

Structural Performance of Adobe Blocks Stabilized with Parkia Biglobosa Seeds Wastewater

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Abstract

Adobe blocks construction remains an essential housing solution in many regions due to its affordability and accessibility. However, traditional adobe blocks face limitations, including low compressive strength and vulnerability to moisture, which restrict their durability and broader use. This study explores the potential of *Parkia biglobosa* wastewater (PBWW) as a sustainable stabilizer for adobe blocks, addressing the limitations of traditional adobe. Red clay soil from Juja, Kenya, was combined with PBWW, whose high calcium and potassium content promotes pozzolanic reactions, forming durable calcium silicate and aluminate hydrates.

The primary objective of this study was to assess the potential of *Parkia biglobosa* wastewater (PBWW) as an environmentally friendly stabilizer for adobe blocks. Specially, it aimed to assess the compressive strength, water absorption, and abrasion resistance of blocks stabilized with different PBWW percentages (0, 5%, 10%, 15%, and 25%). The study also aimed to evaluate the mechanical strength, durability, and sustainability of PBWW-stabilized adobe bricks to those stabilized with conventional and organic methods.

The red clay soil was sieved through 5 mm screen to remove larger particles, ensuring uniformity, and combined with *Parkia biglobosa* wastewater (PBWW) obtained by boiling the seeds for six hours, which was used as a stabilizer in varying the percentages. Adobe blocks measuring $12 \times 14 \times 29 \text{ cm}^3$ were molded from this mixture and cured in shaded conditions for 7, 14, 28, and 56 days to optimize stabilization. The blocks were then tested for compressive strength, water absorption, and abrasion resistance, following British, African Regulatory and Kenyan standards to ensure reliable results.

Results revealed that 10% PBWW achieved optimal compressive strength, surpassing the Kenyan Standard (2.5 MPa, KS 02-1070:1993) and the British Standard for clay bricks (2.8 MPa, BS 3921:1985) at 28 days, while 25% PBWW provided the highest water resistance and durability. The improvement of compressive strength at 10% PBWW is attributed to effective particle bonding and optimal mineral interaction, which enhanced the cohesion of soil particles. These results demonstrated the effectiveness of *Parkia Biglobosa* wastewater in improving the compressive strength and water resistance of soil blocks. However, beyond 10%, diminishing returns were observed, as excess organic material disrupted the soil particle matrix, leading to reduced compressive strength. Similarly, water resistance and durability increased significantly at higher PBWW concentrations, with 25% delivering the best performance by reducing porosity and improving cohesiveness.

The use of *Parkia biglobosa* wastewater (PBWW) as a stabilizer for adobe blocks improves the compressive strength, water absorption, and abrasion resistance. This is due to PBWW's unique mineral composition, particularly its high CaO and K₂O content, enhances pozzolanic reactions more effectively than traditional

organic stabilizers. The use of PBWW also demonstrates significant environmental advantages over conventional stabilizers like cement and lime by reducing the carbon footprint while utilizing a locally available by-product.

Keywords: Clay soil, Stabilize, Adobe blocks, Sustainable construction, Parkia Biglobosa, Structural performance

1. Introduction

Adobe building is still necessary in many countries, like Burkina Faso, where adobe blocks account for around 63% of rural housing due to their cost and availability [5]. Approximately 30% of the global population still lives in earthen structures, indicating adobe's significance as an accessible, low-cost building material, particularly in locations with limited access to contemporary construction materials [4]. Despite its economic and environmental benefits, adobe's limitations, notably its poor mechanical strength and susceptibility to moisture, make it difficult to maintain and use in some areas.

To solve these constraints, researchers have worked on enhancing adobe using stabilizing methods. Studies have shown that adding binders such as cement and gypsum can improve adobe's mechanical qualities; however, these additions come with trade-offs such as greater weight loss, shrinkage, and moisture sensitivity [6]. Moreover, particle packing techniques have been investigated as an efficient method of improving the physical and mechanical characteristics of stabilized earth blocks by optimizing the proportions of clay, silt, and sand in their composition [8]. Recent studies have highlighted the role of natural stabilizers and fibers, such as *Grewia bicolor* bark juice and piassava fibers, in improving the mechanical performance and durability of earth blocks, offering eco-friendly alternatives to cement [2, 9]. However, there is limited experimental evidence on the combined effects of organic stabilizers such as *Parkia biglobosa* wastewater (PBWW) on both the mechanical and durability properties of adobe blocks. This highlights a gap in understanding how PBWW interacts with clay minerals to enhance compressive strength, water resistance, and abrasion performance.

In certain situations, the use of organic and plant-based stabilizers has showed promise for increasing durability while retaining adobe's environmental benefits, highlighting the possibility for sustainable and locally produced solutions [10]. For instance,

the incorporation of natural fibers and stabilizers has been shown to reduce erosion and improve structural stability in ancient Roman adobe bricks [11], while natural reinforcements such as molasses and fly ash enhance the long-term durability of adobe structures [11, 12]

Parkia biglobosa, often known as Nere in Burkina Faso and Africa locust beans in other areas, is a possible organic stabilizer for adobe. The chemical composition of *Parkia biglobosa* seed wastewater contains critical elements such as calcium, magnesium, potassium, and iron, which are also found in traditional stabilizing agents such as lime and cement [1]. This mineral-rich composition implies that *Parkia biglobosa* wastewater might function similarly to these binders, increasing the compressive strength, durability, and water resistance of adobe bricks. Natural stabilizers, such as African locust bean wastewater, have been shown in studies to increase mechanical characteristics and moisture resistance in clay blocks, which is crucial in places with changing weather conditions [14].

Additionally, *Parkia biglobosa* seed high calcium concentration, which can form connections between soil particles like to those seen in cementitious materials, contributes to its chemical stabilization process. In the manufacturing of adobe, where strength and environmental friendliness must be balanced, this technique is especially helpful [15]. For example, research has demonstrated that bricks with adobe that contains natural binders containing calcium, iron, and other stabilizing elements are more resistant to erosion and shrinkage [16]. Because of these characteristics, *Parkia biglobosa* seed wastewater is a perfect fit for adobe stabilization in Burkina Faso and other comparable areas.

When choosing a stabilizer, the sustainability factor is quite important. Eco-friendly substitutes like *Parkia biglobosa* seed wastewater complement global sustainability aims by lessening the ecological footprint of construction, while traditional materials like cement greatly increase

greenhouse gas emissions. In order to ascertain the impact of adding different percentages of *Parkia biglobosa* seed wastewater 0%, 5%, 10%, 15%, and 25% to adobe blocks on their structural qualities, this study will assess the blocks.

2. Objectives

The objectives of this research include characterizing the physical and chemical properties of the materials used to stabilize adobe blocks. The clay soil was evaluated for its moisture content, specific gravity, particle size distribution, Atterberg limits, compaction properties, and chemical composition, while the *Parkia biglobosa* seeds were analysed using XRF tests to determine their mineral content. This characterization provides a foundation for understanding the interactions between the clay soil and PBWW and their potential for producing durable adobe blocks.

Additionally, the study aimed to assess the performance of adobe blocks stabilized with varying percentages of PBWW (0%, 5%, 10%, 15%, and 25%) by evaluating their compressive strength, water absorption, and abrasion resistance. A comparative analysis was also conducted to benchmark the mechanical strength, durability, and sustainability of PBWW-stabilized blocks against conventional stabilizers like cement and organic alternatives, such as *Grewia bicolor* bark juice.

3. Materials and Methods

3.1 Raw materials

The clay soil utilized in this study was gathered from Jomo Kenyatta University of Agriculture and Technology (JKUAT) in Juja, which is located in Kiambu County in central Kenya. With two wet seasons and a mild climate, this area which is situated at latitude 1.1773° S and longitude 37.0775° E is perfect for extracting high-quality clay. Because of its rich clay composition and ease of access to academic institutions, the JKUAT campus was selected to support extensive testing and experimentation for the manufacturing of adobe blocks.

The leguminous tree known as "nere," or *Parkia biglobosa*, is indigenous to West Africa, especially Burkina Faso, where it flourishes in the Sahelian climate. Prized for its seeds, which are used to make the fermented condiment "soubala," the tree

contributes significantly to the environment by improving soil quality and halting erosion. Rich in minerals like calcium, potassium, and magnesium, the wastewater from its seeds stabilizes building materials in an environmentally sustainable and efficient way, increasing their strength and longevity and fostering sustainability in both urban and rural building applications.

The *Parkia biglobosa* seeds used in this study were sourced from Burkina Faso, a region known for its agricultural richness and the abundance of African locust bean trees, as the country is a significant producer of this species due to its favorable Sahelian and Sudanian climates. To comply with Kenyan regulations, authorization was obtained from the Kenya Plant Health Inspectorate Service (KEPHIS) for the importation of the seeds. The seeds were transported by plane to Kenya, ensuring adherence to all ethical and regulatory requirements for international transportation, where they were then utilized in the experiments.

3.2 Manufacture of adobe blocks

To achieve a fine and uniform texture for adobe block manufacture, the red clay soil was prepared and sieved through a 5 mm screen to eliminate bigger particles and stones. This ensured consistency in the clay matrix and improved workability. *Parkia biglobosa* seed wastewater (PBWW), obtained by boiling seeds, was employed as a stabilizer. The PBWW was prepared by boiling 4 kg of *Parkia biglobosa* seeds in 18 kg of potable water for 6 hours, during which the volume of liquid was reduced to approximately 7 kg. The wastewater was extracted using a fine mesh sieve or cheesecloth to separate solids from the liquid, ensuring a clean stabilizer. The average water content of each adobe brick was calculated using the Atterberg liquid and plastic limit values, ensuring ideal brick formation uniformity. Different amounts of PBWW (5%, 10%, 15%, and 25% by weight) were used to replace an equal amount of potable water in the combination. These percentages were selected based on preliminary tests and literature insights, which indicated their effectiveness in improving mechanical properties.

After preparing the components, a uniform clay mud was created by completely mixing the soil with

the PBWW stabilizer. The materials were thoroughly mixed by hand and with shovels to achieve homogeneity, ensuring that the PBWW was evenly distributed throughout the mixture. The material was firmly pressed into rectangular molds ($12 \times 14 \times 29 \text{ cm}^3$), similar to Kenyan earth blocks, to ensure equal compaction and remove air pockets. Careful compaction was critical to eliminate voids and enhance the block's density and strength. To increase durability, the molded adobe bricks were cured in a shaded area, rotated to ensure equal drying during the first several days, and then cured for 7, 14, 28, and 56 days. Curing in shaded conditions minimized rapid moisture loss, which could lead to cracking, while allowing sufficient time for the pozzolanic reactions between clay silica and PBWW minerals to develop stable bonds. These curing processes, which were based on both traditional methods and research, enabled the clay-PBWW combination to stabilize and reach excellent mechanical and physical qualities. The



Figure 1 illustrates adobe blocks after production.

Figure 1: Adobe blocks produced

3.3 Experimental study

a) Chemical analysis

The Laboratory of the Ministry of Mining in Kenya evaluated the red clay soil and *Parkia biglobosa* seeds chemically to determine whether they were suitable for supporting adobe blocks. In addition to calcium and magnesium, which affect flexibility and binding capability, the red clay soil was examined for elements including silicon, aluminum, and iron oxides, which contribute to its mineralogical composition and mechanical strength. It was discovered that the seeds from *Parkia biglobosa* seeds contained vital minerals such calcium and potassium, which are comparable to those found in

conventional stabilizers like lime. These characteristics demonstrated how the wastewater might enhance the durability and compressive strength of adobe bricks, offering a locally sourced, sustainable substitute for building applications.

b) Particle size analysis

The suitability of the red clay soil for adobe block construction was assessed by analyzing its particle size distribution in accordance with BS 1377, Part 2, 1990. Sand and gravel were separated using sieve analysis for soil particles bigger than 0.075 mm, while the proportions of silt and clay were ascertained using hydrometer analysis for finer particles. For sedimentation examination, about 50 g of soil was passed through a 2 mm sieve; more than 60% of the particles passed through the 0.075 mm filter, necessitating hydrometer measurement. Particle settlement rates in suspension were determined using hydrometer analysis to precisely distinguish finer components. The findings gave a thorough analysis of the soil's composition and confirmed that the clay's workability, plasticity, and binding potential satisfied the necessary requirements for adobe stabilization.

c) Atterberg limits

In order to assess the red clay soil's workability and plasticity, the Atterberg limits, a crucial indicator of soil consistency, were established. Tested in accordance with BS 1377-2:1990 standards, these limitations include the liquid limit (LL), plastic limit (PL), and plasticity index (PI). To guarantee homogeneity, the tests were conducted on the soil fraction that had passed through a 0.425 mm screen. The cone penetrometer method, which measures moisture at 20 mm penetration, was used to estimate the liquid limit, which is the moisture content at which soil changes from a plastic to a liquid condition.

The moisture level at which soil crumbles when rolled into thin threads was determined to be the plastic limit. The soil's plastic range was represented by the plasticity index, which was calculated as the difference between the liquid and plastic limits. To measure the percentage length loss as the soil dried, linear shrinkage was also calculated using a one-dimensional approach. These criteria helped evaluate the soil for stabilizing

adobe blocks by offering important insights into its behavior.

d) Moisture content

The gravimetric method described in BS 1377-2:1990 was used to measure the moisture content, also known as the water content. In order to eliminate all moisture, a 30 g soil sample was dried in an electric oven set at $105 \pm 5^\circ\text{C}$ for at least 12 hours. The weight of the water in the sample divided by the weight of the dry soil solids was then used to determine the water content. This approach guaranteed accurate moisture level estimation, which is essential for assessing soil characteristics in both field and lab settings.

Moisture content (%):

$$w = \frac{M_w}{M_s} = \frac{M_a - M_b}{M_b - M_c} \times 100 \quad (1)$$

where M_a = Mass of tin + wet soil specimen (g)

M_b = Mass of tin + dry soil specimen (g)

M_c = Mass of moisture content tin (g)

e) Specific gravity

According to BS 1377-2:1990, the 100 ml pycnometer method was used to measure the specific gravity of soil solids. In order to do this, 100 g of soil particles smaller than 2 mm have to be crushed and sieved. The liquid media was distilled water, while soils with soluble salts might benefit more from kerosene or white spirit. The pycnometer's weights in the following states were used to compute the specific gravity: empty, with dry soil, with soil and water, and fully filled with water. The density of the soil particles was precisely measured using this technique.

Specific gravity:

$$G_s = \frac{M_1 - M_2}{(M_4 - M_1) - (M_3 - M_2)} \quad (2)$$

where M_1 = Mass of empty density bottle (g)

M_2 = Mass of bottle + oven-dry soil (g)

M_3 = Mass of bottle + soil + water (g)

M_4 = Mass of bottle full of water (g)

f) Compaction test

Compaction tests for soil-gravel mixtures were carried out in accordance with BS 1377-4:1990.

Both standard Proctor and modified Proctor techniques were applied; the latter compacted the material into five layers inside the same mold using a 4.5 kg rammer. By dividing the weight difference between the mold with and without the compacted sample by the internal volume of the mold, the bulk density of the compressed specimen was determined.

Bulk density:

$$\rho_w = \frac{M_2 - M_1}{V} \quad (3)$$

where M_2 = Mass of mold + compacted wet specimen (Mg)

M_1 = Mass of empty mold (Mg)

V = Internal volume of mold (m³)

The dry density was then derived by accounting for the specimen's moisture content.

Dry density:

$$\rho_d = \frac{\rho_w}{1 + w/100} = \frac{100\rho_w}{100 + w} \quad (4)$$

A compaction curve was generated by plotting dry density against moisture content, and the Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) were identified at the curve's peak for each soil mixture.

3.4 Technological properties

a) Compressive test

Using the Universal Testing Machine (UTM) as shown Figure 2, the blocks' compressive strength, a crucial characteristic for evaluating structural performance, was assessed. Following standard protocol, tests were carried out at 7, 14, 28, and 56 days. Each block's weight and dimensions were noted in order to determine the loaded area, and the blocks were oriented in relation to the loading axis of the UTM. The compressive strength was calculated using the following formula, with the maximum load being applied at a rate of 2.5 N/mm² per second until failure:

$$\sigma = \frac{F}{S} \quad (5)$$

Where: σ : maximum stress,

F : maximum load,

S: loaded area.



Figure 2: Compressive test on a block



Figure 3: Abrasion test on a block

b) Abrasion test.

In accordance with ARS 683: 1996, the abrasion as shown Figure 3 test was carried out at 28 and 56 days to evaluate the adobe blocks' resistance to wear, specifically for facing masonry. In contrast to compressive strength, this test assesses material durability, which is impacted by soil composition and stabilization rates. To measure the detached material, the block was weighed (m_1), brushed for 60 cycles (one back-and-forth motion per second) with a steel wire brush loaded with a 3 kg mass, and then reweighed (m_2). The following formula was used to determine the brushed surface area:

$$S = L \times W \text{ (in mm)} \quad (6)$$

Where:

L = Length of the brushed face of the block

W = width of the brush

Abrasion loss Al was determined as the mass of detached matter divided by the mass of the block, providing a measure of the block's resistance to surface wear.

Abrasion loss:

$$Al = \frac{m_1 - m_2}{m_1} \times 100 \text{ in } \% \quad (7)$$

c) Water absorption

The water absorption test as shown Figure 4 was used to determine the moisture content of adobe bricks as a proportion of their dry weight, in accordance with British Standard 1377:1967. Blocks were weighed (W_b) after being dried in an oven for 24 hours, submerged in water for an additional 24 hours, and then weighed again (W_a). Using the following formula, the water absorption was determined:

$$Mc = \frac{(W_a - W_b)}{W_b} \times 100 \quad (8)$$

Where:

W_a : mass after absorption

W_b : mass before absorption

Mc : percentage moisture absorption on a dry basis (%)



Figure 4: Water absorption test

4. Results

4.1 Chemical analysis

Table Error! No text of specified style in document.I: **Chemical analysis of the clay soil**

Clay Composition	Percentage (%)
SiO ₂	54.832
CaO	1.348
Al ₂ O ₃	20.61
Fe	14.882
Ti	4.085
Cl	1.634
K ₂ O	1.161
Other remaining	0.946

Table II: **Chemical analysis of the seeds**

Seeds Composition	Percentage (%)
SiO ₂	8.336
CaO	16.620
S	43.010
Fe	5.314
Ti	0.266
Cl	2.389
K ₂ O	23.703
Other remaining	0.360

4.2 Physical Properties of the Soil

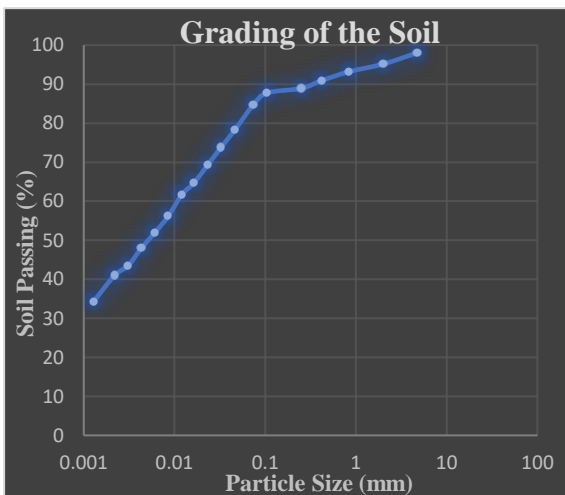


Figure 5: Particle size analysis of the soil sample

Table III: Physical properties of the clay soil

Clay properties	Results
Soil type	Predominantly clayey soil
Liquid limit (%)	42%
Plastic limit (%)	22.4%
Plastic index (%)	19.6%
Linear shrinkage	8.36
Specific gravity	2.5
Maximum Dry Density (kg/m ³)	1405 kg/m ³
Optimum Moisture Content (%)	27%
Color	Red clay

4.3 Adobe blocks compressive test

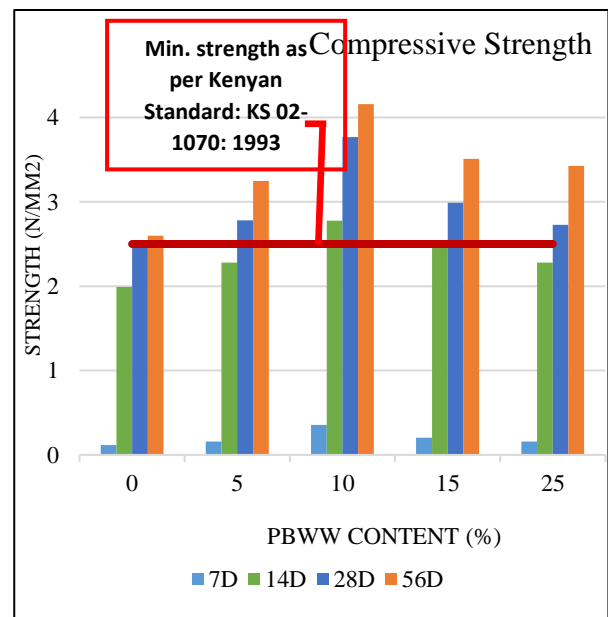


Figure 6: Compressive test results

4.4 Abrasion test

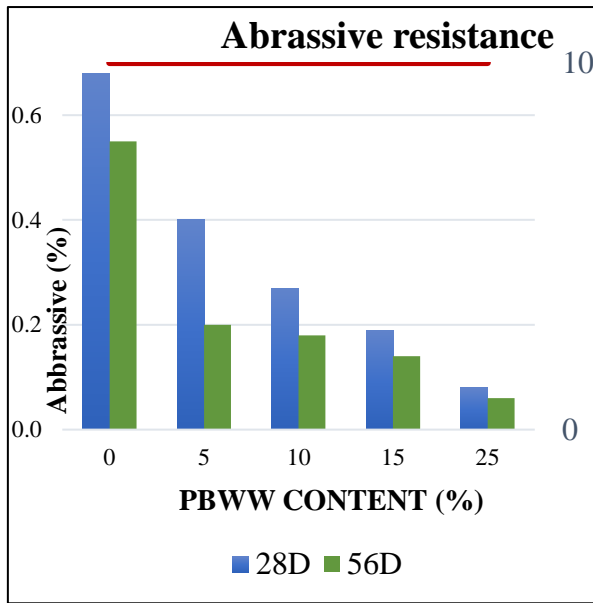


Figure 7: Abrasion test results

4.5 Water absorption test

Table Error! No text of specified style in document.IV: Water absorption test results

Age (days)	Mix Proportion	Average time to start disintegrating	Average time to block rupture
7	0%PBWW + 100%OMC	5 min	25 min
	5% PBWW + 95%OMC	10 min	35 min
	10% PBWW + 90%OMC	15 min	39 min
	15% PBWW + 85%OMC	15 min	46 min
	25% PBWW + 75%OMC	25 min	58 min
	0% PBWW + 100%OMC	8 min	50 min

14	5% PBWW + 95%OMC	15 min	55 min
	10% PBWW + 90%OMC	19 min	1h15 min
	15% PBWW + 85%OMC	27 min	1h35 min
	25% PBWW + 75%OMC	25 min	2h19 min
28	0% PBWW + 100%OMC	11 min	1h17 min
	5% PBWW + 95%OMC	22 min	2hrs
	10% PBWW + 90%OMC	30 min	2hrs 34 min
	15% PBWW + 85%OMC	30 min	2hrs 58 min
	25% PBWW + 75%OMC	38 min	3hrs 40 min
56	0% PBWW + 100%OMC	17 min	1hr 45 min
	5% PBWW + 95%OMC	35 min	3hrs
	10% PBWW + 90%OMC	39 min	3hrs 33 min
	15% PBWW + 85%OMC	43 min	4hrs
	25% PBWW + 75%OMC	57 min	5hrs

5. Discussion

5.1 Chemical analysis

The clay soil's chemical composition, high in SiO₂ (54.832%) and Al₂O₃ (20.61%), affects pozzolanic reactions when mixed with CaO (16.62%) from *Parkia biglobosa* seeds as shown Table I and Table II. Pozzolanic reactions occur when silica and alumina in clay react with calcium oxide in the presence of water, producing calcium silicate hydrate (C-S-H) and calcium aluminate hydrate (C-A-H). These chemicals considerably increase the compressive strength, cohesiveness, and durability of adobe bricks. This process is consistent with the findings of [18, 17], who suggest that such reactions increase structural integrity by lowering porosity and improving bond strength. The seeds' high K₂O (23.703%) concentration accelerates the pozzolanic process by activating silica and alumina, facilitating quicker stabilization and cure, according to [1].

The presence of S (43.01%) in the seeds improves the moisture resistance and longevity of the blocks, enhancing the clay's natural binding qualities. Furthermore, the clay's Fe (14.882%) concentration improves mechanical performance, enhancing resistance to mechanical stress and environmental deterioration, as reported by [22, 20]. This combination of clay and seed components not only capitalizes on natural pozzolanic processes, but also offers an environmentally responsible and cost-effective stabilizing option. [19, 21] found that the combination of these materials improves adobe block mechanical strength, reduces shrinkage, and increases durability.

5.2 Physical Properties of the Soil

The red clay soil examined has 50% clay and 28.4% silt, for a total of 78.4% fines. [25] advised a fine range of 18-55% for earth block manufacture, which this surpasses. The gravel and sand concentrations are 4.8% and 16.8%, respectively, which are lower than the suggested values of 25-80% sand and 0-40% gravel for optimum particle dispersion in block building. As shown in Fig. 2, the particle size analysis of the soil sample supports these findings, with the majority of the soil particles falling within the fine range. As a result, the soil needs stabilization to enhance its coarser fraction balance, which is essential for decreasing shrinkage

and enhancing mechanical strength. Studies such as [26, 27] emphasize the need of adding stabilizers or mixing soils to satisfy these requirements, resulting in improved compaction and structural performance.

The Atterberg limits, as summarized in Table III, show a liquid limit of 42% and a plasticity index of 19.6%, indicating moderate plasticity appropriate for adobe manufacture. However, the linear shrinkage of 8.36% indicates a significant likelihood of drying fractures, which might jeopardize block integrity. [23, 3] underline the importance of stabilizing measures, such as the use of organic or mineral additives, in reducing shrinkage. Stabilizers such as seagrass fibers, recycled agricultural by-products, and synthetic materials can improve structural stability and prevent shrinkage in fine-grained soils [24, 19].

The maximum dry density (1405 kg/m³) and optimum moisture content (27%) are consistent with fine-grained soils, which normally require more moisture for compaction. The results align with the findings of [28, 29], who discovered that stabilization not only improves compaction but also increases the strength and durability of adobe blocks. The soil's specific gravity of 2.5 validates its mineralogical composition, as summarized in Table III, indicating that it is ideal for sustainable building when combined with proper stabilizers. These actions will improve the soil's performance while addressing its physical limits for earth block manufacturing.

5.3 Adobe blocks compressive test

The compressive strength test findings in Fig. 3 show how *Parkia biglobosa* wastewater (PBWW) composition affects the performance of adobe bricks across different curing times (7, 14, 28, and 56 days). Blocks without PBWW (0%) had compressive strengths lower than the Kenyan standard of 2.5 MPa (KS 02-1070:1993), particularly at 7 and 14 days, suggesting the necessity for stabilization. [22, 1] found similar findings, indicating that untreated soils lacked adequate bonding and structural stability. Similarly, research has shown that substituting clay and silt with fly ash in stabilized earth blocks can improve compressive strength by enhancing particle packing and

decreasing porosity [30]. As the PBWW level rises to 10%, the compressive strength exceeds the minimal criterion after 28 days, demonstrating the stabilizer's capacity to improve soil cohesion and particle bonding.

The best compressive strength is obtained at 10% PBWW, especially after 28 and 56 days of curing, when values surpass 3.5 MPa. This improvement is similar with the findings of [17, 18], who emphasized the importance of organic stabilizers in boosting load-bearing capacity and durability. Beyond 10% PBWW, compressive strength begins to fall significantly, especially at 15% and 25%, most likely due to an excess of organic material lowering particle bonding effectiveness. [21, 31] found comparable declining results at greater stabilizer concentrations, emphasizing the need of optimizing additive proportions for peak performance.

[27, 19] found that prolonged curing durations improve mechanical stability by optimizing hydration and chemical bonding. This enhancement guarantees that the blocks exceed critical building criteria, notably those pertaining to compressive strength and durability, which are critical for sustainable construction techniques. Thus, 10% PBWW appears to be the appropriate stabilizer concentration, achieving a compromise between structural performance and environmental sustainability. The combination of proper stabilizer content and delayed curing improves the long-term performance of adobe blocks, allowing them to fulfill structural integrity regulations while lowering environmental effect. This not only assures compliance with construction regulations, but it also encourages the development of low-cost, environmentally friendly building materials for use in sustainable design and engineering.

5.4 Abrasion test

The abrasion resistance data demonstrate how different percentages of *Parkia biglobosa* wastewater (PBWW) affect the durability of adobe bricks after 28 and 56 days of curing. As shown in Fig. 4, after 0% PBWW, the blocks have the greatest abrasion loss, with 0.6% material loss after 28 days and 0.4% at 56 days. This suggests low surface durability, most likely owing to a lack of stability. [22, 17] found that un-stabilized adobe bricks had

poor particle cohesion, which leads to increased wear under mechanical stress.

The use of PBWW considerably lowers abrasion loss, with the lowest values seen at 10% stabilizer concentration. At this ideal level, material loss is modest (less than 0.2%) on both 28 and 56 days. The mineral concentration in PBWW contributes to improved particle bonding and surface cohesion. [1, 32] indicate similar patterns, with organic stabilizers improving mechanical deterioration resistance by filling gaps and lowering porosity. However, at greater concentrations (15% and 25% PBWW), abrasion resistance drops marginally, presumably due to excess organic material disturbing soil particle matrix, as highlighted by [3].

Curing time improves abrasion resistance at all stabilizer doses, with considerable gains reported between 28 and 56 days. [27, 19] found that prolonged curing improves the integration of stabilizer components with soil particles and reduces surface wear. These findings highlight the importance of PBWW as an effective and long-lasting stabilizer for increasing the surface durability of adobe bricks, with 10% content and prolonged curing proving ideal for excellent performance.

5.5 Water absorption test

All stabilized blocks burst after a certain amount of time, as stated in the table 4. Blocks containing 0% PBWW began degrading in 3 minutes and broke fully after 25 minutes after 7 days of cure. In comparison, blocks stabilized with 25% PBWW performed substantially better, taking 25 minutes to begin dissolving and 58 minutes to rupture. The results show that raising the PBWW concentration increases water resistance by lowering porosity and boosting block cohesiveness. However, at the early curing phases, even stabilized blocks are moderately susceptible to water exposure.

After 56 days of curing, all blocks' water resistance had greatly improved. Blocks stabilized with 25% PBWW withstood disintegration for 57 minutes before rupturing after 5 hours, whereas blocks stabilized with 10% PBWW lasted 3 hours and 39 minutes. The prolonged curing period allowed the pozzolanic reaction between clay silica and PBWW calcium to produce stronger connections, resulting

in increased durability. These findings as shown Table IV indicate that adobe blocks stabilized with PBWW are better suitable for usage in construction where moisture exposure is limited, such as inside walls, to avoid fast degradation due to excessive soaking. [9]

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