mathematical model is expressed by the following equation with its corresponding coefficients and presented in Fig. 12.

$$Rc = 19.67104 - 0.41889 * stab - 1.13182 * Abs + 0.02226 * stab^2 + 0.01863 * Abs^2$$

$$R^2 = 0.6$$

The model demonstrates strong predictive capability, as evidenced by the close agreement between laboratory-measured values and model predictions. This correlation is quantitatively confirmed by the coefficient of determination ( $R^2$ ), while residual analysis reveals an average deviation of 0.6 between observed and predicted values, indicating good model accuracy.

- The second model is a non-linear modeling of the flexural strength as a function of water absorption. The mathematical model is expressed by the following equation with its corresponding coefficients and presented in Fig. 12.

$$Rf = 3.31362 - 0.28720 * Abs + 0.00648 * Abs^2$$

$$R^2 = 0.63$$

The second model demonstrates good predictive performance, with close alignment between experimental measurements and model outputs. This reliability is quantitatively validated by the model's coefficient of determination ( $R^2$ ). Furthermore, residual analysis reveals an average absolute deviation of 0.63 between observed and predicted values, confirming the model's robust predictive capability.

## 6 Conclusion

This study systematically evaluated the construction potential of soils from Ebolowa in Cameroon's South Region. Sixteen representative soil samples were collected across the study area for comprehensive geotechnical characterization. Physico-mechanical and chemical-mineralogical tests were performed on these samples, followed by soil classification. Moreover, the clay bricks were characterized using prepared test pieces. The physical test findings suggest that these soils are mainly lateritic gravels. The results also revealed that these soils are made of very plastic silty soils and very plastic organic soils in proportions that prohibited them from being used for earthen construction in their natural states. The addition of a certain proportion of lime (0 to 8%) in the formulation of the compressed earth bricks allowed us to overcome the plasticity problems of the studied soils. The mineralogical and chemical compositions of these soils include clay minerals represented by Kaolinite and illite and non-clay minerals, mainly quartz, feldspar, goethite, hematite, magnetite, and boehmite. Classification according to the Highway Research Board (HRB) system identifies the investigated soils as clayey materials falling under subgroup A-7-5. Compressed earth brick specimens exhibited mechanical properties compliant with NC 102–115 standards. The compressive and flexural strength of earth bricks correlates well with the lime rate and absorption. These relationships enable reliable prediction of compressive strength based on absorption rates and lime stabilization percentages within the study region.

Beyond these findings, the study contributes to the broader discourse on sustainable construction by promoting the use of locally available materials to reduce environmental impact and construction costs. However, the scope of the investigation was limited to a specific geographic region and stabilization agent. Future research should explore alternative eco-friendly stabilizers, long-term durability under varying climatic conditions, and the integration of recycled materials. Expanding the modeling framework to include machine learning techniques and larger datasets could further enhance predictive accuracy and support scalable applications in low-cost housing initiatives across sub-Saharan Africa.

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### Author contributions

Soumayah Bachirou: Conceptualization, Methodology, Investigation, Writing - original draft. Mouafo Fotsing Ivan Emmanuel: Validation, Writing - review & editing, Visualization, Writing - original draft. Mache Jacques Richard: Methodology, Writing review & editing, Writing - original draft. Taypondou Darman Japhet: Methodology, Investigation, review & editing, Writing - original draft. Molo Rodrigue Athanase: Methodology, Investigation, Methodology, Resources, Writing - original draft. Tchedele Langollo Yannick: Conceptualization, Supervision, Methodology, Writing - review & editing, Visualization, Writing - original draft. Mambou Ngeuyep Luc Leroy: Supervision, Methodology, Resources, Writing - original draft. Mohammad I. AlBiajawi: Writing – Editing, Reviewing.

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**Data availability**

All data generated or analyzed during this study are included in this article.

**Code availability**

Not applicable.

**Declarations****Ethics approval and consent to participate**

This is an observational study that did not involve human participants or biological materials, thus, not requiring ethical approval of the Research Ethics Committee of the authors' institution.

**Consent for publication**

Not applicable.

**Competing interests**

The authors declare no competing interests.

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