Journal of Civil, Construction and Environmental Engineering
2025, Vol. 10, No. 6, pp. 216-229
https://doi.org/10.11648/j.jccee.20251006.12

Research Article

Mechanical Behaviour and Sound Intensity Characteristics of Compressed Earth Blocks Reinforced with Powdered Pozzolan and Cocoa Pod Husk Ash

Penka Jules Bertrand[1,*], **Ndjanfang Desire**[2], **Wetka Tchoupe Ulrich Parfait Lelong**[1]

[1]Department of Civil Engineering and Architecture, National Higher Polytechnic Institute of The University of Bamenda, Bambili, Cameroon

[2]Department of Mechanical and Industrial Engineering, National Higher Polytechnic Institute of The University of Bamenda, Bambili, Cameroon

Abstract

The construction industry in developing countries increasingly seeks sustainable, low-cost, and acoustically efficient building materials. Compressed Earth Blocks (CEBs) are widely recognized as an environmentally friendly alternative; however, their limited mechanical strength and poor sound insulation restrict broader adoption. This study explores the potential of enhancing CEB performance through natural stabilizers that is powdered pozzolan and cocoa pod husk ash (CPHA). The research aimed to address two critical questions: (i) how the combined use of these additives influences the mechanical behaviour of CEBs, and (ii) whether they can improve acoustic insulation properties. Experimental CEB samples were prepared with varying proportions of pozzolan (0-20%) and CPHA (0-10%). Mechanical tests, including compressive and flexural strength, were conducted, alongside assessments of acoustic performance. The results demonstrated that incorporating 10% pozzolan with 10% CPHA significantly enhanced compressive strength and ductility, achieving 0.215 MPa compared to 0.121 MPa for the control. Flexural strength improved markedly in blocks containing 20% pozzolan and 10% CPHA, reaching 0.156 MPa, more than double the control value. Acoustic evaluation revealed that blocks with 5% pozzolan and 10% CPHA reduced sound transmission by over 16 dB relative to the control, highlighting their potential in improving indoor comfort. Overall, the findings confirm that the synergistic use of pozzolan and CPHA not only mitigates the mechanical shortcomings of traditional CEBs but also provides significant acoustic benefits. This study contributes to the knowledge base on sustainable construction materials and demonstrates a practical pathway for developing eco-friendly, affordable, and higher-performing housing solutions in resource-constrained contexts.

Keywords

Compressed Earth Blocks, Pozzolan, Cocoa Pod Husk Ash, Mechanical Behaviour, Sound Intensity

[*]Corresponding author: penkajules@gmail.com (Penka Jules Bertrand)

Received: 23 September 2025; **Accepted:** 4 October 2025; **Published:** 12 November 2025

Copyright: © The Author(s), 2025. Published by Science Publishing Group. This is an **Open Access** article, distributed under the terms of the Creative Commons Attribution 4.0 License (http://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution and reproduction in any medium, provided the original work is properly cited.

1. Introduction

Compressed Earth Blocks (CEBs) are increasingly regarded as sustainable alternatives to conventional brick and concrete construction materials, particularly in regions with abundant soil resources. Their production requires significantly less energy compared to fired bricks and cement-based products, resulting in lower carbon emissions and reduced environmental impact [1]. However, a persistent challenge lies in their relatively low mechanical strength and poor durability, which limit their widespread application in modern housing.

To address these limitations, researchers have explored the use of natural pozzolans and agricultural by-products as stabilizers. Natural pozzolans, such as volcanic ash, have been shown to significantly enhance compressive strength, durability, and water resistance of stabilised earth blocks, provided that the pozzolanic reactions are effectively activated [2]. Parallel studies on agricultural residues have highlighted their potential in sustainable construction. Cocoa Pod Husk Ash (CPHA), for instance, has been investigated as a stabilizer for weak lateritic soils, where improvements in liquid limit and particle size distribution were reported, though its effect on bearing capacity was less pronounced [3]. These findings suggest that CPHA may contribute useful binding properties but requires further evaluation in masonry applications.

While extensive research has examined the mechanical and thermal performance of CEBs stabilized with pozzolanic materials [4], little attention has been paid to their acoustic behavior, particularly sound transmission loss (STL). This represents a critical gap, as indoor acoustic comfort is an important yet often overlooked aspect of sustainable housing.

The present study therefore investigates the combined use of powdered pozzolan and CPHA as natural stabilizers in CEBs. Specifically, it examines their effects on compressive and flexural strength as well as sound transmission characteristics. By integrating mechanical and acoustic assessments, the study seeks to provide a more holistic understanding of how these eco-friendly additives can enhance the performance of CEBs for sustainable and affordable housing.

2. Materials and Methods

2.1. Sampling

The soil sample used for block production was lateritic soil collected from mile5 Nkwen, Bamenda III of the Northwest Region of Cameroon. Preliminary laboratory tests confirmed its suitability for CEB production, based on its granular composition, plasticity index, and compaction characteristics. During sampling, the organic part of the soil was removed by digging 1m deep to expose the sub-soil. A large quantity of the sub-soil samples were then collected and air dried. The soil was homogenized by removing coarse fragments and sieved using a 5 mm mesh sieve. A spade was used to collect sample into a bag as seen in figure 1 and then transported to the laboratory. The pozzolan was gotten from Foumbot, Noun division, West Region of Cameroon. The pozzolan was collected with a spade and 10 litres bucket and put in a bag as seein in figure 2. It was grinned and sieved through a 1mm sieve to enhance reactivity. The pozzolan served as a partial cementitious stabilizer to improve strength and durability through pozzolanic reactions and Cocoa pod husk was gotten from Foumbot, Noun division, West region of Cameroon. After collection it was air dried as seen in Figure 3, burnt under controlled temperatures and transported to the laboratory where it was calcined at a temperature of 750°C in an electric furnace (brand: Enitherm) for 24 hours as seen in figure 4 and grinned to fine powder passing through a 250µm sieve.

Portable tap water was used for mixing. It met the physical and chemical requirements for use in cementitious materials as specified by ASTM C1602.

Figure 1. *Soil sample.*

Figure 2. *Sample of pozzolan.*

Figure 3. *Air drying CPH.*

Figure 4. *Calcination of CPHA.*

Figure 5. *Molding and compaction of blocks.*

Table 1. *Formulation table.*

Sample	Soil (%)	Pozzolan (%)	CPHA (%)	Water (%)
F0 (Control)	100	0	0	18
F1	90	5	5	18
F2	80	10	10	18
F3	70	20	10	18

Table 2. *Formulation for tensile strength test.*

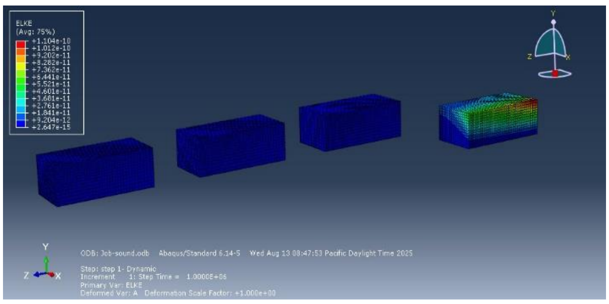
	% T	% P	% C	$M_s(g)$	$M_p(g)$	$M_c(g)$	$M_w(g)$
M_0	100	0	0	571.39	0	0	102.85
M_1	90	5	5	514.25	27.39	38.78	104.48
M_2	80	10	10	457.11	54.78	77.57	106.10

	% T	% P	% C	$M_s(g)$	$M_p(g)$	$M_c(g)$	$M_w(g)$
M_3	70	20	10	399.97	109.57	77.57	105.68

Table 3. Formulation for compressive Strength test.

	% T	% P	% C	$M_s(g)$	$M_p(g)$	$M_c(g)$	$M_w(g)$
F_0	100	0	0	68.68	0	0	12.36
F_1	90	5	5	61.81	3.29	4.66	12.56
F_2	80	10	10	54.94	6.58	9.32	12.75
F_3	70	20	10	48.08	13.17	9.32	12.70

Figure 6. Crushing blocks samples.



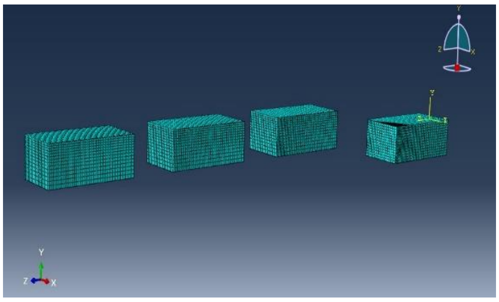


Figure 7. CEB Simulation.

2.2. Methods

2.2.1. Geotechnical Properties

The soil sample used for this study was collected from Mile 5 Nkwen, Bamenda III Subdivision (North West Region of Cameroon). Preliminary characterization included determination of the natural water content and absolute density of the soil, pozzolan, and cocoa pod husk ash (CPHA). Tests were conducted in accordance with the French Standard NF P94 series, commonly applied in geotechnical investigations. Grain size distribution was determined following NF EN 933-1. Atterberg limits were obtained according to NF 94-051, yielding liquid limit (LL), plastic limit (PL), and plasticity index (PI), calculated as:

$$PI = LL - PL \quad (1)$$

These properties provided a baseline understanding of the soil's suitability for stabilization.

2.2.2 Mix Design and Block Preparation

Four formulations of Compressed Earth Blocks (CEBs) were prepared by varying the percentages of pozzolan (0%, 5%, 10%, 20%) and CPHA (0%, 5%, 10%). CPHA was obtained from cocoa pod husks, calcined in an electric furnace at 750 °C for 24 h to eliminate organic impurities, then ground to pass a 75 µm sieve. Soil was air-dried, pulverized, and homogenized with the stabilizers in dry state before adding water to reach the optimum moisture content (OMC) determined from Proctor tests.

The mixtures were compacted into metallic molds of dimensions 160 × 40 × 40 mm using a hydraulic press under a pressure of 4-7 MPa. The specimens were demolded after 24 h and oven-dried at 105 °C for 24 h to ensure uniform moisture removal before testing.

2.2.3 Mechanical Properties

The Modified Proctor Test (NF P 94-093) was performed to determine maximum dry density (MDD) and OMC of the soil. Mechanical testing of stabilized blocks included:

1) Flexural strength test: Conducted in three-point bending according to NF EN 1015-11. A loading rate of 50 N/s was applied until failure.
2) Compressive strength test: Carried out on prism halves obtained from the flexural test, following NF EN 1015-11. A constant loading rate of 2.5 kN/s was applied until crushing.

For each formulation, three replicates were tested and average values reported.

2.2.4. Numerical Acoustic Simulation

To evaluate acoustic performance, a numerical simulation was performed using Abaqus/CAE. A 3D solid model of the CEB specimen was generated. The material properties (Young's modulus, Poisson's ratio, and density) were derived from experimental characterization. A Dynamic Explicit step was defined with a total analysis time of 0.02 s. Boundary conditions were applied such that the bottom face was fully fixed, while vertical faces were laterally restrained to approximate a half-space condition.

A sinusoidal load was applied at frequencies corresponding to 70, 80, 90, and 100 Hz. The soil block was discretized with linear 8-node brick elements (C3D8R), with a global mesh seed size of 0.05 m and local refinement to 0.02 m around stress concentration zones, ensuring 8-10 elements per wavelength.

Simulation outputs included nodal displacements, stress fields, and time-history data, which were exported for post-processing. Sound transmission loss (STL) was estimated by comparing incident and transmitted sound power curves derived from displacement-time responses.

3. Results and Discussions

3.1. Geotechnical Characterization

3.1.1. Natural Moisture Content

The natural moisture content of the soil as shown in table 4 averaged *28.54%*, indicating a high-water retention capacity typical of lateritic clays in humid tropical regions. Similar high values were reported in North-Central Nigeria, where lateritic soils showed water contents above 25%, contributing to weak subgrade performance [5]. In contrast, the pozzolan sample had a significantly lower moisture content of *15%* as shown in Table 5, reflecting its coarser grading and reduced hygroscopicity, a trend consistent with findings that volcanic ash-based stabilizers absorb less moisture, thereby improving dimensional stability [6]. The cocoa pod husk ash (CPHA) exhibited the lowest moisture content of *6.78%*, as shown in Table 6 confirming its relatively dry, organic-ash nature. Comparable results reported CPHA to contain less bound water, making it effective in reducing overall soil moisture sensitivity [3]. These results suggest that while natural soil alone is highly moisture-susceptible, blending with pozzolan or CPHA can lower water retention, thereby improving the engineering behavior of stabilized earth materials.

Table 4. *Natural moisture content results for soil.*

Can Number	U1	U2
Weight of Can (M1)	31.85	28.45
Wet Weight of can + Soil	212.87	206.40
Dry Weight of can + Soil	172.68	166.88
Mass of pore Water (Mw)	40.19	39.52
Mass of soil (Ms)	140.83	138.42
Moisture content (%)	28.53	28.55
Average	28.54%	

Table 5. *Natural moisture content results for pozzolan.*

Water content of pozzolan		
Can Number	**U1**	**U2**
Weight of Can (M1)	30.35	29.45
Wet Weight of can + Soil	38.96	35.05
Dry Weight of can + Soil	37.85	34.31
Mass of pore Water (Mw)	1.11	0.74
Mass of soil (Ms)	7.5	4.86
Moisture content (%)	14.8	15.2
Average water content:		15%

Table 6. Natural moisture content results for CPHA.

Designation	U1	U2
Weight of Can (W1)	30.35	29.45
Weight of can + wet CPHA (W2)	50.35	50.40
Weight of can + dry CPHA (W3)	49.15	48.95
Mass of Water (Mw)	1.2	1.45
Mass of dry CPHA (Ms)	18.8	19.5
Moisture content (%)	6.38	7.18
Average	6.78%	

Table 7. Dry density determination.

Mould Number	09	09	09	09
Total Weight	7200	7560	7900	7820
Weight of Mould	3420	3420	3420	3420
Weight of soil	3780	4140	4480	4400
Volume of Mould	2262	2262	2262	2262
Humid density of soil	1.671	1.830	1.981	1.945
Dry density of soil	1.453	1.560	1.661	1.602

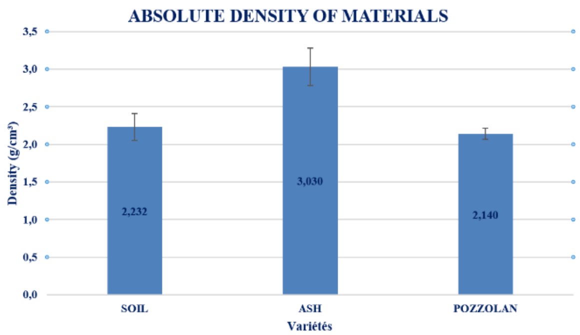


Figure 8. Absolute Density of Materials.

3.1.2. Absolute Density

The results of the absolute densities shown in figure 8 with soils having absolute density of 2.232 g/cm³, which falls within the typical range of lateritic soils (2.2-2.7 g/cm³). Similar findings were reported in Minna, Nigeria, where densities of about 2.3 g/cm³ were observed for lateritic soils [5]. The ash (CPHA) exhibited the highest density at 3.030 g/cm³, which is higher than that of the soil and pozzolan. This value aligns with previous results, which reported CPHA as a dense stabilizing material [3], due to its high silica and alumina content, enhancing compaction properties. The pozzolan showed a lower density of 2.140 g/cm³, which is consistent with volcanic pozzolans typically ranging from 2.1-2.4 g/cm³ [6]. This relatively low density suggests that pozzolan is lighter and less compact than ash, but still beneficial in reducing the overall bulk density of stabilized earth blocks. Collectively, these results confirm that incorporating ash and pozzolan modifies the density of mixtures, potentially improving compaction, strength, and durability of stabilized earth construction materials.

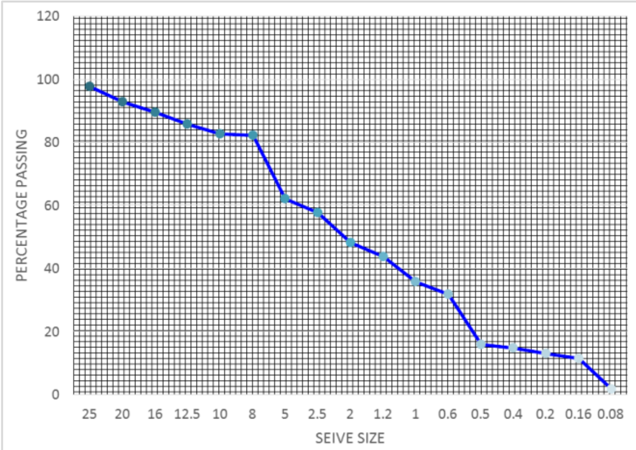


Figure 9. Soil Grain size curve.

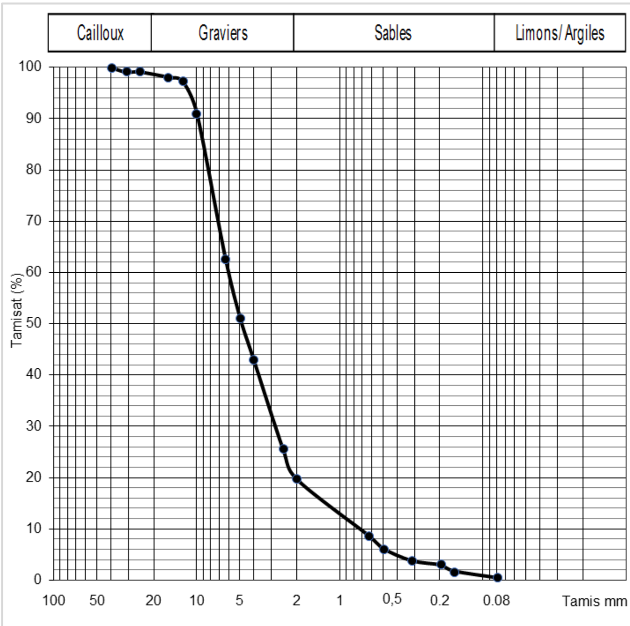


Figure 10. Graph of Grain size analysis of Pozzolan.

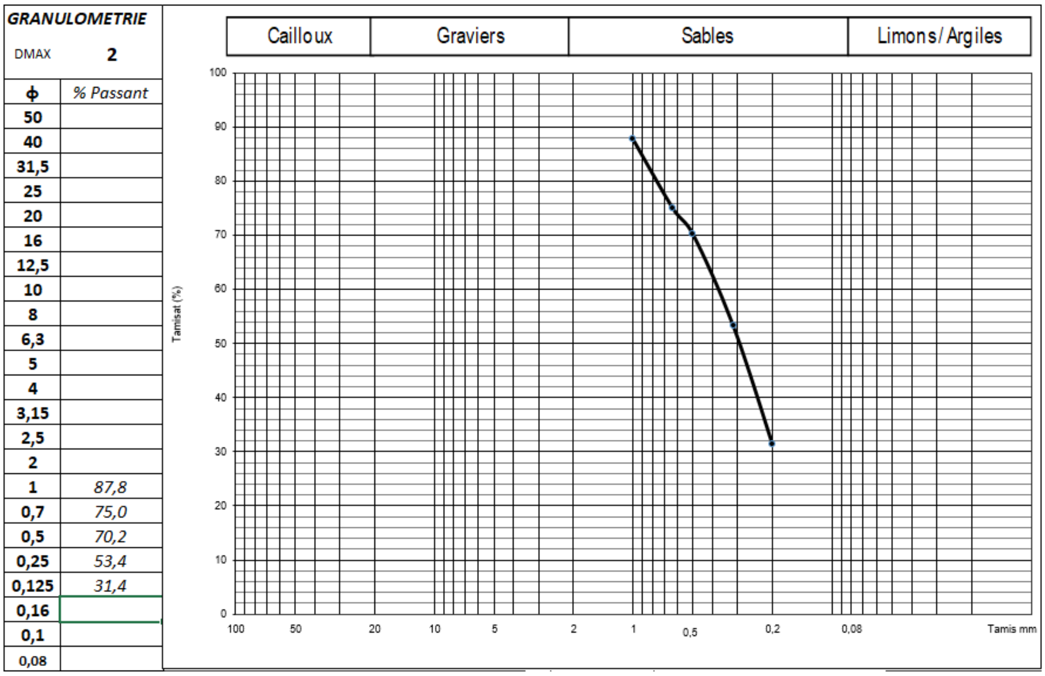


Figure 11. *Graph of grain size analysis of CPHA.*

3.1.3. Grain size Analysis

The grain size analysis results for soil, pozzolan and CPHA are shown in Figures 9, 10 and 11 respectively. The analysis of the grain size distribution indicates that the soil particles are greater in fine category (less than 2 mm). The percentage of gravel in the soil sample was 8.0%, that of sand was 40.1% and that of silt/clay was 51.9%. Based on the AURAM Press 3000, soil containing 15% gravel, 50% sand, 15% silt and 20% clay is considered as having the best soil composition for producing CEBs. The results obtained are similar to that of this standard; therefore, the soil sample was suitable for making CEBs

3.1.4. Modified Proctor Compaction Test

Figure 12 illustrate the results of proctor compaction test on soils sample, The obtained optimum water content of *18.9%* and maximum dry density of *1.668 g/cm³* fall within the typical range for lateritic and clayey soils reported in tropical regions. It has been highlighted that soils compacted wet of optimum exhibit a more dispersed structure, which is weaker and less resistant to volume changes [7]. It was also confirmed that compaction on the dry side of optimum leads to a flocculated structure that increases shear strength and stiffness, in agreement with the present results [8]. Furthermore, OMC values between 15-20% are common for fine-grained soils [9], with MDD values around 1.6-1.8 g/cm³, which closely match the values obtained in Mile 16 soils. Similarly, compaction characteristics are influenced by soil mineralogy and moisture conditions and that wet-of-optimum compaction produces softer, more ductile structures, as observed here [10]

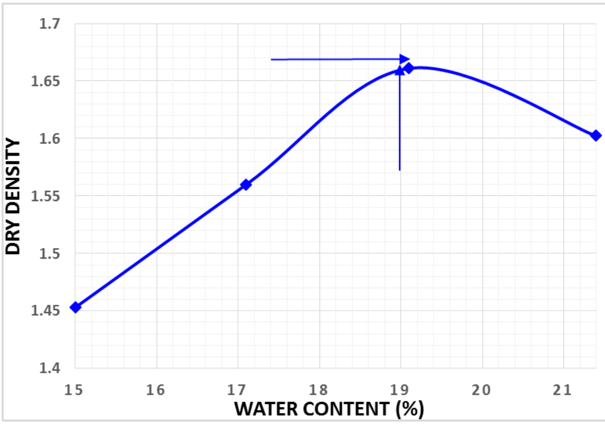


Figure 12*. Proctor curve.*

3.1.5. Atterberg's Limit

Liquid limit shown in Table 8 and plastic limit in Table 9. The results of the Atterberg limits test showed that the soil used in the production of CEB prototypes was classified as clayey soil. The liquid limit (LL) was *73.2%*, and the plastic limit (PL) was *31.0%*, giving a plasticity index (PI) of *42.2%*. This PI value exceeds the maximum threshold stipulated in earlier studies [11], indicating a cohesive soil with very high plasticity, capable of achieving proper compaction to enhance strength and durability. According to the soil classification system based on LL, PI, and sieve No. 200 [12], the sample was placed in the *A-7-5 group*. With LL > 41, PI > 11, and more than 35% passing the No. 200 sieve, the soil is confirmed to be clayey in nature, with sand content significantly greater than gravel.

Table 8. Liquid Limit determination.

Number of blows	16	20	24	28	32
Can Nº	K	Y	A5	F	J1
Total Humid Weight	22.04	24.67	20.83	20.05	19.94
Total Dry Weight	20.31	23.28	19.57	19.08	19.16
Weight of Water	1.73	1.39	1.26	0.97	0.78
Weight of Can	18.03	21.43	17.86	17.75	18.07
Dry Weight of soil	2.28	1.85	1.71	1.33	1.09
Water content (%)	75.9	74.9	73.8	72.7	71.4
LIQUID LIMIT	73.2				

Table 9. Plastic Limit determination.

Can Nº	E1	O
Total Humid Weight	18.57	18.45
Total Dry Weight	18.42	18.29
Weight of Water	0.15	0.16
Weight of Can	17.94	17.78
Dry Weight of soil	0.49	0.51
Water content (%)	30.6	31.4
PLASTIC LIMIT	31.0	

3.2. Mechanical Properties of Blocks Sample

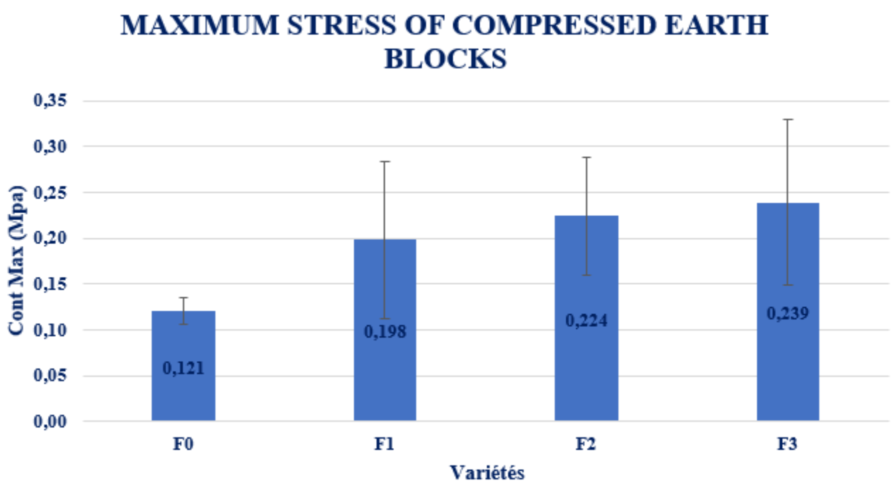


Figure 13. Maximum Stress of Compressed Earth Blocks.

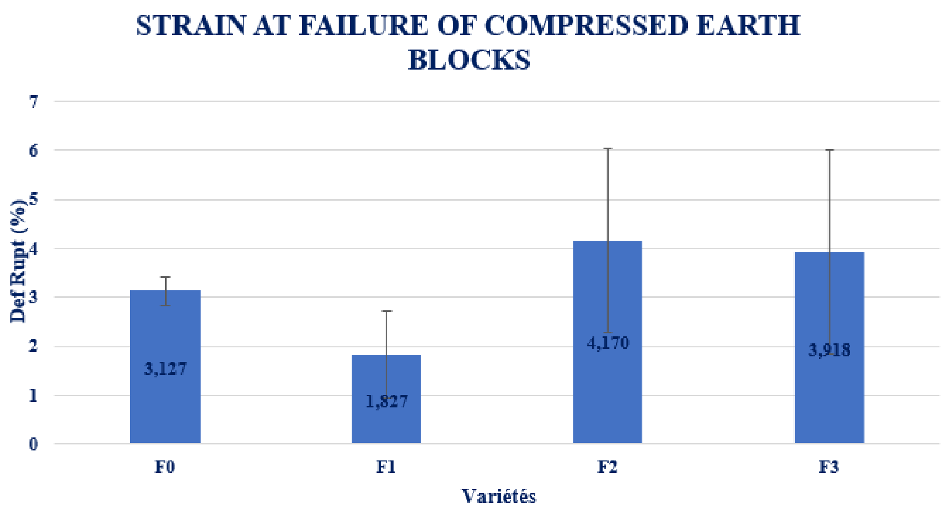
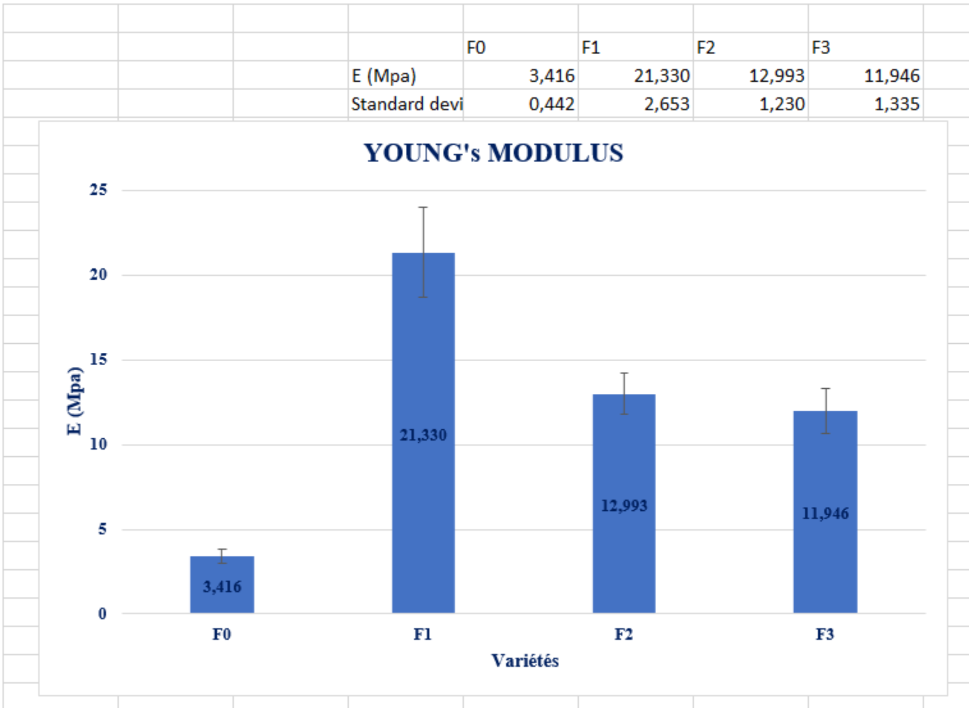


Figure 14. *Strain at Failure of CEBs.*



	F0	F1	F2	F3
E (Mpa)	3,416	21,330	12,993	11,946
Standard devi	0,442	2,653	1,230	1,335

Figure 15. *Young's Modulus of Different Formulations.*

3.2.1. Compressive Strength of Blocks Sample

In Figures 13, 14, and 15, the results for maximum stress, strain at failure, and Young's Modulus of CEBs are presented respectively, showing clear trends influenced by pozzolan and CPHA stabilization. For maximum stress, the control mix F0 (0.121 MPa) was weakest, consistent with earlier findings [13], while the inclusion of stabilizers progressively increased stress capacity, reaching 0.239 MPa in F3, in line with earlier studies [14, 15], though over-stabilization effects were also observed in earlier work [16]. Strain at failure highlighted ductility differences: F0 was highly deformable (3.127%), F1 became more brittle (1.827%), F2 achieved the highest ductility (4.17%), and F3 slightly decreased to 3.918%, reflecting the balance between stiffness and flexibility [17-19]. For Young's Modulus, F0 recorded the lowest stiffness (3.416 MPa), while F1 peaked at 21.33 MPa due to strong pozzolanic bonding, Consistent findings have been reported in previous studies [14, 15]. Intermediate values for F2 (12.993 MPa) and F3 (11.946 MPa) indicated that optimal stabilization (10% pozzolan + 10% CPHA) balanced rigidity and ductility, aligning with findings reported in Donkor et al [20], while excess stabilizer reduced stiffness, confirming the warnings of prior studies [16]. Overall, the results demonstrate that moderate incorporation of pozzolan and CPHA enhances the mechanical integrity of CEBs, confirming their suitability for sustainable construction when carefully optimized.

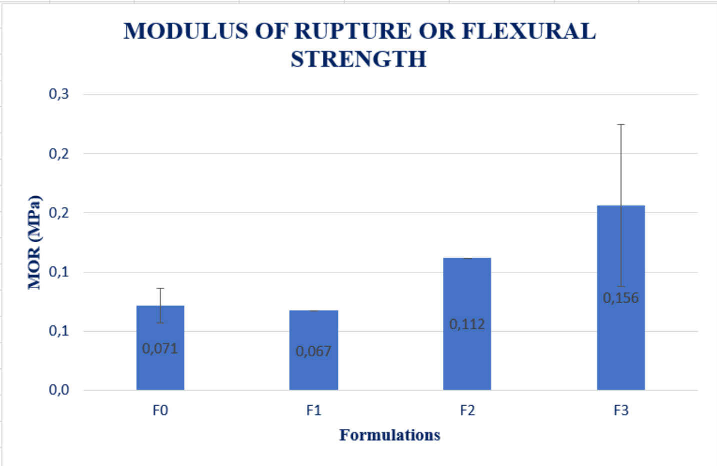


Figure 16. Flexural strength graph for different formulations.

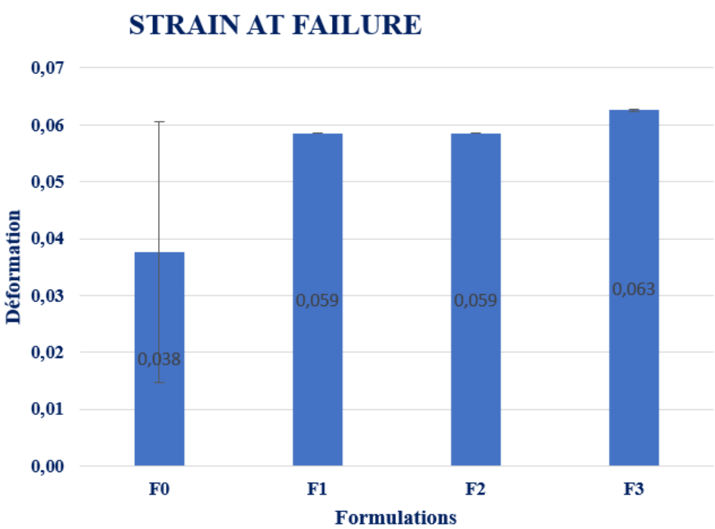


Figure 17. Strain At Failure.

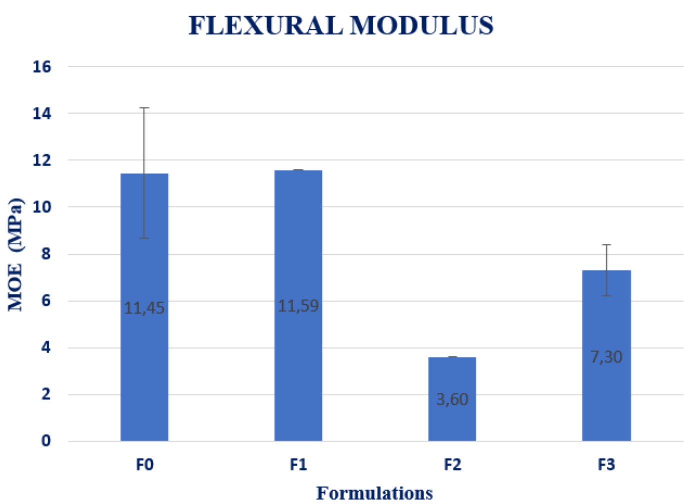


Figure 18. Flexural Modulus.

3.2.2. Blocks Flexural Strength

In Figures 16, 17, and 18, the flexural strength, strain at failure, and flexural modulus of elasticity of the CEB formulations are presented, highlighting the effects of pozzolan and CPHA stabilization. The flexural strength results showed that the control mix F0 had the lowest MOR (0.071 MPa), consistent with earlier findings [14], while F1 with 5% stabilizers offered negligible improvement, as also reported in previous work [16]. Significant enhancement occurred in F2 (0.112 MPa), attributed to optimal pozzolanic reactions, in agreement with findings [21], whereas F3 achieved the highest MOR (0.156 MPa), consistent with previous studies [20], though previous works [19] cautioned against excessive stabilizer additions that could induce brittleness. Strain at failure trends (reported earlier) confirmed that F2 best balanced ductility and strength, which corroborates earlier findings [18], while F3 showed slightly reduced ductility due to higher stiffness. Flexural modulus results further indicated that F0 and F1 were the stiffest (11.45-11.59 MPa), in alignment with previous findings [22], who observed limited benefits from low stabilizer content. By contrast, F2 recorded the lowest MOE (3.60 MPa), demonstrating improved ductility as highlighted in previous works [18], while F3 (7.30 MPa) provided a compromise between stiffness and flexibility, consistent with earlier findings [23]. Overall, these findings confirm that optimal stabilization (F2) provides the most favorable balance of strength, stiffness, and ductility, making it the most efficient formulation for structural applications in sustainable construction.

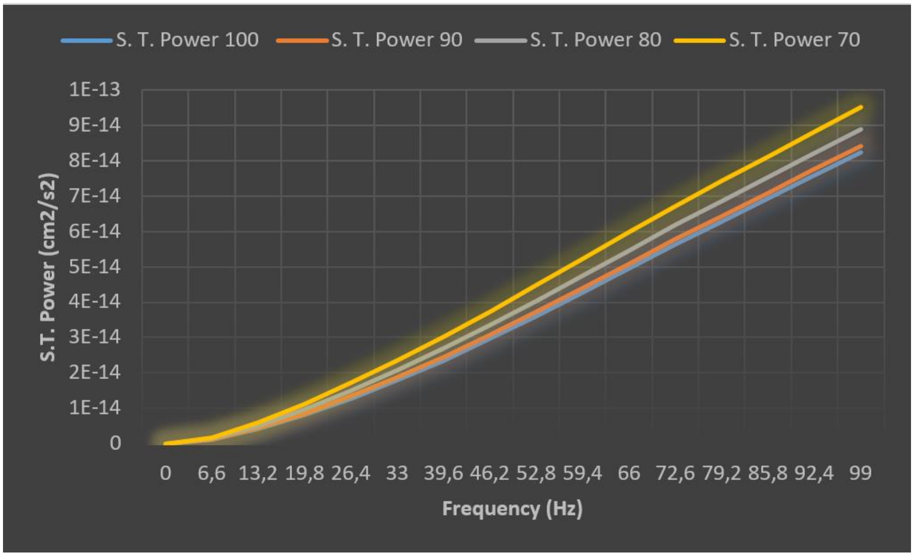


Figure 19. Curve of Sound Transmission Power Vs Frequency.

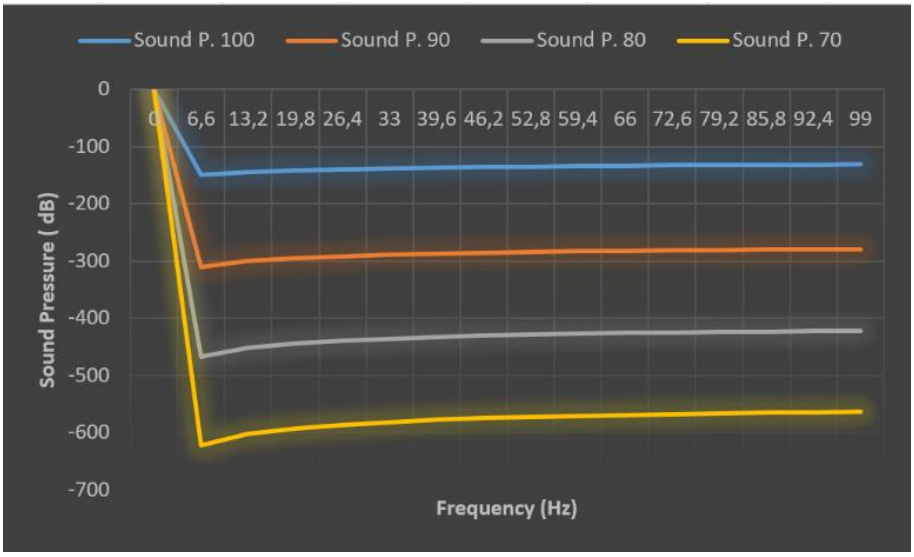


Figure 20. Curve of Sound Pressure Vs Frequency.

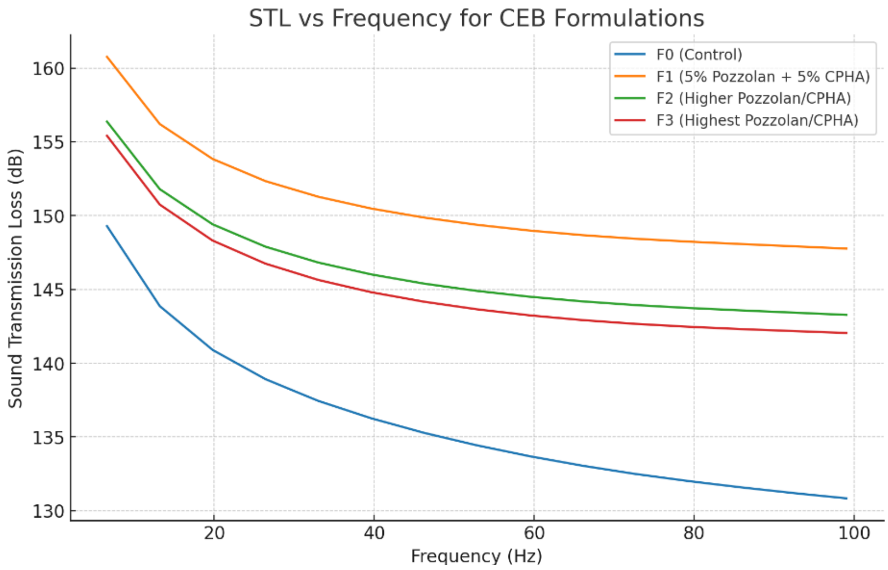


Figure 21. *Sound Transmission Loss Vs Frequency Curve.*

3.3. Acoustic Simulation in Abaqus

The results presented in Figures 19, 20 and 21 demonstrate the sound intensity characteristics of compressed earth blocks (CEBs) reinforced with powdered pozzolan and cocoa pod husk ash (CPHA). From the trend, it is evident that sound transmission loss (STL) increases significantly with the addition of pozzolan and CPHA, particularly in formulation F1 (5% Pozzolan + 5% CPHA), which consistently outperformed the control (F0) across all frequency ranges.

For the *control sample (F0)*, STL values were the lowest, with sound pressure levels ranging between -149.3 dB and -130.8 dB over the tested frequency range (6.6-99 Hz). In contrast, the *F1 formulation* demonstrated superior acoustic resistance, with sound pressure levels between -160.7 dB and -147.8 dB. Formulations *F2* and *F3* also showed improved STL compared to the control but slightly lower than F1, suggesting that an optimal combination of pozzolan and CPHA enhances acoustic properties more effectively than higher dosages. This could be attributed to microstructural densification and pore refinement, which limit wave propagation and energy transfer through the blocks. These findings align with earlier studies reporting that *agro-waste ashes and pozzolanic additives improve both density and microstructural compactness of CEBs, thereby enhancing sound insulation*. For instance, supplementary cementitious materials have been shown to reduce porosity and improve acoustic resistance [24]. Similarly, organic agricultural residues such as husks and shells have been reported to enhance acoustic resistance [19]. Moreover, the observed trend where F1 outperformed F2 and F3 suggests that *excessive replacement with pozzolanic ash may create weak bonding zones or microcracks*, reducing acoustic efficiency. This is consistent with findings that higher replacement levels of pozzolanic materials sometimes compromise compaction [25], thereby affecting mechanical and acoustic behaviour. The results also corroborate studies highlighting that the mechanical integrity of CEBs directly correlates with acoustic attenuation [26], since denser and stronger matrices impede vibrational energy transfer more effectively. In this case, F1 provided an optimal balance between strength gain and acoustic absorption. In practical terms, these findings suggest that *CEBs reinforced with moderate proportions of pozzolan and CPHA could be utilized in low-cost sustainable housing to improve indoor acoustic comfort*, particularly in noisy urban environments. This application is in line with global trends promoting eco-friendly building materials that address both environmental and functional performance requirements [21].

4. Conclusion

This study investigated the geotechnical, mechanical, and acoustic behaviour of compressed earth blocks (CEBs) reinforced with powdered pozzolan and cocoa pod husk ash (CPHA). The geotechnical characterization revealed that the natural soil exhibited high moisture content (28.54%) and plasticity (PI = 42.2%), which could adversely affect durability if unstabilized. In contrast, pozzolan and CPHA demonstrated lower moisture contents and higher densities, confirming their potential as effective stabilizers. These findings are consistent with earlier reports on the beneficial role of volcanic pozzolans and agro-waste ashes in reducing soil moisture sensitivity and improving compaction characteristics.

The mechanical performance of stabilized CEBs showed significant improvements compared to the control. Compressive and flexural strength results demonstrated that stabilization enhanced both strength and stiffness, with optimal performance recorded for formulations incorporating balanced proportions of pozzolan and CPHA. Excessive stabilization, however, led to reduced ductility and marginal decreases in modulus, highlighting the importance of dosage optimization. These trends corroborate past research emphasizing that moderate incorporation of supplementary cementitious materials enhances the structural integrity of earth blocks, while over-stabilization may induce brittleness.

Acoustic simulations further demonstrated that stabilization substantially improved the sound transmission loss (STL) of CEBs. Among the formulations, F1 (5% Pozzolan + 5% CPHA) consistently exhibited the highest acoustic resistance, outperforming both the control and higher replacement levels. This behaviour was attributed to pore refinement and matrix densification, which effectively hinder wave propagation. These results agree with prior studies confirming that improved density and microstructural compactness enhance acoustic attenuation in stabilized earthen materials.

Overall, the findings confirm that *the combined use of pozzolan and CPHA provides a sustainable and technically viable approach to improving the durability, mechanical integrity, and acoustic comfort of CEBs*. The optimal formulation (F1) achieved the best balance of strength, stiffness, and acoustic performance, underscoring the potential of these locally available materials in sustainable and affordable housing. Future work should focus on long-term durability assessments under varying environmental conditions and life-cycle performance evaluation to further support large-scale adoption.

Declaration of generative AI and AI-assisted technologies in the manuscript preparation process

During the preparation of this work the author(s) used chat gpt in order to correct the English and better organize the results and discussions. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the published article.

Abbreviations

PI	Plasticity index
LL	Liquid limit
PL	Plastic Limit
STL	Sound Transmission Loss
CEBs	Compressed Earth Blocks (CEBs
CPHA	Pozzolan and Cocoa Pod Husk Ash
OMC	Optimum Moisture Content
MDD	Maximum Dry Density

Acknowledgments

The Authors acknowledge the laboratory staff of CER BTP Bafoussam Cameroon.

Author Contributions

Penka Jules Bertrand: Conceptualization, Data curation, Funding acquisition, Methodology, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing

Désiré Ndjanfang: Methodology, Software, Validation, Writing – original draft, Writing – review & editing

Wetka Tchoupe Ulrich Parfait Lelong: Formal Analysis, Methodology, Software, Visualization, Writing – original draft, Writing – review & editing

Funding

This research was self-sponsored.

Conflicts of Interest

The authors declare that no conflict of interest exist regarding the publication of this article.

References

[1] Adamah, M., Messan; Courard, L.; Nshimiyimana, P. (2022). *Calcium Carbide Residue and Rice Husk Ash for improving the Compressive Strength of Compressed Earth Blocks*. MRS Advances, Cambridge Core. https://www.cambridge.org/core/journals/mrs-advances/article/calcium-carbide-residue-and-rice-husk-ash-for-improving-the-compressive-strength-of-compressed-earth-blocks/F537392232964450A87645E7C584A0E2?utm_source=chatgpt.com

[2] Stabilization of Laterite Soil with Pozzolan-Calcium hydroxide Binders for Construction of Low Volume Roads in Mbeya Tanzania. (2023). American Scientific Research Journal for Engineering, Technology, and Sciences. https://asrjetsjournal.org/index.php/American_Scientific_Journal/article/view/11174?utm_source=chatgpt.com

[3] Woode, A., Amoah, D. K., Nartey, D., Misefah, D., Anyetei Nai, F., Abane, R., & Nsoh, R. A. (2019). An experiment to determine the prospect of using cocoa pod husk ash as stabilizer for weak lateritic soils. *Civil and Environmental Research, 11*(3), 1-10. Retrieved from https://www.iiste.org/Journals/index.php/CER/article/view/16397

[4] Danso, H., & Adu, S. (2019). Characterization of Compressed Earth Blocks Stabilized with Clay Pozzolana. *Journal of Civil and Environmental Engineering*. https://www.hilarispublisher.com/abstract/characterization-of-compressed-earth-blocks-stabilized-with-clay-pozzolana-33026.html?utm_source=chatgpt.com

[5] Vincent, E., & Mallo, S. J. (2023). Geotechnical investigation of the sub-soils condition around Yelwa North central part of Nigeria For the construction of infrastructures. *Nigerian Journal of Technology*, *42*(1), 99-106. https://www.ajol.info/index.php/njt/article/download/247207/233826

[6] Cottrell, J. A. (2024). *Investigation into the Geometry and Aspect Ratio of Fibre Reinforced Compressed Earth Composites* (Doctoral dissertation, University of Portsmouth United Kingdom). https://researchportal.port.ac.uk/files/96143436/Thesis_Jack_Cottrell_UP685134_-_Final.pdf

[7] Mitchell, J. K., Soga, K., & O'Sullivan, C. (2025). *Fundamentals of soil behavior*. John Wiley & Sons https://www.academia.edu/download/58321042/kupdf.net_fundamentals-of-soil-behavior-jk-mitchell-amp-k-soga.pdf

[8] Atkinson, J. (2017). *The mechanics of soils and foundations*. CRC press. https://webapps.unitn.it/Biblioteca/it/Web/EngibankFile/2044783.pdf

[9] American Association of State Highway and Transportation Officials (AASHTO). (2004). *Standard specification for classification of soils and soil-aggregate mixtures for highway construction purposes (AASHTO M 145)*. Washington, DC: AASHTO.

[10] Houben, H., & Guillaud, H. (1994). *Earth construction: A comprehensive guide*. London: Intermediate Technology Publications.

[11] Islam, M. S., Tausif-E-Elahi, Shahriar, A. R., Nahar, K., & Hossain, T. R. (2020). Strength and durability characteristics of cement-sand stabilized earth blocks. *Journal of Materials in Civil Engineering*, *32*(5), 04020087. https://ascelibrary.org/doi/abs/10.1061/(ASCE)MT.1943-5533.0003176

[12] Daramola, S. O., Hingston, E. D. C., & Demlie, M. (2024). A review of lateritic soils and their use as landfill liners. *Environmental Earth Sciences*, *83*(3), 118. https://link.springer.com/article/10.1007/s12665-023-11392-2

[13] Millogo, Y., Morel, J. C., Aubert, J. E., & Ghavami, K. (2014). Experimental analysis of pressed adobe blocks reinforced with Hibiscus cannabinus fibers. *Construction and Building Materials, 52*, 71-78. https://doi.org/10.1016/j.conbuildmat.2013.10.094

[14] Amu, O. O., Ogunniyi, S. A., & Oladeji, O. O. (2011). Geotechnical properties of lateritic soil stabilized with sugarcane straw ash. *American Journal of Scientific and Industrial Research, 2*(2), 323-331. https://doi.org/10.5251/ajsir.2011.2.2.323.331

[15] Ngania, S., Elenga, H., Meukam, P., & Jannot, Y. (2018). Stabilization of compressed earth blocks with lime and termite hill powder for sustainable building. *Journal of Building Engineering, 20*, 617-622. https://doi.org/10.1016/j.jobe.2018.08.001

[16] Millogo, Y., Aubert, J. E., Séré, A. D., Fabbri, A., & Morel, J. C. (2012). Earth blocks stabilized by cow-dung. *Materials and Structures, 45*(9), 1447-1458. https://doi.org/10.1617/s11527-012-9844-5

[17] Rigassi, V. (1995). *Compressed earth blocks: Vol. I. Manual of production*. Eschborn: Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ).

[18] Yoon, K. B., Ryu, H. M., Lee, G. H., Gopalan, A. I., Sai-anand, G., & Lee, D. E. (2021). Enhanced compressive strength of rammed earth walls stabilized with eco-friendly multi-functional polymeric system. *Renewable and Sustainable Energy Reviews*, *152*, 111681. https://www.sciencedirect.com/science/article/pii/S1364032121009552

[19] Danso, H. (2018). Characteristics of materials for earth construction. *Materials Science and Engineering*, 431, 092001. https://doi.org/10.1088/1757-899X/431/9/092001

[20] Donkor, P., Obonyo, E., & Ferraro, C. (2021). Fiber reinforced compressed earth blocks: Evaluating flexural strength characteristics using short flexural beams. *Materials*, *14*(22), 6906. https://www.mdpi.com/1996-1944/14/22/6906

[21] Ngowi, A. B. (1997). Improving the traditional earth construction: A case study of Botswana. *Construction and Building Materials*, 11(1), 1-7. https://doi.org/10.1016/S0950-0618(96)00030-6

[22] Rigassi, V. (1995). Compressed earth blocks: Vol. I. Manual of production. Eschborn: Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ).

[23] Jayasinghe, C., & 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.2006.05.046

[24] Oti, J. E., & Kinuthia, J. M. (2015). Stabilised unfired clay: From laboratory to construction. Proceedings of the Institution of Civil Engineers - Engineering Sustainability, 168(2), 74-84. https://doi.org/10.1680/ensu.13.00052

[25] Jayasinghe, C., & Mallawaarachchi, R. (2009). Flexural strength of compressed stabilized earth blocks. Materials & Design, 30(9), 3859-3868. https://doi.org/10.1016/j.matdes.2009.01.018

[26] Bui, Q. B., Morel, J. C., Hans, S., & Meunier, N. (2009). Compression behaviour of non-industrial materials in civil engineering by three scale experiments: The case of rammed earth. Materials and Structures, 42(8), 1101-1116. https://doi.org/10.1617/s11527-008-9446-y