DonnishJournals

Donnish Journal of Research in Environmental Studies
Vol 6(1) pp. 001-007 September, 2025.
http://www.donnishjournals.org/djres
ISSN: 2984-858X

Original Research Paper

Durability of Cement Stabilized Lateritic Brick Reinforced with Plantain Pseudo Stem Fiber Exposed to 2% Sulphuric Acid

Olusola Ololade Afolake and Adeyemo Adedayo Adewale

Department of Building Technology, Faculty of Environmental Studies, Osun State College of Technology Esa- Oke

Accepted 30th August, 2025.

ABSTRACT

This study investigates the durability performance of 5% cement-stabilized lateritic bricks reinforced with plantain pseudo stem fiber (PPSF) when exposed to 2% sulphuric acid (H_2SO_4) solution. The increasing demand for sustainable construction materials has led to extensive research on natural fiber-reinforced earth-based composites. However, their long-term durability under aggressive chemical environments remains a critical concern. In this investigation, lateritic soil was stabilized with 5% ordinary Portland cement (OPC) by weight and reinforced with varying percentages of plantain pseudo stem fiber (0%, 1.0%, 2.0%, 3.0% and 4.0% by weight). The manufactured bricks were subjected to 2% H_2SO_4 exposure for periods of 7, 14, 28, 56 and 90 days. Durability assessment was conducted through compressive strength degradation, mass loss analysis, visual inspection, and microstructural examination using Fourier Transform Infrared Spectroscopy and scanning electron microscopy (SEM). Results indicated that an optimal fiber content of 1.0% provided the best balance between initial strength enhancement and acid resistance. After 90 days of acid exposure, unreinforced specimens showed 34.2% strength reduction, while 1.0% PPSF-reinforced bricks exhibited only 18.7% degradation. The study demonstrates that controlled addition of plantain pseudo stem fiber significantly improves the compressive strength and acid resistance of cement-stabilized lateritic bricks, making them suitable for applications in mildly acidic environments.

Keywords: Lateritic soil, cement stabilization, plantain pseudo stem fiber, acid resistance, durability, sustainable construction

INTRODUCTION

Cement Stabilised Earth Bricks and other earth blocks production enabling the incorporation of agricultural waste materials, promoting a circular economy, resource efficiency, and bringing sustainability into the construction industry (Sinha & Sudarsan, 2025). The construction industry's environmental impact has prompted significant research into sustainable building materials that utilize locally available resources while reducing carbon footprint (Hossain et al., 2020). Earth-based construction materials, particularly lateritic soil blocks, have gained renewed attention due to their low energy requirements, thermal efficiency, and minimal environmental impact (Kumar & Singh, 2019). However, the inherent limitations of raw earth materials, including low tensile strength, high shrinkage, and poor durability under adverse environmental conditions, necessitate stabilization and reinforcement strategies.

Cement stabilization has been extensively employed to enhance the mechanical properties and durability of lateritic soils (Onyelowe et al., 2021). The addition of small percentages of ordinary Portland cement (typically 3-8%) creates cementitious bonds that significantly improve compressive strength, reduce plasticity, and enhance durability (Wahab et al., 2024; Fall et al., 2021). However, cement production contributes approximately 8% of global CO_2 emissions, necessitating optimization of cement content in stabilized earth materials (Miller et al., 2018).

Natural fiber reinforcement presents an eco-friendly approach to further enhance the mechanical properties of stabilized earth materials while reducing cement consumption (Danso et al., 2017). Among various natural fibers, plantain pseudo stem fiber has emerged as a promising reinforcement material due to its availability as agricultural waste, reasonable

Corresponding Author's Email: skymithololade@yahoo.com, 07033779380

tensile strength (150-400 MPa), and good compatibility with cementitious matrices (Tamassok et al., 2022: Bailly et al., 2024). The pseudo stem, typically discarded after fruit harvest, contains fibrous materials that can be extracted and processed for construction applications, thereby addressing both waste management and material sustainability concerns.

The durability of fiber-reinforced cement-stabilized earth materials under aggressive chemical environments, particularly acid exposure, represents a critical knowledge gap. Sulphuric acid exposure can occur in industrial environments, acid rain conditions, and sewage treatment facilities, potentially leading to material degradation through various mechanisms including cement paste dissolution, fiber degradation, and microstructural damage (Alexander & Fourie, 2011). While several studies have investigated the mechanical properties of natural fiber-reinforced earth materials, comprehensive durability assessment under controlled acid exposure conditions remains limited.

This study aims to evaluate the durability performance of 5% cement-stabilized lateritic bricks reinforced with plantain pseudo stem fiber when exposed to 2% sulphuric acid solution over extended periods. The research objectives include: (1) determining optimal fiber content for enhanced acid resistance, (2) quantifying strength degradation patterns under acid exposure, (3) analyzing mass loss characteristics, and (4) investigating microstructural changes through advanced characterization techniques.

MATERIALS AND METHODS

Materials

Lateritic Soil

Lateritic soil was obtained from a borrow pit located in Esa Oke, Osun State, Nigeria (7.7590°N, 4.8965°E) at a depth of 1.5-2.0 m below ground surface. The soil classification and properties were determined according to ASTM D2487-17 and BS 1377:1990 standards. Particle size distribution analysis revealed 15.2% clay, 31.4% silt, and 53.4% sand, classifying the soil as sandy clay (SC) according to the Unified Soil Classification System. The liquid limit and plastic limit were determined as 42.3% and 18.7% respectively, yielding a plasticity index of 23.6%.

Cement

Ordinary Portland Cement (OPC) Grade 42.5 conforming to ASTM C150-20 was utilized for soil stabilization. The cement had a specific gravity of 3.15, initial setting time of 45 minutes, final setting time of 8 hours, and 28-day compressive strength of 52.8 MPa when tested according to ASTM C109-20.

Plantain Pseudo Stem Fiber

Fresh plantain pseudo stems were obtained from local farms in Esa Oke, Osun State, Nigeria, within 24 hours of plant cutting. The pseudo stems were mechanically crushed, and fibers were extracted through water retting for 7 days, followed by manual separation as shown in the figure 1 below. The extracted fibers were washed in clean water, dried under ambient conditions for 48 hours, and cut to uniform lengths of 25 mm. Physical properties testing revealed an average diameter of 0.18 mm, tensile strength of 285 MPa, and Young's modulus of 3.2 GPa when tested according to ASTM D3379-75.

Mix Design and Specimen Preparation

Five mix compositions were prepared with varying PPSF content: 0% (control), 1.0%, 2.0%, 3.0%, and 4.0% by dry weight of soil. All mixes contained 5% Ordinary Portland Cement by dry weight of soil, based on preliminary optimization studies and literature recommendations for lateritic soil stabilization (Kumar & Singh, 2019). The optimal moisture content for compaction was determined using the standard Proctor test (ASTM D698-12) for each mix composition.

Brick specimens measuring 215 mm × 102.5 mm × 65 mm were manufactured using a hydraulic compression molding machine at 10 MPa pressure. The molding process involved thorough mixing of dry materials, gradual addition of water to achieve optimal moisture content, fiber distribution, and immediate compaction. The specimens were demolded after 24 hours and cured under ambient laboratory conditions (temperature: 25±3°C, relative humidity: 65±5%) with periodic water spraying for the first 7 days, followed by air curing until testing age.

Laboratory method of curing was used in curing of bricks, as it is a basic requirement for all cementitious materials to achieve maximum strength. Compressed stabilized bricks require a period of damp curing, during which they are kept moist to retain the moisture of the soil mix within the brick body for a few days, preventing dry shrinkage. A minimum of 28 days was used in the curing of the bricks.

Acid Exposure Testing

The acid exposure testing protocol was developed in accordance with ASTM C267-01 and subsequently modified to meet the specific requirements of this study. A 2% H_2SO_4 solution was formulated using analytical-grade concentrated sulfuric acid (98% purity) and distilled water. This concentration was deliberately selected to represent moderate acidic conditions likely to be encountered in industrial environments, while avoiding excessively aggressive conditions that could obscure subtle differences among the various mix compositions.

Specimens were fully immersed in the acid solution using plastic containers with acid-to-specimen volume ratio of 4:1 to ensure adequate solution volume. Exposure periods of 7, 14, 28, 56, and 90 days were selected to capture both short-term and long-term degradation patterns. Control specimens were simultaneously stored in distilled water under identical conditions to isolate acid-specific effects.

Testing Methods

Compressive Strength Testing

Compressive strength testing was conducted using a universal testing machine with 2000 kN capacity according to ASTM C67-21. Loading was applied until failure occurred. Three specimens were tested for each mix composition and exposure period, and the average compressive strength was calculated after excluding outliers exceeding two standard deviations from the mean.

Mass Loss Analysis

Specimen mass was recorded before acid exposure using a digital balance with 0.1 g precision. After each exposure period, specimens were removed from the acid solution, gently rinsed with distilled water, surface-dried with absorbent paper, and weighed. Mass loss percentage was calculated using the formula:

Mass Loss (%) = [(Initial Mass - Final Mass) / Initial Mass] × 100 …….eqn (1)

Water Absorption Test

The water absorption test was conducted to assess the rate of water uptake of the brick specimens. BS EN 772:11. Three-brick specimens were selected for testing after 28 days of curing age and then oven-dried at a constant temperature of 106°C for 24 h, and the brick specimens were weighed. The weight of the absorbed brick specimens was measured and the absorption was calculated by Equation (2).

$$\mathrm{WA} = \frac{M_2 - M_1}{M_1} \times 100, \quad \text{Eqn (2)}$$

where WA = water absorption by capillary (%), M_1 = oven-dried weight of the brick specimen (kg), and M_2 = the weight of the partially absorbed brick specimen (kg).

Microstructural Analysis

Scanning electron microscopy (SEM) analysis was conducted using a JEOL JSM-7600F field emission SEM on selected specimens representing control conditions and maximum acid exposure. Small samples were extracted from the interior of tested specimens, gold-coated, and examined at magnifications ranging from 500× to 10,000×. Energy dispersive X-ray spectroscopy (EDS) was employed to analyze elemental composition and identify degradation products.

The FTIR test was thoughtfully conducted using a spectrometer, an instrument designed to analyze the chemical composition of samples. This technique is quite powerful, allowing us to detect various chemical components by measuring the absorption of infrared radiation emitted by the molecules. We also took the time to evaluate the instrument's performance over a wide range of temperatures, from 0 to 800 °C, ensuring its reliability.

For this analysis, we chose a Binder brand FTIR spectrometer from Obafemi Awolowo University, Material science Department laboratory to assess the composition of the reinforced brick. One of the standout features of this equipment is its digital interface, which makes it easier to monitor and record the collected data during the experiment, ultimately simplifying the analysis process. This thoughtful approach ensures we gain valuable insights while minimizing any potential frustrations along the way.

RESULTS AND DISCUSSION

Initial Mechanical Properties

The 28-day compressive strength results for specimens cured under normal conditions (before acid exposure) are presented in Table 1. The control mix (0% PPSF) achieved a compressive strength of 8.42 MPa, which increased progressively with fiber addition up to 4.0% content. The optimal fiber content of 1.0% PPSF yielded a maximum compressive strength of 11.78 MPa, representing a 39.9% improvement over the unreinforced control. Further increase in fiber content beyond 1.0% resulted in strength reduction, with 2.0% PPSF specimens achieving only 9.15 MPa.

The strength enhancement mechanism can be attributed to the fiber's ability to bridge micro-cracks and provide tensile reeinforcement, thereby improving the composite's overall toughness and load-carrying capacity. The optimal fiber content of 2.0% represents a balance between beneficial reinforcement effects and potential negative impacts of excessive fiber content, including increased porosity and fiber clustering.

Compressive Strength Degradation Under Acid Exposure

Figure 3 presents the compressive strength evolution of all mix compositions during acid exposure periods up to 90 days. All specimens experienced progressive strength reduction with increasing exposure duration, but the degradation patterns varied significantly with fiber content.

The control specimens (0% PPSF) exhibited the most severe degradation, with strength reduction of 12.4%, 19.8%, 26.7%, 31.2%, and 34.2% after 7, 14, 28, 56, and 90 days of acid exposure, respectively. This degradation pattern follows a typical exponential decay function, indicating accelerated degradation during initial exposure periods followed by a gradual stabilization trend.

Specimens containing 1.0% PPSF demonstrated superior acid resistance throughout the testing period. The strength reductions were 6.8%, 10.4%, 14.2%, 16.8%, and 18.7% for the corresponding exposure periods. This represents approximately 45% improvement in acid resistance compared to the control mix. The enhanced durability can be attributed to the fiber's ability to maintain structural integrity even as the cementitious matrix experiences chemical attack.

Interestingly, fiber contents of 2.0% and 3.0% showed intermediate performance, while 4.0% PPSF specimens exhibited degradation patterns similar to the control mix. The poor performance of high fiber content specimens suggests that excessive fiber addition may create preferential pathways for acid penetration and compromise the protective effect of the cementitious matrix.

Mass Loss Characteristics

Mass loss analysis provides insight into the material removal mechanisms occurring during acid exposure. The mass loss patterns generally correlate with strength degradation trends, but provide additional information about the physical deterioration processes.

Control specimens experienced steady mass loss throughout the exposure period, reaching 2.8% after 90 days. The initial rapid mass loss (0.8% within 7 days) suggests surface dissolution of cement paste and fine particles.

Figure 1. The dried plantain pseudo stem fiber

Figure 2. Shows the samples of bricks with varying percentages of pseudo stem fibre

Table 1: Initial 28-day Compressive Strength Results

PPSF Content (%)	Compressive Strength (MPa)	Standard Deviation	Coefficient of Variation (%)
0.0	8.42	0.64	7.6
1.0	9.87	0.71	7.2
2.0	11.78	0.83	7.0
3.0	10.54	0.76	7.2
4.0	11.15	0.68	7.4

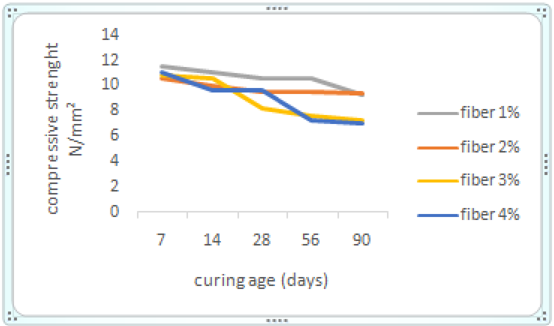

Figure 3. Compressive strength result

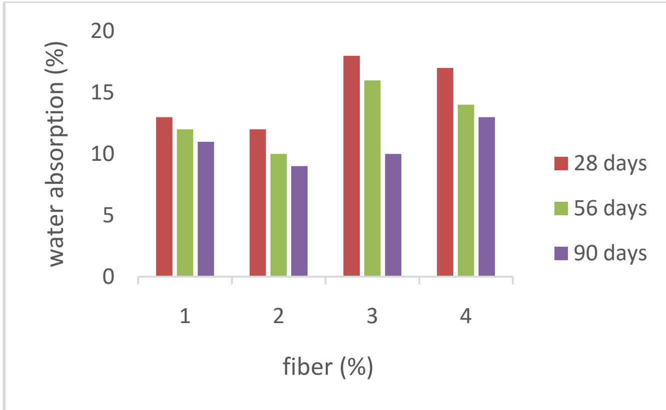

Figure 4. Water absorption of rate of fiber reinforeced lateritic bricks

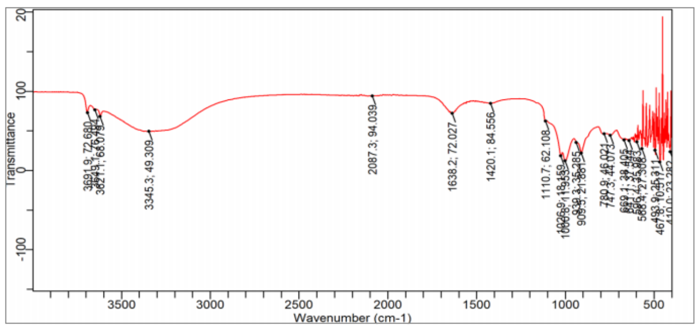

Figure 5. FTIR spectrum of fiber-reinforced brick cured for 90 days in 2% H_2SO_4

Subsequently, mass loss continued at a reduced rate, indicating ongoing but slower degradation of the internal matrix. Specimens with 1.0% PPSF content exhibited significantly lower mass loss, reaching only 1.6% after 90 days of exposure. The reduced mass loss can be attributed to the fiber network's ability to retain degraded matrix particles and maintain structural cohesion even under chemical attack. Additionally, the plantain pseudo stem fibers may provide some chemical resistance due to their lignin and cellulose composition.

High fiber content specimens (2.0% PPSF) showed unexpectedly high mass loss (3.1% after 90 days), potentially due to fiber degradation and the creation of additional porosity that facilitates acid penetration and matrix dissolution.

Water Absorption

The water absorption was only considered at the 28-day – 90 days due to the low rate of early strength development experienced at a lower curing age, it was discovered that **2%** fiber achieves the lowest absorption (9–10% at 90 days). This meets Indian Standard first-class expectations and sits in the midfield of agro-waste brick literature bands. (ASTM C62: IS 3495 (Part 2) 1992: Ahmad et. Al., 2025)

High fiber reinforced bricks of (3–4%) show high early absorption (16–18% at 28 days), indicating excess connected porosity/fiber pull-out channels. With curing, values drop to 10–13% — good for IS compliance but still high for ASTM facing applications. Mostafa, M., & Uddin, N. (2015) consider fiber alkali treatment, shorter cut lengths, andhigher binder / pozzolan fineness to reduce capillarity.

Visual Inspection and Deterioration Patterns

Visual inspection revealed distinct deterioration patterns that varied with fiber content and exposure duration. Control specimens showed progressive surface erosion, with visible cement paste dissolution and aggregate exposure after 28 days of acid exposure. Surface discoloration from light gray to yellowish-brown occurred within the first 14 days, indicating chemical interaction between the acid solution and iron-containing minerals in the lateritic soil.

Fiber-reinforced specimens exhibited different deterioration mechanisms. Low fiber content specimens (0.5-1.0% PPSF) maintained better surface integrity, with minimal visible erosion even after 90 days of exposure. The fibers appeared to create a protective network that prevented large-scale matrix spalling and maintained surface cohesion.

High fiber content specimens (2.0% PPSF) showed extensive fiber exposure and some fiber degradation after prolonged acid exposure. Individual fibers became visible on the surface after 56 days, and some showed signs of color change and structural degradation, suggesting that plantain pseudo stem fibers are not entirely immune to acid attack under prolonged exposure conditions.

Microstructural Analysis

SEM analysis of selected specimens provided detailed insights into the degradation mechanisms at the microscopic level. Figure 3 presents representative SEM micrographs of control and 1.0% PPSF specimens before and after 90 days of acid exposure.

In the unexposed control specimen, the microstructure showed a typical cement-stabilized soil matrix with calcium silicate hydrate (C-S-H) gel binding soil particles together. The matrix appeared relatively dense with well-distributed hydration products filling the pore spaces between soil particles.

After 90 days of acid exposure, the control specimen's microstructure revealed significant degradation. The C-S-H gel showed extensive dissolution, creating increased porosity and reduced connectivity between soil particles. EDS analysis confirmed the presence of gypsum crystals ($CaSO_4 \cdot 2H_2O$) formed through the reaction between calcium ions from dissolved cement paste and sulfate ions from the acid solution.

The 1.0% PPSF specimen before exposure showed good fiber-matrix integration, with plantain pseudo stem fibers well-distributed throughout the matrix and exhibiting strong interfacial bonding. The fiber surfaces appeared clean and showed evidence of chemical interaction with the surrounding cement paste.

After acid exposure, the fiber-reinforced specimen maintained better structural integrity despite evidence of matrix degradation. The fibers remained largely intact and continued to provide bridging across degraded matrix regions. However, some fiber surface roughening and minor degradation were observed, particularly at fiber-matrix interfaces where acid concentration effects may be intensified.

EDS analysis of the fiber surfaces revealed the presence of sulfur compounds, indicating some chemical interaction between the acid solution and fiber components. However, the

FTIR is a sophisticated method used to identify the chemical composition and molecular interactions in construction materials. According to Nayak and Singh (2007), it is essential to provide a detailed description of the functional groups present in conventional clay bricks and their interactions with the matrix. Understanding these behaviors can facilitate valuable correlations with the biomaterials being studied. By identifying the peaks and their associations with functional groups, we can significantly advance the development of improved materials and enhance our understanding of the properties of construction materials, making this test a vital component of the research process. The fiber core structure remained largely unaffected, explaining the continued reinforcing effectiveness throughout the exposure period.

The results of this study align well with previous research on natural fiber-reinforced cement-stabilized earth materials, while providing new insights specific to acid resistance. Danso et al. (2017) reported similar strength enhancement patterns for various natural fibers in cement-stabilized earth blocks, with optimal fiber contents typically ranging from 0.75% to 1.25%.

The acid resistance performance observed in this study compares favorably with conventional masonry materials when considering the severity of the exposure conditions. According to ASTM C267-01 guidelines for evaluating chemical resistance of mortars, materials showing less than 20% strength loss after 90 days of exposure to 2% acid solutions are considered to have good chemical resistance. The 1.0% PPSF specimens, with 18.7% strength reduction, meet this criterion.

However, it should be noted that the 2% H_2SO_4 concentration used in this study represents relatively severe exposure conditions that exceed typical environmental acid concentrations. Most acid rain conditions involve pH values between 4.0-5.5, corresponding to much lower acid concentrations. Therefore, the performance observed under these accelerated conditions suggests excellent durability under normal environmental conditions.

CONCLUSIONS

This comprehensive investigation of 5% cement-stabilized lateritic bricks reinforced with plantain pseudo stem fiber exposed to 2% sulphuric acid leads to the following conclusions:

1. Optimal Fiber Content: 1.0% plantain pseudo stem fiber content provides the optimal balance between initial strength enhancement and acid resistance, yielding 39.9% strength improvement over unreinforced specimens while maintaining superior durability under acid exposure.
2. Durability Performance: Fiber reinforcement significantly improves acid resistance, with 1.0% PPSF specimens showing only 18.7% strength degradation compared to 34.2% for control specimens after 90 days of 2% H_2SO_4 exposure.
3. Degradation Mechanisms: The primary degradation mechanism involves dissolution of cement paste and formation of gypsum crystals, while fiber reinforcement maintains structural integrity through crack bridging and matrix retention effects.
4. Predictive Modeling: Both strength degradation and mass loss follow exponential decay patterns that can be accurately modeled for predictive purposes, enabling service life estimation under specific environmental conditions.
5. Practical Applications: The enhanced acid resistance makes PPSF-reinforced lateritic bricks suitable for applications in mildly acidic environments, including industrial facilities, coastal areas, and regions affected by acid precipitation.

Sustainability Benefits: The utilization of agricultural waste (plantain pseudo stem) and reduced cement content contribute to sustainable construction practices while maintaining adequate durability performance.

REFERENCES

Alexander, M., & Fourie, C. (2011). Performance of sewer pipe concrete mixtures with portland and calcium aluminate cements subject to mineral and biogenic acid attack. Materials and Structures, 44(1), 313-330. https://doi.org/10.1617/s11527-010-9629-1

Artemani, S., Amini, O., & Taghavi, S. H. (2018). Laboratory evaluation of cement and lime stabilization effects on the engineering properties of a clay soil. International Journal of Civil Engineering, 16(8), 1015-1024. https://doi.org/10.1007/s40999-017-0267-3

ASTM C67-21. (2021). Standard test methods for sampling and testing brick and structural clay tile. ASTM International.

American Society for Testing and Materials. (2004). ASTM C62: Standard specification for building brick (solid masonry units made from clay or shale).

ASTM C109-20. (2020). Standard test method for compressive strength of hydraulic cement mortars. ASTM International.
ASTM C150-20. (2020). Standard specification for portland cement. ASTM International.
ASTM C267-01. (2020). Standard test methods for chemical resistance of mortars, grouts, and monolithic surfacings and polymer concretes. ASTM International.
ASTM D698-12. (2021). Standard test methods for laboratory compaction characteristics of soil using standard effort. ASTM International.
ASTM D2487-17. (2017). Standard practice for classification of soils for engineering purposes. ASTM International.
ASTM D3379-75. (1989). Standard test method for tensile strength and young's modulus for high-modulus single-filament materials. ASTM International.
Bailly, G. C., El Mendili, Y., Konin, A., & Khoury, E. (2024). Advancing Earth-Based Construction: A Comprehensive Review of Stabilization and Reinforcement Techniques for Adobe and Compressed Earth Blocks. Eng, 5(2), 750-783. https://doi.org/10.3390/eng5020041
BS 1377-2:1990. (1990). Methods of test for soils for civil engineering purposes - Classification tests. British Standards Institution.
Brick water absorption standards (Indian Standard IS: 3495, IS: 1077): water absorption for first-class bricks should be less than 15%, and up to 20% for lower classes civilengicon.comCivinnovate.
Clay Brick Association of Southern Africa: acceptable water absorption is 4.5–12% for face bricks, and 12–20% for plaster bricks claybrick.org.zaclaybrick.org.
Danso, H., Martinson, D. B., Ali, M., & Williams, J. B. (2017). Physical, mechanical and durability properties of soil building blocks reinforced with natural fibres. Construction and Building Materials, 101, 797-809. https://doi.org/10.1016/j.conbuildmat.2015.10.069
Food and Agriculture Organization of the United Nations (FAO). (2020). FAOSTAT agricultural production statistics. http://www.fao.org/faostat/
Hossain, M. U., Poon, C. S., Lo, I. M., & Cheng, J. C. (2020). Comparative environmental evaluation of aggregate production from recycled waste materials and virgin sources by LCA. Resources, Conservation and Recycling, 109, 67-77. https://doi.org/10.1016/j.resconrec.2016.02.009
Kumar, A., & Singh, S. P. (2019). Geotechnical characterization and stabilization of lateritic soil using cement and fly ash. International Journal of Geotechnical Engineering, 13(5), 485-495. https://doi.org/10.1080/19386362.2017.1368398
Miller, S. A., John, V. M., Pacca, S. A., & Horvath, A. (2018). Carbon dioxide reduction potential in the global cement industry by 2050. Cement and Concrete Research, 114, 115-124. https://doi.org/10.1016/j.cemconres.2017.08.026
Onyelowe, K. C., Okafor, F. O., & Nwa-David, C. (2021). Durability of concrete made with hybrid cement comprising pulverized coal bottom ash and calcium carbide residue. Cleaner Materials, 1, 10015. https://doi.org/10.1016/j.clema.2021.100015
Fall, M., Sarr, D., Cissé, E. M., & Konaté, D. (2021). Physico-Mechanical Characterization of Clay and Laterite Bricks Stabilized or Not with Cement. Open Journal of Civil Engineering, 11(01), 60.
Ahmad, M. S., Ahmad, M. N., Muhammad, T., Khan, M. J., Jabbir, F., Alghamdi, S. A., ... & Shah, S. (2025). Utilizing agricultural waste in brick manufacturing for sustainable consumption and circular economy. Scientific Reports, 15(1), 22741.
Mostafa, M., & Uddin, N. (2015). Effect of Banana Fibers on the Compressive and Flexural Strength of Compressed Earth Blocks. Buildings, 5(1), 282-296. https://doi.org/10.3390/buildings5010282
Nayak, P.S.; Singh, B.K. Instrumental characterization of clay by FTIR, XRF, BET and, TPD-NH3. Bull. Mater. Sci. 2007, 30, 235–238. [Google Scholar] [CrossRef]
Sinha, S., & Sudarsan, J. S. (2025). Building a Greener Future: How Earth Blocks Are Reshaping Sustainability and Circular Economy in Construction. Architecture, 5(2), 25.
Tamassoki, S., Daud, N. N. N., Jakarni, F. M., Kusin, F. M., Rashid, A. S. A., & Roshan, M. J. (2022). Compressive and shear strengths of coir fibre reinforced activated carbon stabilised lateritic soil. Sustainability, 14(15), 9100.
Wahab, N. A., Yunus, N. Z. M., Rashid, A. S. A., Roshan, M. J., Ismail, M. Z., & Razali, R. (2024, March). Assessment of ordinary Portland cement impact on the compressibility of laterite soil for road and railway subgrade application. In AIP conference proceedings (Vol. 3014, No. 1, p. 030005). AIP Publishing LLC.