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Strength and Durability Analysis of Compressed Lateritic Soil Bricks Stabilised with Pulverised Oyster Shells

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ABSTRACT
The rising demand for affordable, sustainable and environmental-friendly building materials has necessitated the exploration of alternative binders and stabilisers in soil bricks production. In this work, compressed lateritic soil bricks were produced with varying pulverized oyster shells contents (0%, 0.5%, 1%, 1.5%, 2%, 2.5%, and 3%) and tested for strength and durability characteristics in the 7, 14, 21, and 28 days, curing periods. The test results revealed that 2% pulverised oyster shells addition represents the optimal threshold for improving soil bricks compressive and tensile strengths, water absorption and erosion resistance. For instance, in the 28 days curing duration, the 2% pulverised oyster shells addition recorded a compressive strength of 1.97N/mm², tensile strength of 0.16 N/mm² which are 28.9% and 25% higher than the control respectively. Similarly, water absorption and erosion resistance tests recorded 3.21% and 0.9 mm, depth respectively. While compressive strength and split tensile strength of the 2% pulverised oyster shells addition soil bricks increased by 28.9% and 25% over the control, water absorption and erosion resistance decreased by 33.5% and 89% respectively. It is therefore, recommended that 2% pulverised oyster shells addition should be taken as the optimum for a sustainable and affordable lateritic soil bricks production.
Keywords: pulverised oyster shells, compressive strength, split tensile strength, water absorption, erosion resistance

1 INTRODUCTION

The world is witnessing an alarming surge in population growth and rapid urbanisation (Achamwie & Danso-Wiredu, 2021). This growth is projected to hit 9.7 billion in 2050 and 11.20 billion in 2099 and, 90 percent of this population growth is predicted to take place in Africa (United Nations Report, 2020). Globally, the housing deficit stands at 268 million housing units, affecting 1.26 billion people (Bebr et al., 2021) with Africa already having over 60 percent of its population living in slums and informal settlements (Muraguri, 2011). This surge in the world's population growth and urbanisation raises high demand for adequate and affordable housing (Dadzie et al., 2020; Obianyo et al., 2021). According to Yalley and Badu (2018) the housing gap is widening because of the rising cost of traditional imported materials. Jannat et al. (2022) reported that the cost of housing provision reached 8.7 trillion US Dollars in 2012 and is projected to reach 15 trillion US Dollars by 2025. In Ghana, the housing deficit statistics follow the global trend. For instance, Ghana's housing deficit is at 1.8 million housing units (Ghana Statistical Service 2022).

The demand for housing units to close the housing deficit gap in both urban and rural settlements is responsible for the continuous increase of the prices of imported building materials (Ansah & Danso, 2025; Dadzie et al., 2020; Obianyo et al., 2021). For instance, Adedeji (2010) indicated that about 60 percent of the total cost a housing project is spent on materials due to the high cost associated with imported materials. Again, Millogo et al. (2016) also indicated that most of the population in developing countries, especially Africa cannot afford imported cementitious building materials for low-income urban and rural housing provision due to the high cost associated with cement production and transportation. Currently, there is an increased interest in the search of alternative locally sourced building materials to meet the rising need for economical and sustainable housing materials for affordable housing provision in developing countries (Naapuo & Danso, 2025; Adetooto et al., 2022).

One material that is available everywhere and has been used for housing provision for centuries in many different parts of the world is lateritic soil. Historical evidence showed that soil material was a highly popular building material for housing provision in very dry ecological regions. Soil material is still used in low-income urban and rural areas in the world where access to other forms of imported building materials is restricted by location or costs, though studies

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have shown that not all soils are suitable for building purposes. Nawar (2020) reported that soil specification and stabilisation is very important to ensure that it meet all strength and durability requirements. According to Olowu et al. (2014) the purpose of stabilising soil with additives is to alter it physical properties and increase strength and durability properties for better performance. Hence, different types of additives have been used to stabilised soil building materials, among which are cement (Danso & Manu, 2020; Seifu et al., 2022), lime (Olowu et al., 2014), agricultural-based waste (Millogo et al., 2016; Ramachandran et al., 2018; Malbila et al., 2021; Kamat et al., 2021). Cement and lime additives exhibited the most improvement in soil strength and durability performance, however, their use currently is less appreciated because of increasing cost and environmental concerns related to their production processes (Sharma & Sivapullaiah, 2011; Danso & Manu 2020; Shao et al., 2022; Kusi et al., 2024).

Studies have shown that despite the influx of modern and innovative building materials in the market, there is still the need to return to readily available locally-sourced materials (Manu et al., 2025). It is in the light of this that current research interest has shifted to the use of agricultural-based waste materials as an affordable and environmentally-friendly and sustainable alternative additive material for the stabilisation of compressed soil materials that avoids the use of energy-intensive activities during the building life cycle (Teye et al., 2026; Malbila et al., 2021). New trends and standards for sustainable architecture and construction are being imposed. One example of soil-built structure that is well-known is the Islamic Heritage Mosque at Larabanga in Damongo, Northern Ghana (Figure 1).

Figure 1: Larabanga Mosque, Damongo

Houses made from alternative building materials such as straw, clay, adobe, in which people once lived are becoming increasingly attractive (Zlateva et al., 2020). Oyster shell is one of such agricultural-based waste material from marine sources, heavily researched for soil material stabilisation. Oysters are marine habitants found commonly in communities along the coast and large rivers. In Ghana, oysters are commonly found in the sea and the river volta (Okine et al., 2024). The shells primarily composed of a high amount of calcium carbonate and other compounds such as magnesium carbonate, silica, organic matter and minute traces of other compounds. When the shells are ground into fine powder, it exhibits high pozzolanic reactivity properties, making it suitable for use in stabilising soils and as cement substitute in concrete production. Again, the calcium carbonate content in oyster shells interacts with siliceous and aluminous materials in the soil to form cementitious compounds, thereby improving the strength and durability properties of stabilised soil materials (Liu et al., 2022).

Hence, the influence of oyster shells for concrete production and soil stabilisation have widely been studied. In a previous study, it was found that partially replacing fine aggregate with oyster shell fine particles improved the concrete lightweight properties with further replacement and, the strength and durability properties at the 5% replacement level (Kuo et al., 2013). Also partially replacing cement with pulverised (powdered) oyster shell enhances mortar and concrete (Silva et al., 2019; Liu et al., 2022) strength and durability properties. When studied for soil stabilisation, oyster shell powder improves the geotechnical properties of the soil material for road construction and base for foundations for buildings (Fernando, 2019), enhances the strength and durability properties of fired clay bricks (Chen et al., 2019; Fernando, 2019; Kusi et al., 2024). Despite the potential use of oyster shell as a good soil stabiliser, limited studies have investigated the use of oyster shell powder in unfired lateritic soil bricks, particularly for combined strength and durability performance. Thus, the present work studies the strength and durability properties of compressed lateritic soil bricks stabilised with pulverised (powdered) oyster shells.

Oyster shells are found in the seas and large rivers. The shells are abundant in Ghana, particularly in the coastal regions and along the volta river which stretches from the northern to the southern part of Ghana. according to Islam et al. (2023) and Kusi et al. (2024) the shells are becoming an environmental problem since there is no proper disposal practices. Incorporating these shells in housing construction will not only have positive impact on the environment but will significantly reduce housing costs in rural communities. Thus, the motivation for using the powdered oyster shells for unfired lateritic soil bricks stabilisation is based on availability, low cost and sustainability.

2 MATERIALS AND METHODS

2.1 Materials

The following constituent materials were used to prepare the test samples for the experimental study: lateritic soil material, oyster shells and clean water.

2.1.1 Lateritic Soil Material

The lateritic soil material used for this study was obtained from Tanoso in the Atwima Nwabiagya District of the Ashanti Region of Ghana. After clearing the site of vegetation and excavating the soil, it was bagged and transported to the University of Skills Training and Entrepreneurial Development (USTED), Kumasi, Building Department Laboratory. There, it was air-dried to reduce its moisture content, aiding in subsequent processing. To ensure uniformity, the dried lateritic soil material was spread on a clean platform and sieved using a 5 mm mesh to remove large particles and organic matter that could weaken the brick structure (Figure 2a). This sieving process ensured a consistent particle size distribution, which is crucial for enhancing inter-particle bonding and improving the strength and durability of the soil brick samples.

2.1.2 Oyster Shells

The oyster shells used were obtained from the volta river at Adidome in the Volta Region of Ghana. The discarded shells were collected from open-air deposits around the fisherfolks residential areas. Only cleaned and relatively intact shells were selected to facilitate easier processing (Figure 2b).

2.1.3 Water

Clean tap water was obtained from the Building Construction Department Laboratory of University of Skills Training and Entrepreneurial Development, Kumasi, supplied by Ghana Water Company. Its quality standards conform to the BS EN 1008 (2002) specifications.

Figure 2: Materials for experimental work: (a) Sieved lateritic soil, (b) Oyster shells, (c) oyster shells powder

2.2 Methods and Procedures

2.2.1 Oyster Shells Preparation

The collected shells were thoroughly washed with clean water to remove dirt, sand, and any organic residues. They were sun-dried for 30 days in a normal daily average temperature of 36 degrees Celsius, purposely to eliminate all moisture for easy grinding and prevention of machine clogging. The dried shells were broken into smaller fragments with a hammer, bagged and transported to the laboratory where they were further ground into finer particles.

To get the required particle size, the finer particles were poured into the Los Angeles abrasive machine for further grinding. The ground shells powder was sieved using a 425-micron sieve to remove coarse particles. Oversized particles were re-ground using the Los Angeles Abrasion machine to achieve uniform fineness. The final oyster shells powder of average particle size of 0.4 mm (Figure 2c) was stored in airtight containers to prevent moisture absorption and contamination prior to their use. The chemical composition of ground oyster shells powder has already been studied as presented in Table 1.

Table 1: Chemical composition of oyster shells powder (Liu et al. 2022)

Component	Value (%)
Calcium carbonate ($CaCO_3$)	90 – 95
Magnesium carbonate ($MgCO_3$)	1 – 3
Silica (SiO_2)	< 1
Organic matter	1 – 2
Other traces	< 1

2.2.2 Soil Particle Size Distribution

The lateritic soil material used was analysed for particle size distribution using the sieve analysis test method in conformity with BS 1377-2 (2022). The purpose was to determine the predominant particles size that form the bulk of the soil since this has an effect on the compressed soil bricks density.

2.2.3 Mix Design

The oyster shells powder was incorporated into the lateritic soil bricks at varying percentages of 0%, 0.5%, 1.0%, 1.5%, 2.0%, 2.5% and 3.0%. The batching process was carried out using the weight method. Initially, the lateritic soil material and the oyster shells powder were measured separately and placed onto the mixing platform and mixed properly. The soil material quantities for all addition levels were determined based on the number of bricks to be produced and the volume of the mould. Hence, 25.0 kg of soil/oyster shell powder mixture samples and a constant water content of 6.25 kg were used to prepared the brick samples for each batch. The amount of water used was, per the optimum moisture content (25%) by weight of the soil. The lateritic soil was first spread on a platform (Figure 3a), then the oyster shells powder was spread on top and turned over and over until a uniform mixture was obtained. Next; water was added by sprinkling on the mixture and repeatedly turned to obtain a homogenous mixture. The bricks were made with a BREPAC block-making machine (Figure 3b) with a constant pressure rate of 2kN/sec as per the recommended optimum compaction pressure for soil brick production. The mould size of the BREPAC block-making machine was 100 x 100 x 130 mm. Five tests were conducted using 42 number bricks for each, hence, a total of 210 bricks of size 100 x 100 x 130 mm as shown in Figure 3c were moulded. The dried and hardened bricks were tested for strength and durability behaviour after 7, 14, 21 and 28 days of drying and curing.

Figure 3: Preparation of bricks: (a) mixing of materials, (b) moulding of bricks, (c) drying of bricks

2.2.4 Test Procedures

The lateritic soil brick samples were tested for density, compressive strength and split tensile strength for the 7, 14, 21 and 28 days of curing, while the water absorption and erosion tests were performed after 28 days of curing. The densities of the lateritic soil bricks were tested for the 7, 14, 21, and 28 days, curing durations. After each curing age, the test soil brick samples were weighed, and their masses recorded. The volumes of the soil brick samples were determined, from which the densities (kg/m³) were calculated using equation 1.

$$\text{Density} = M/V \quad [1]$$

Where:
M = mass of the soi brick, and V = volume of the soil brick

The compressive strength test of the lateritic soil brick samples was conducted for the 7, 14, 21 and 28 days, curing phases following guidelines outlined in BS EN 12390-3 (2019). The tests were performed using a computerized Universal compressive strength testing machine with a maximum capacity of 1000 KN (Figure 4a). A continuous load at a constant rate of 0.05 N/mm²/s was applied until the brick sample failed. The failure load was recorded, and the cross-sectional area of each brick was calculated from which the maximum compressive strength was determined using equation 2.

$$\text{Compressive strength} = P/A \quad [2]$$

Where:
P = maximum load applied, and A = cross-sectional area of the brick

The split tensile strength test was carried out for the 7, 14, 21 and 28 days, curing phases in accordance with BS EN 12390-6 (2019). A continuous load was applied at a constant rate of 0.05 N/mm²/s until failure occurred (Figure 4b). The maximum load at failure was recorded and the split tensile strength was then calculated from equation 3.

$$\text{Split tensile strength} = 2F/\pi r^2 L \qquad [3]3$$

Where:
F = maximum load applied, л = a mathematical constant (Pi), r = radius of the test sample, and L = length of the test sample.

The water absorption test was conducted in accordance with procedures specified in BS EN 771-1 (2011). Soil brick samples from each mix ratio were oven-dried for 24 hours, and their dry masses were recorded as (M_1). The dried soil brick test samples were then placed on wooden strips and partially submerged in water to a depth of 5 mm for 5 minutes (Figure 4c). After this period, the wet mass of each soil brick sample (Figure 11) was recorded as (M_2) from which the percentage of water absorption was then calculated using equation 4.

$$\text{Water absorption (\%)} = (M_2 - M_1)/M_1 \times 100 \qquad [4]$$

Where:
M_l = Mass of brick before absorption and, M_2 = Mass of brick after absorption

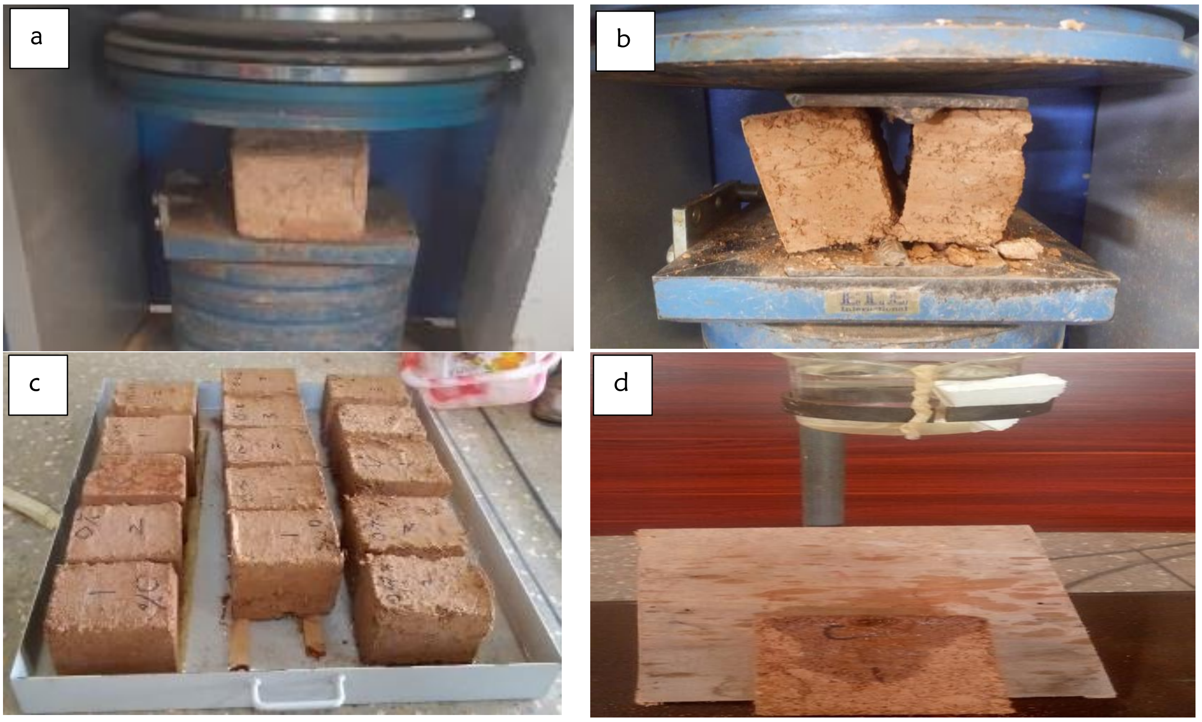

Figure 4: Testing of blocks: (a) compressive strength, (b) split tensile strength, (c) water absorption, (d) erosion

The erosion test was conducted using the Geelong Method to assess the rate at which the lateritic soil bricks deteriorate when exposed to simulated rainfall. The procedure followed the guidelines outlined in the New Zealand Standard (2024). After curing for 28 days, the initial weights of the specimens were recorded. The test setup included a transparent glass container filled with water, with a 100 ml mark measured from the top. A 16 mm diameter Wettex (J-cloth) was positioned inside the container to absorb and transmit water onto the brick surface. The test brick was inclined at an angle of 27° at the base of the apparatus, with the J-cloth placed 400 mm above the brick. Water droplets were allowed to fall continuously onto the 130 mm × 100 mm face of the specimen for 40 minutes (Figure 4d). Following the test, the depth of the erosion pit formed on the brick surface was measured, and the erodibility index was determined.

3 RESULTS AND DISCUSSIONS

3.1 Lateritic Soil Material Particle Size Distribution

The particle size distribution results for the pulverised (powdered) oyster shells used in this study are presented in Table 2 and plotted in Figure 5.

Table 2: Particle size distribution

Sieve Sizes (mm)	Percentage passing (%)
2	86.61
1.18	69.38
0.6	32.68
0.3	16.76
0.15	8.52
0.075	4.12
0.063	1.68
Pan	0.00

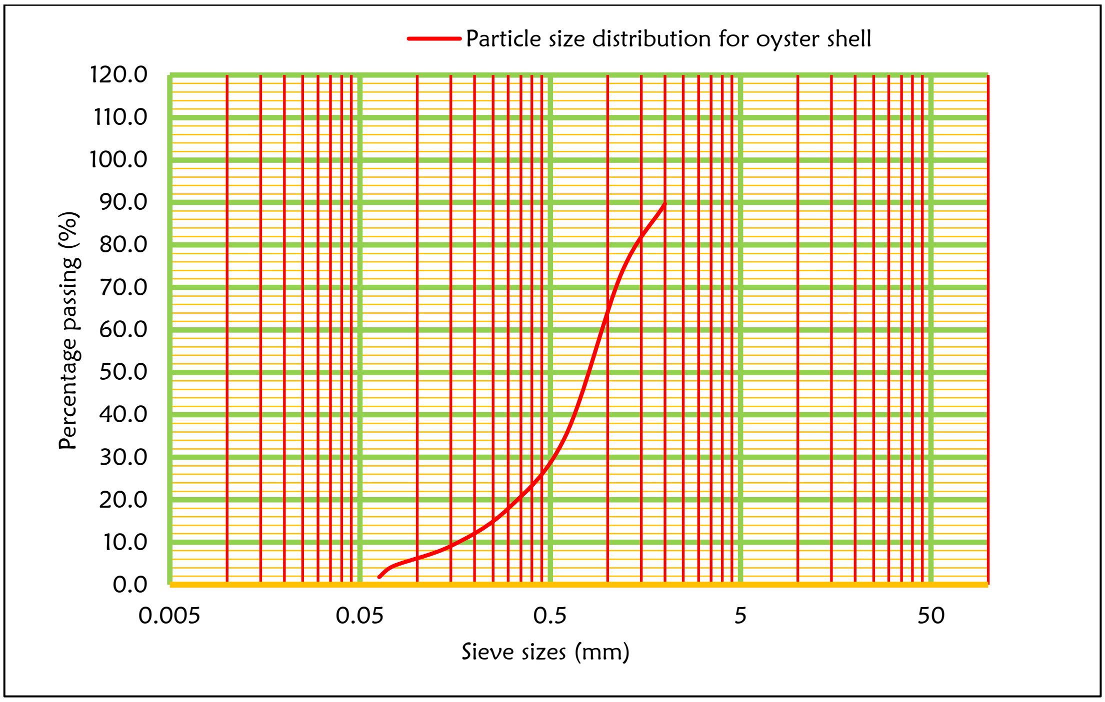

Figure 5: Particle size distribution curve

The data reveals a steady decrease in particle size from 2 mm to 0.063 mm, with a sharp drop in the percentage passing through sieve size 1.18 mm (69.38%) and sieve size 0.6 mm (32.68%). The oyster shells powdered sample is therefore considered poorly graded, with a relatively low fines content (only 4.12% passing the 0.075 mm sieve). This intermediate grading and lack of very fine particles suggest its suitability as a stabilizing agent in earth bricks or soil blocks, contributing to improved structural performance.

3.2 Density Test results

The mean density values of the lateritic soil bricks enhanced with varying proportions of pulverized oyster shells and tested for the 7, 14, 21, and 28 days are shown in Table 3 and plotted in Figure 6. From the results, density increases with extended curing durations, which suggests enhanced compaction and steady moisture loss over time. For example, at 1% oyster shell content, density increased from 1718 kg/m³ at 7 days to 1779 kg/m³ at 28 days. In the 7 days curing duration, the recorded densities were 1672, 1716, 1718, 1749, 1752, 1728, and 1592 kg/m³ for 0%, 0.5%, 1%, 1.5%, 2%, 2.5%, and 3% oyster shell content, respectively. This trend confirms that extended curing results in better matrix development, leading to lesser voids and increased material compactness. In 14 days curing duration, the control brick samples recorded a mean density value of 1665 kg/m³. Density values steadily increased to 1743 kg/m³ at the 2% oyster shell powder addition, before declining slightly to 1729 kg/m³ and 1621 kg/m³ at the 2.5% and 3% oyster shells powder addition levels respectively. This indicates that while lower oyster shell additions enhance density, higher amounts may begin to negatively affect the matrix structure. At 28 days, the densities recorded were 1727, 1768, 1779, 1769, 1806, 1740, and 1744 kg/m³ for the 0%, 0.5%, 1%, 1.5%, 2%, 2.5%, and 3%, oyster shells powder addition levels respectively. Notably, the highest density was achieved at 2%, affirming its effectiveness in densifying the brick matrix.

Table 3: Density test results (kg/m³)

	Oyster shell percentages						
Curing days	0%	0.5%	1%	1.5%	2%	2.5%	3%
7	1672	1716	1718	1749	1752	1728	1592
14	1665	1668	1772	1735	1743	1729	1621
21	1658	1724	1724	1741	1747	1729	1705
28	1727	1768	1779	1767	1806	1740	1744

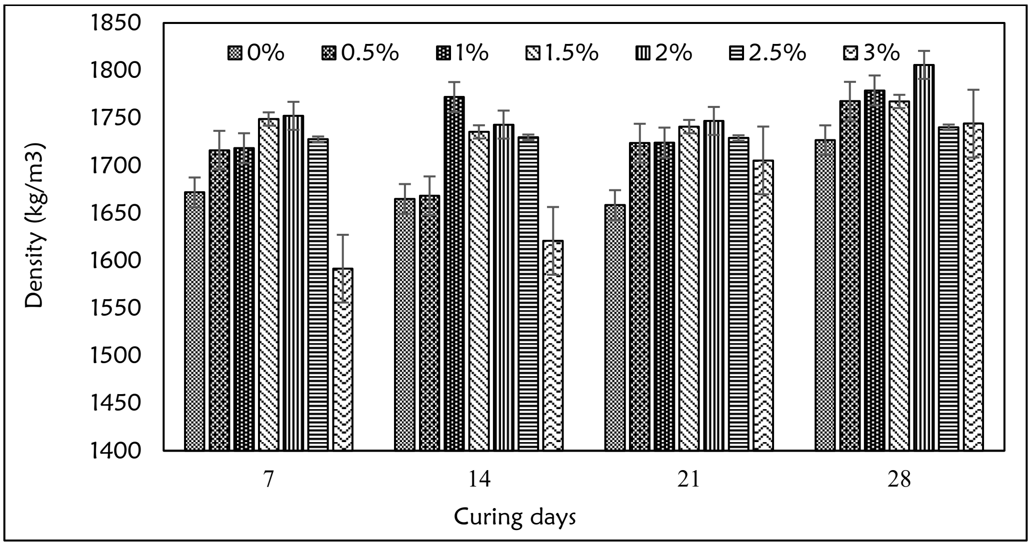

Figure 6: Variation of density with curing durations

The results demonstrate that 2% addition of oyster shells powder consistently yields the highest density across all curing periods. This enhancement is linked to the filler effect of fine shell particles and possible formation of calcium silicate hydrates (C-S-H), which enhance interparticle bonding and reduce void ratio. However, at 2.5% oyster shells powder content, the slight reduction in density indicates a point of diminishing returns, while at 3% oyster shells powder content, the significant drop particularly at early curing ages may result from poor particle distribution, excess unreacted material, or disruption of cohesive bonds. Oke et al. (2022) studied the strength characteristics of oyster shell ash and periwinkle shell ash as eco-friendly stabilizers for lateritic soils in pavement construction. Their results showed massive enhancement in the soil dry density. Furthermore, Ez-zaki et al. (2019) observed that incorporating calcined oyster shell waste and other marine residues led to decrease in density and increase in porosity. In contrast, the present study found that the density of the lateritic soil bricks was influenced by curing periods consistent with Liu et al. (2022) who reported that the inclusion of pulverized oyster shells improved compressed soil density up to an optimum dosage of 2%, beyond which a decline was noted. The density values recorded fall within the acceptable range specified for compressed earth bricks, confirming the potential of oyster shells powder as a viable stabilizing agent for unfired lateritic soil bricks.

3.3 Compressive Strength Test Results

The results given in Table 4 and plotted in Figure 7 showed consistent appreciation in compressive strength with increasing curing duration, indicating that extended curing period enhances matrix densification and promotes ongoing hydration. In 7 days curing duration, the control brick samples recorded a compressive strength value of 1.16 N/mm². Compressive strength values increased to 1.23 N/mm², 1.31 N/mm² and 1.40 N/mm² for the 14, 21 and 28 days, curing durations respectively, reflecting the continued development of strength with time. The maximum compressive strength value of 1.97 N/mm² was obtained at the 2% oyster shells powder content in the 28 days, curing duration. This performance was significantly higher than the 1.40 N/mm² recorded at 0% oyster shells powder content samples, representing a 28.9% increase in strength. The results confirm that both curing duration and oyster shells powder content significantly influenced the compressive strength behaviour. The optimal performance at 2%

oyster shells powder content is attributed to the filler effect where fine particles reduce internal voids and gradual pozzolanic reactions that enhance the structural matrix over time. Conversely, the reduced performance at 3% oyster shells powder content indicates that over-replacement can compromise the integrity of the mix, underscoring the importance of dosage optimization.

Table 4: Compressive strength test results (N/mm²)

	Oyster shell percentage additions						
Curing days	0%	0.5%	1%	1.5%	2%	2.5%	3.0%
7	1.16	1.33	1.41	1.45	1.49	1.42	1.27
14	1.23	1.49	1.51	1.67	1.69	1.60	1.34
21	1.31	1.55	1.61	1.69	1.76	1.65	1.36
28	1.40	1.57	1.65	1.82	1.97	1.78	1.42

The ANOVA analysis revealed that strength increases steadily from 1.40 N/mm² at the 0% oyster shells powder content to 1.97 N/mm² at 2% oyster shells powder content (Table 5). The lowest variability (Std Dev = 0.027; SEM = 0.016) was observed at 2% oyster shells powder content, indicating consistent and reliable strength results. This statistical summary supports the recommendation of using 2% oyster shells powder content for producing high strength and reliable stabilized lateritic soil bricks. The result revealed that a significantly difference exist among the treatment levels.

For practical application in stabilized lateritic soil bricks production, a 2% oyster shells powder content with 28 days of curing is recommended to achieve maximum compressive strength. The results of the present study agree with findings reported by Liu et al. (2022), who investigated the recycling of calcined oyster shell ash as a partial replacement for lime in the production of unfired fly ash bricks. They observed a notable improvement in the bricks' compressive strength development however, excessive addition was found to slightly reduce durability, suggesting an optimal threshold for oyster shells ash usage.

3.4 Split Tensile Strength Test Results

The results presented in Table 6 and plotted in Figure 8 indicate a steady increase in split tensile strength with curing time across all oyster shells powder addition levels, highlighting the positive effect of prolonged curing on strength development. The highest split tensile strength value of 0.16 N/mm² was obtained at the 2% oyster shells powder content in the 28 days, curing duration. This performance was significantly higher than the 0.12 N/mm² recorded at 0% oyster shells powder content samples, representing a 25% increase in strength. However, increasing the dosage beyond 2% oyster shells powder content resulted in a decline, with a 25% strength reduction at the 3% pulverised oyster shells addition compared to the 2% pulverised oyster shells addition lateritic soil bricks.

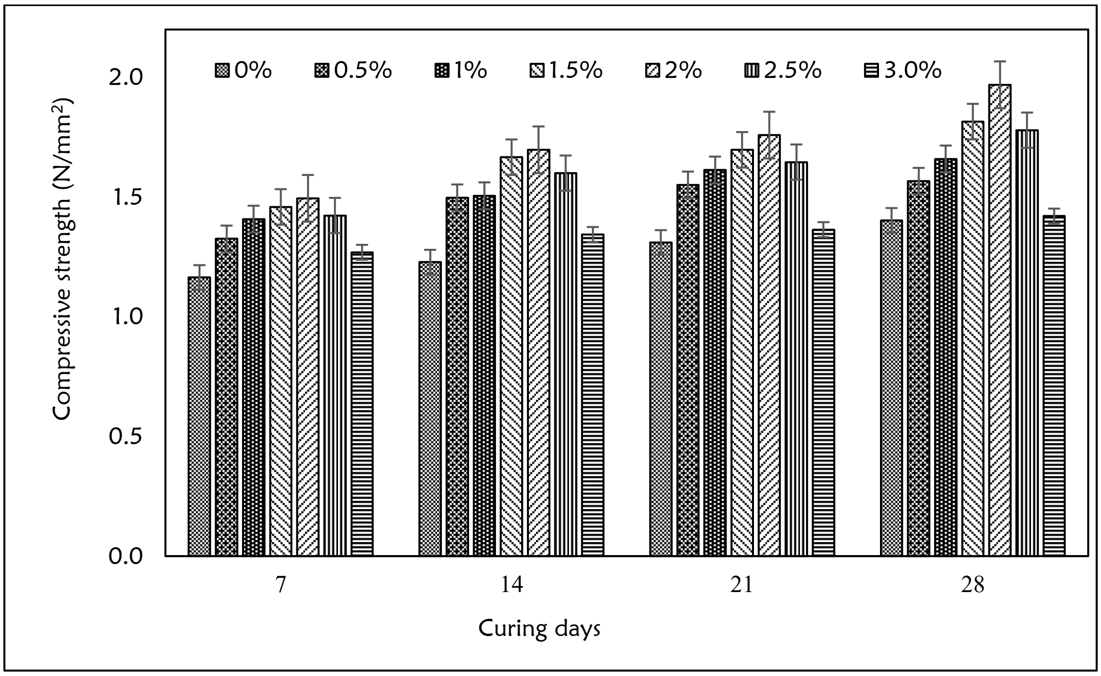

Figure 7: Variation of compressive strength with curing durations

Table 5: ANOVA analysis of compressive strength values after 28 days

Treatment level	N	Missing	Mean	Std Dev	SEM
0.0%	3	0	1.40	0.137	0.079
0.5%	3	0	1.57	0.135	0.078
1.0%	3	0	1.65	0.100	0.058
1.5%	3	0	1.82	0.064	0.037
2.0%	3	0	1.97	0.027	0.016
2.5%	3	0	1.78	0.045	0.026
3.0%	3	0	1.42	0.104	0.060

Table 6: Split tensile strength test results (N/mm²)

	Oyster shell percentages						
Curing days	0%	0.5%	1%	1.5%	2%	2.5%	3.0%
7	0.05	0.06	0.07	0.08	0.09	0.08	0.06
14	0.07	0.08	0.09	0.09	0.10	0.09	0.08
21	0.08	0.09	0.09	0.12	0.13	0.11	0.09
28	0.12	0.12	0.14	0.15	0.16	0.14	0.12

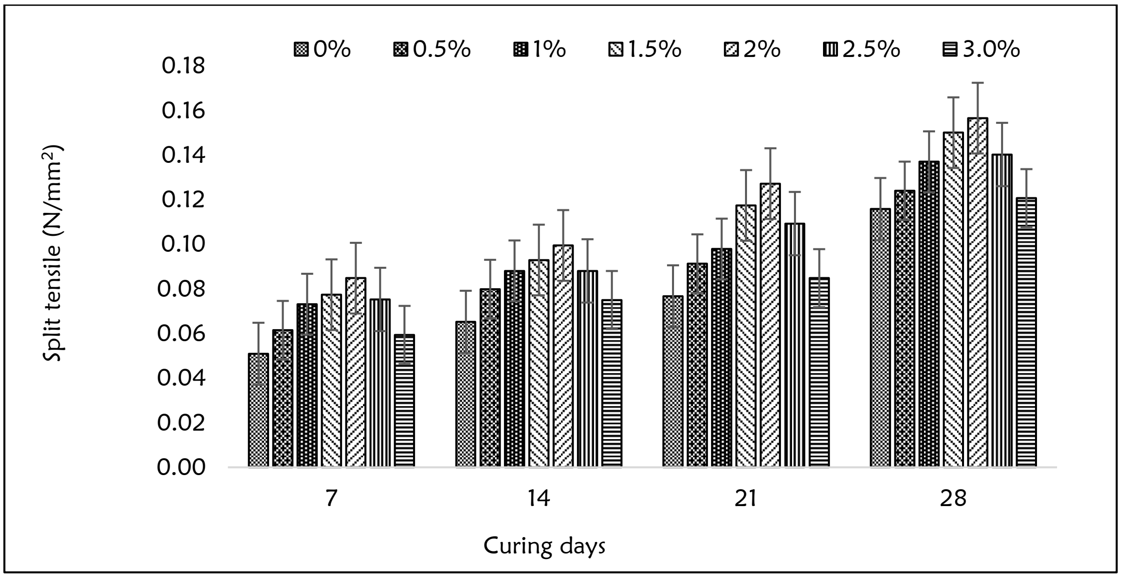

Figure 8: Variation of split tensile strength with curing durations

Table 7: ANOVA analysis of split tensile strength values after 28 days

Treatment level	N	Missing	Mean	Std Dev	SEM
0.0%	3	0	0.12	0.027	0.016
0.5%	3	0	0.12	0.015	0.009
1.0%	3	0	0.14	0.007	0.004
1.5%	3	0	0.15	0.002	0.001
2.0%	3	0	0.16	0.002	0.001
2.5%	3	0	0.14	0.007	0.004
3.0%	3	0	0.12	0.029	0.017

The ANOVA analysis presented in Table 7 showed a maximum split tensile strength value of 0.16 N/mm² obtained at 2% oyster shells powder addition level with a low standard deviation (0.002) and SEM (0.001), indicating minimal variability in the data. The analysis indicates that 2% oyster shell powder content could be added to soil for maximum split tensile strength gain and material efficiency. However, exceeding 2% oyster shells powder addition content, could lead to diminishing returns and greater variability. The result revealed that a significantly difference exist among the treatment name groupings. The results of this study align with the findings of Liu et al. (2022) who reported that the addition of oyster shells powder increased compressed soil split tensile strength marginally up to an optimum, and declined with further addition.

3.5 Water Absorption Test Results

From the results given in Table 8 and plotted in Figure 9, there is a consistent decrease in water absorption with increasing oyster shells powder content up to the 2% addition level. For instance, the control soil bricks recorded an average percentage water absorption value of 4.83%. Water absorption percentage value dropped to 3.21% at the 2% oyster shells powder addition level, representing an overall reduction of 33.5% in water absorption compared to the control soil brick samples. Beyond the 2% oyster shells powder content, water absorption begins to increase marginally with further addition of the oyster shells powder. The incorporation of the oyster shells powder to soil material appears to significantly reduce the porosity of bricks at lower contents and increase porosity at higher additions. Liu et al. (2022) found that the incorporation of pulverised oyster shells in soil material refined the pore size distribution and reduced the overall porosity as well as the water absorption of the brick composites. Again, Chen et al. (2019) also observed that cement mortar samples containing 30% oyster shell waste consistently exhibited lower water absorption values at 7, 28, and 90 days compared to the control samples.

Table 8: Water absorption test results (%)

	Oyster shell percentage additions						
Curing days	0%	0.5%	1%	1.5%	2%	2.5%	3%
28	4.83	4.55	4.26	4.01	3.21	3.68	3.79

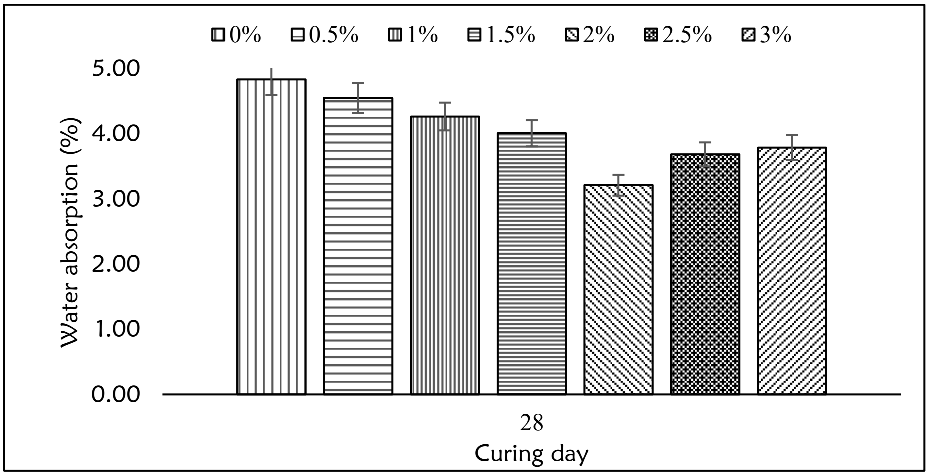

Figure 9: Average water absorption percentage values of soil bricks (%)

3.6 Erosion Test Results

Table 9 shows the results of the oyster shells powder content lateritic soil brick samples erosion behaviour. The average depth of penetration, erodibility index (EI) and the corresponding qualitative erosion rating were analysed. The results show that erosion resistance improves with increasing oyster shells powder content up to the 2% addition level, where the lowest erosion depth of 0.9 mm was recorded representing 89% reduction over the control brick samples. Beyond this optimum point, erosion resistance declined, as evidenced by the increase in erosion depth to 2.9 mm at 3% oyster shells powder content. Pit depths of 8.5 mm, 5.7 mm and 4.8 mm were recorded at the 0%, 0.5% and 1% oyster shells powder content lateritic soil bricks stabilisation levels, which fall within the erosive rating. However, soil bricks stabilised with 1.5%, 2%, 2.5% and 3% oyster shells powder recorded lower pit depth values of 2.3 mm, 0.9 mm, 1.2 mm and 2.9 mm respectively. These depths of penetration fall below the erodibility index value of 4, showing considerable level of resistance to wear according to New Zealand Standard 4298 (2024).

The 2% oyster shells powder stabilised soil bricks recorded the lowest depth of penetration of 0.9 mm, and beyond that the depth of penetration starts increasing marginally with further oyster shells powder addition. Therefore, for practical applications especially in external walls or moisture-prone environments a 2% oyster shells powder addition is recommended to enhance erosion resistance and structural durability. In similar studies, Lejano et al. (2019) observed that compressed earth blocks incorporating 10% green mussel shell powder and 0.75% pig hair fibre performed best in a drip erosion test, indicating that the green mussel shell and pig hair fibre combination effectively enhanced erosion resistance. Liao et al. (2022) also found that partially replacing cement with oyster shell waste powder increases cement mortar resistance to erosion with further addition. They attributed this to the formation of pozzolanic reaction products, which reduced the total pore volume.

Table 9: Erosion test results (mm)

Curing duration	% addition of oyster shells powder	Average depth of pit (mm)	Erodibility Index (E1)	Rating
28 days	0.0%	8.5	2	Erosive
	0.5%	5.7	3	Erosive
	1.0%	4.8	2	Erosive
	1.5%	2.3	2	Slightly erosive
	2.0%	0.9	2	Slightly erosive
	2.5%	1.2	2	Slightly erosive
	3.0%	2.9	2	Slightly erosive

4 CONCLUSIONS

The study investigated the density, compressive strength, split tensile strength, water absorption and erosion resistance behaviour of lateritic soil bricks stabilised with pulverised (powdered) oyster shells. Based on the analysis and discussions of the test results, the following conclusions can be drawn:

i. The density, compressive strength and split tensile strength of the experimental lateritic soil bricks increased steadily up to the 2% pulverized (powdered) oyster shells stabilization level. Beyond the 2% stabilization level, the soil brick samples density, compressive strength and split tensile strength declined with further addition of the powdered oyster shells.
ii. Again, the addition of the powdered oyster shells reduced the stabilized lateritic soil bricks water absorption steadily up to the 2% stabilization level representing 33.6% reduction in water absorption compared to the control soil bricks. Water absorption increased marginally with further addition of the powdered oyster shells beyond the 2% addition level.
iii. Furthermore, the stabilized lateritic soil bricks resistance to erosion steadily increased with increasing addition of the powdered oyster shells content. Lateritic soil brick samples stabilized with 2% powdered oyster shells recorded the lowest erosion depth of 0.9 mm representing 89% reduction in erosion compared to the control lateritic soil brick samples.
iv. From the results, the study therefore concludes that 2% powdered oyster shells content represents the optimal threshold for improving unfired lateritic soil bricks density, compressive strength, split tensile strength, water absorption and erosion resistance without compromising structural integrity. Exceeding this dosage may lead to diminishing returns or performance decline.
v. The stabilized soil bricks are therefore suitable for medium load-bearing earth walls in moderately damped climatic environments for improved short-term strength and durability properties. This study did not investigate the long-term stabilization effect of the powdered oyster shells on the strength and durability properties of the stabilized soil bricks. Hence, it is recommended that further studies could done to determine the long-term strength and durability properties of powdered oyster shells stabilized soil bricks for sustainable soil housing in rural areas.

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