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ARTICLE

Improving the Structural Properties of Sustainable Earthen Construction by Incorporating Lime

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ABSTRACT

Sustainable construction targets the reduction of the negative impacts of construction operations on the environment and improving the utilization of natural resources. It does this by reducing the cost of carbon emissions, the utilization of environmentally friendly materials, reducing energy and water usage, which increases the life of buildings, and reducing wastage through recycling. It is against this background that the current study discusses in detail how the physical characteristics of clay and sand bricks can be enhanced by the application of lime addition. From the results, it was concluded that 5%, 10%, 15%, and 20% of lime addition in the bricks improved the physical properties of the bricks considerably by raising their density from 2.1% to 4.65% and reducing their water absorption by 6.36%, as well as their strength and durability towards the environmental factors. There were also mechanical property improvements, where compressive strength was improved in the range of 27.27% to 43.66% and modulus of elasticity was improved in the range of 1.8% to 11.5%, being more load-carrying. The findings confirm the possibility of the utilization of lime as an eco-friendly alternative in traditional construction practice, in alignment with the trend for the creation of more environmental and effective construction materials.

Keywords: Sustainable Construction; Earth Bricks; Lime; Physical Properties; Mechanical Properties

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1. Introduction

Research and development in sustainable building materials have become increasingly important in the modern construction sector due to global awareness of the growing environmental impacts. Everyone needs to adopt more environmentally friendly practices [1]. The conventional construction sector is responsible for more than 40% of global energy consumption, 50% of resource consumption, and 20% of global pollution emissions [2]. If the current trend continues, the consequences for the entire planet will be alarming. Building facades are critical for finding environmentally friendly solutions and sustainable development opportunities [3]. Including lime in building materials may be feasible for lessening vitality utilization and carbon outflows. Lime generation requires less warmth than cement, diminishing fossil fuel utilization and related outflows. It also contributes to lessening carbon dioxide outflows, particularly in carbonation preparation, as slaked lime retains carbon dioxide from the environment amid its utilization. Besides, lime progresses the warm cover of dividers, lessening vitality utilization related to warming and cooling. These properties make lime a viable and maintainable fabric that contributes to decreasing the carbon impression and expanding vitality productivity within the development division. Emerging new building materials have been analyzed to overcome the environmental footprint of traditional materials. This is expected to represent an increasing market share for future buildings. Alternative construction methods allow for the design of durable buildings with high sustainability and occupant satisfaction but at a low cost [4]. For a few reasons, lime with clay may be a superior alternative to cement and gypsum. Lime decreases carbon emanations amid generation due to lower terminating temperatures than cement, making it a more economical alternative. Moreover, lime diminishes shrinkage and splitting when drying and moves forward inner cohesion, whereas clay gives more noteworthy adaptability and resistance to warm changes. Lime also improves brick resistance to acids and chemical erosion, expanding the fabric's life and its maintainability. Moreover, it contributes to progressed warm separators and diminished water porousness, which decreases vitality prerequisites for warming and cooling and upgrades the natural execution of buildings. Adapting to the environment and available raw materials in each region is fundamental for building healthy living environments. This concept is a contemporary challenge and should be the foundation for future development [5]. Sustainable housing practices relate to protecting and enhancing the environment and providing economic means. This concept extends to energy conservation, the use of sustainable materials, construction techniques that reduce harmful environmental impacts, and a climate conducive to human habitation [6]. Construction made from traditional, natural materials provides more suitable living conditions for humans than construction made from industrial materials. Environmentally friendly, renewable, soil-based materials are also economically beneficial. The construction industry is a major resource and energy consumer, generating significant waste and pollution [7]. To reduce environmental pollution and achieve rational, economical use of materials, the principles of sustainability and environmental sustainability are increasingly being considered in all industrial and construction activities. Demand for sustainable materials in the construction sector is growing in the modern construction industry. The recovery and use of natural, renewable, and environmentally friendly materials in the construction sector will ensure the long-term conservation of natural resources [8]. In a study by Dawood et al., the compressive strength of unfired clay bricks reinforced with straw was examined. The researchers focused on their use in sustainable construction. They mixed clay, coarse sand, and straw. They concluded that these sustainable resources would be useful in future housing contexts [9].

Another study examined brick waste generated from construction and demolition activities and its relationship to pollution. The researchers proposed replacing a portion of Portland cement with bricks to reduce the environmental impact of concrete. This would enhance the sustainability of building materials and contribute to sustainable global prosperity [10]. In another study, a percentage of cement between 7.5% and 22% was replaced with clay. The results showed that adding clay in specific proportions contributed positively to increased compressive strength and a 23% reduction in carbon emissions compared to the reference mixture [11]. Clay is considered the first building material used by humans [12]. Clay architecture has been used for centuries in construction around the world. It is the oldest building material known to humans. Historical evidence indicates that stone walls were covered with clay and clay mortar in most parts of the world. Traditional clay buildings can blend into their environments, resulting in an aesthetically pleasing urban landscape, and they still exist in many developed and developing countries [13]. Clay has a remarkably low carbon footprint compared to other building materials, making it a good building material from a carbon footprint perspective when used in the construction industry for walls or roofs. Clay masonry is strong enough to bear the load of the superstructure built on it. Due to this property of clay masonry, it has been used for centuries as a building material for load-bearing walls.

This research examines an experimental study of earthen bricks composed of clay, sand, and lime. The experiments focus on the effect of the lime ratio on the mechanical and physical properties of the resulting bricks. The experiments are based on standardized criteria to ensure accuracy and reliability. The study includes four main sections: The first section focuses on determining the optimal clay-sand-lime ratio. The second section addresses how to determine the water-lime ratio. The third section is devoted to studying physical properties such as changes in density and water absorption. The fourth section focuses on studying the mechanical properties of these bricks, with the research devoted to examining compressive strength and modulus of elasticity. The results obtained enable an assessment of this mixture's economic feasibility and sustainability, contributing to the development of more efficient and sustainable solutions in the field of building materials.

2. The Importance of Clay as a Sustainable Building Material

The global construction industry uses significant raw materials and generates waste. Therefore, focusing on sustainable building materials is essential to mitigating the associated environmental, social, and economic problems. Construction materials have traditionally been used without consideration of their impacts. However, public awareness and the demand for environmentally friendly buildings are promoting the use of resources that are not harmful to the planet [14]. Clay is among the best materials for scientific selection and guidance of design strategies in green construction. Walls are constructed from bricks bonded with clay mortar. Clay brick construction has an authentic appearance and can be used in traditional and modern architectural styles. Since clay bricks are primarily composed of natural quartz, they are incompatible with cement. These construction techniques, which use clay bricks, require minimal electricity consumption and are, therefore, effective in sustainability [15]. Clay has a few properties that make it unique compared to advanced engineered building materials. It is completely natural and reusable, making it a maintainable and naturally inviting choice. Due to its common properties, clay provides successful warm and sound separators, lessening the need for an extra separator. It also shows versatility in handling warm changes, decreasing the chance of splitting. Cost-wise, clay is conservative and promptly accessible in regions with appropriate soil. However, its resistance to natural variables may require suitable treatment, such as the expansion of lime. In differentiation, engineered materials such as concrete are safer than natural variables but are less feasible.

3. Materials Used

3.1. Clay

Clay is the main component in the manufacture of earthen bricks. Clay extracted from the Adrar region in southern Algeria was used. It is characterized by its red color, a density of 2.6 g cm^{-3}, and a composition of 63% SiO_2. The properties of the clay used are shown in **Table 1** [16].

3.2. Sand

Sand is used to increase clay's permeability, reducing its adhesion and water absorption. The sand used in this research is dune sand, free of organic residues. The properties of the sand used are shown in **Table 2** [16].

Table 1. Clay properties.

Geotechnicals Properties							
Sand (> 0.02 mm)	Silt (0.02–0.002 mm	Clay (<0.002 mm)	Liquid limit WL	Plastic limit WP	Plastic index IP	VB	Specific density γs
0.09	0.54	0.37	0.81	0.34	0.47	8	2.6 g cm^{-3}
Chemical Composition							
SO_4^{2-}	$CaCO_3$	Cl^-	SiO_2	Al_2O_3	Fe_2O_3	MgO	Other
0.41%	3.6%	0.14%	0.63	0.16	0.07	2.4%	7.46%

Table 2. Sand properties.

Geotechnicals Properties			
Sand equivalent	Specific density	Apparent density	Fineness Model
36.49%	2.5 g cm^{-3}	1.46 g cm^{-3}	2.79

Chemical Composition							
SiO_2	Al_2O_3	Fe_2O_3	CaO	K_2O	0.05%	0.05%	0.05%
93.66%	1.52%	0.59%	1.14%	0.43%	0.05%	0.05%	0.05%

3.3. Lime

The lime used is sourced from the Ghardaia region in southern Algeria. It has a density of 3.3 g cm^{-3} and contains a high percentage of CaO, 83%. It produces heat when it reacts with water. The properties of lime are shown in **Table 3** [17].

Table 3. Chemical and physical properties of lime used.

Chemical Composition									
Na_2O (%)	CO_2 (%)	$CaCO_3$ (%)	Al_2O_3 (%)	SiO_2 (%)	SO_3 (%)	CaO (%)	SiO_2 (%)	Fe_2O_3 (%)	Insoluble material (%)
0.4–0.5(%)	< 5(%)	< 10(%)	< 1.5(%)	< 2.5(%)	< 0.5(%)	< 83.3(%)	MgO (%)	< 2(%)	< 1(%)

Physical Properties		
Apparent density (g L^{-1})	More than 90 µm (%)	More than 630 µm (%)
600–900	<10	0

Lime was used because it is less expensive than cement and gypsum. A 50 kg bag of cement costs 750 DZD, a 50 kg bag of gypsum 800 DZD, and a 50 kg bag of lime costs 500 DZD (10 DZD = 1 kg).

Including lime in clay altogether makes strides in the mechanical properties of the coming-about fabric, making it a great choice for brick and building materials. When lime is blended with clay, a pozzolanic response happens, expanding the compressive quality and strength of the fabric. This expansion also makes a difference decrease the common shrinkage of the clay upon drying by improving inside cohesion, in this way diminishing the chance of splitting. Moreover, lime increases the material's resistance to chemical erosion, making it more tolerant to acids and salts, amplifying its benefit life. Besides, the expansion of lime progresses ductility and formability, making the fabricating preparation simpler and more productive, especially within the making of bricks and boards. It contributes to progressed warm solidness, giving the material a more prominent capacity to resist tall temperatures. At last, lime diminishes water penetrability by minimizing open pores, protecting the fabric from dampness, and maintaining strength. These properties make this blend a tough and feasible choice for development.

3.4. Water

Tap water is used at 37 °C. The chemical composition of the water used is shown in **Table 4** [16].

Table 4. Chemical composition of water.

Element	HCO^{3-}	Na^+	Ca^{2+}	Cl^-	So_4^{2-}	Mg^{2+}	K^+	NO^{3-}
Concentrations (mg L^{-1})	124	536	242	755	755	125	31	14.5

3.5. The Effect of Chemical Elements

Its chemical constituents significantly affect the quality of clay utilized in development. Both silica (SiO_2) and alumina (Al_2O3) play a key part in improving the properties of clay. Silica gives clay hardness and increases its resistance to breaking, whereas alumina contributes to its versatility, making it less demanding and reasonable for different applications. Press oxide (Fe_2O_3) gives the clay greater quality after firing and impacts the ultimate color. Lime (CaO) decreases shrinkage and increases the clay's resistance to dampness, whereas magnesium oxide (MgO) moves forward by and large steadiness and decreases breaking. Antacids such as sodium oxide (Na_2O) and potassium oxide (K_2O) encourage the terminating handle by lowering the softening temperature.

4. Mixture Preparation

The clay and sand are sieved through a 5 mm sieve. According to previous research, 70% clay is mixed with 30% sand to obtain the soil [18].

- Lime is added to the clay and sand soil at a ratio ranging from 0% to 20%.
- The water ratio is also varied from 4% to 20%.

Figure 1 shows how earthen bricks are made.

4.1. Methods Used

- An electric mixer is used to thoroughly mix the ingredients.
- An electric balance is used to weigh the lime quantities.
- A metal mold measuring 20 × 10 × 5 cm³.

- A graduated laboratory funnel to measure the amount of water.

According to the Proctor test, the best samples are selected based on the highest density.

In geotechnical engineering, researchers use the Proctor test to determine the moisture content corresponding to the highest dry density of the soil to ensure maximum strength and stability of the bricks. This ratio makes the soil particles perfectly uniform by minimizing air voids [19]. This test is used as a standard reference in preparing clay and earth mixtures, where the water ratio is adjusted based on laboratory results to achieve the required technical specifications. **Figure 1** shows the change in the volumetric mass of the samples as the lime-to-water ratio changes.

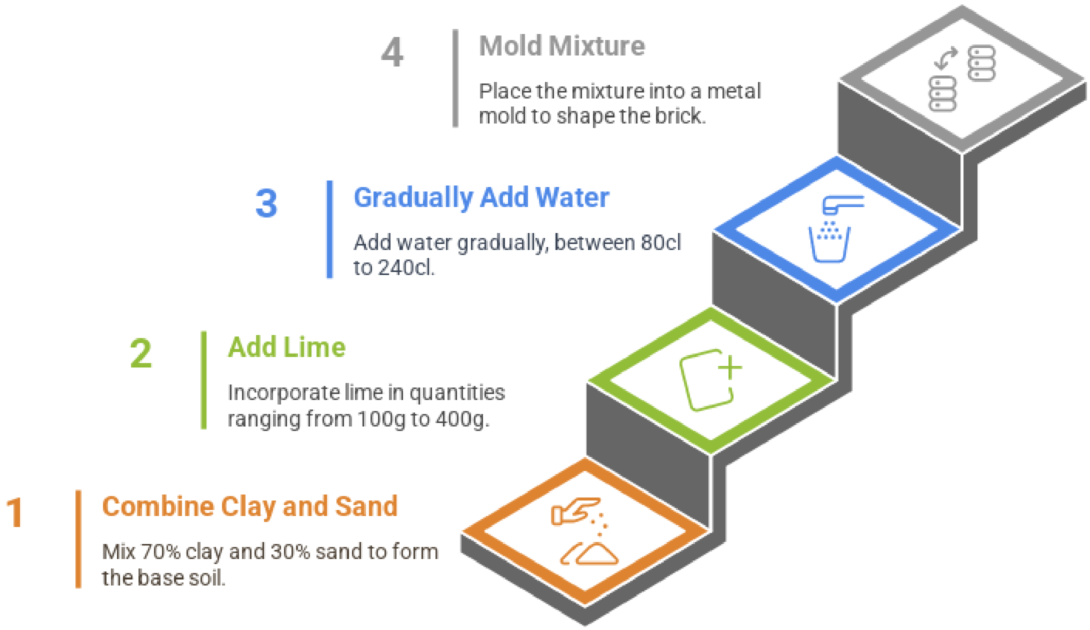

Figure 1. Stages of making earthen bricks.

Including gypsum cement in clay bricks influences the mechanical properties of the coming about fabric in different ways, each with its claim of kind characteristics:

- **Cement:** When added to clay bricks, cement essentially improves the compressive quality, which is much appreciated due to the pressure-driven bonds that form amid its interaction with water. Cement gives the bricks a strong capacity to resist overwhelming loads and decreases breaks that will result from shrinkage. It also makes the bricks more resistant to erosion and dampness, but it can increase thickness and diminish relative warm separator.
- **Gypsum:** When blended with clay, gypsum makes strides in formability and speeds up brick setting, making it appropriate for use in situations requiring quick fabricating. Be that as it may, its impact on compressive quality is less than that of cement and lime. Furthermore, gypsum moves forward the bricks' appearance and diminishes water penetrability, but it shows a decrease in chemical resistance on the off chance that uncovered to ceaseless dampness.

In the Proctor test for determining maximum clay density, a high bulk density indicates that the compacted soil has reached an optimal state of cohesion and compaction. This is typically related to the amount of water added during the compaction process. Water acts as a lubricant for the particles, enhancing their mobility and cohesion to achieve the highest density. If the water content is too low, the soil becomes stiff and difficult to compact efficiently, resulting in a lower density. Conversely, if the water content is too high, this can cause the particles to split and expand, reducing the bulk density. In this test, a high density indicates that the amount of water added during mixing is close to ideal, allowing the soil to reach its maximum density without adversely affecting its structure.

The dough is placed in a metal mold. Six samples are made from each sample. According to previous research, the samples are left to dry for 28 days [20].

The experimenters select a reference mass of 2000 g, which includes clay, sand, lime, and water. **Table 5** shows the best samples in density with the best water-to-lime ratio. When analyzing this **Figure 2**, it is noted that the best samples in terms of density are:

- At a concentration of 0% (0 g) lime, the maximum density value is 1.78 g cm^{-3}, corresponding to 160 Cl of water.
- At a concentration of 5% (100 g) lime, the maximum density value is 1.72 g cm^{-3}, corresponding to 80 Cl of water.
- At a concentration of 10% (200 g) lime, the maximum density value is 1.733 g cm^{-3}, corresponding to 200 Cl of water.

- At a concentration of 15% (300 g) lime, the maximum density value is 1.75 g cm^{-3}, corresponding to 240 Cl of water.
- At a concentration of 20% (400 g) lime, the maximum density value is 1.748 g cm^{-3}, corresponding to 200 Cl of water.

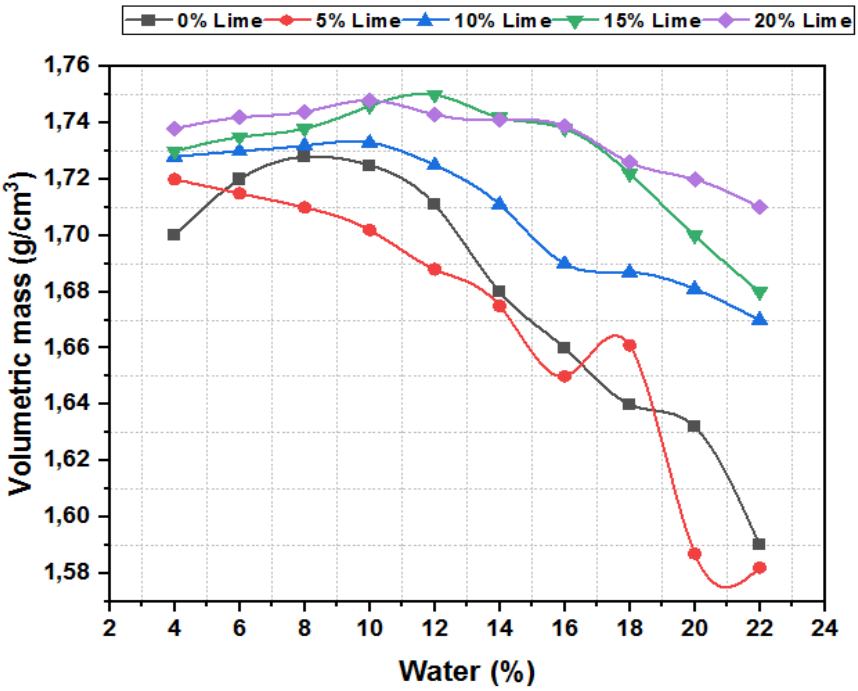

Figure 2. Change in volume mass due to adding lime and water to earthen bricks.

Table 5. Sample preparation.

Clay (%)	Sand (%)	Lime (%)	Water (%)	Code
64	28	0	8	L0
62	29	5	4	L5
56	24	10	10	L10
51	22	15	12	L15
49	21	20	10	L20

4.2. Experiments

4.2.1. Density Measurement

Density is measured by weighing the samples and their dimensions according to Equation (1).

$$\rho = \frac{m}{v} \qquad (1)$$

Density in clay bricks refers to the relationship between mass and volume, expressing the sum of materials contained in a unit volume, including voids. Density is a key indicator of brick properties, such as quality and durability. When mass increases while volume remains constant, density increases, resulting in a denser, less porous brick. Conversely, if the mass-to-volume ratio decreases, this results in a lightweight but less robust brick. Understanding this relationship contributes to improving brick quality in various construction applications.

The results of the density measurement are shown in **Figure 3**.

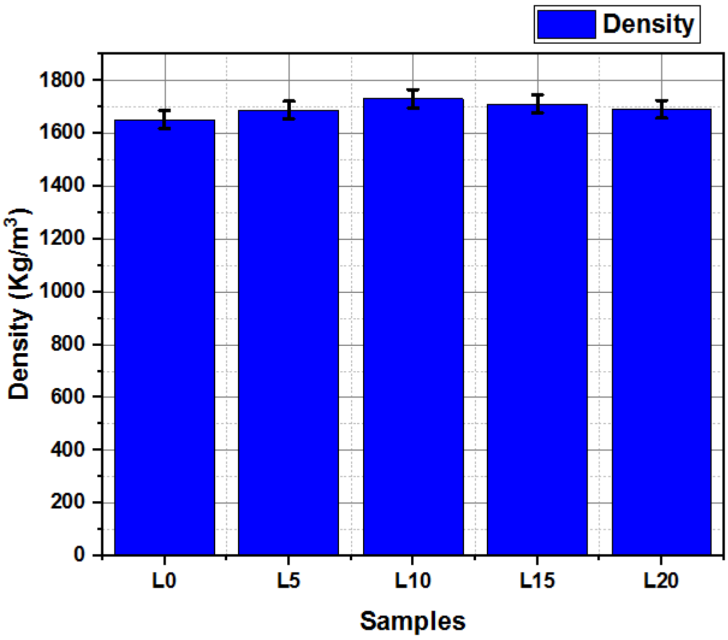

Figure 3. Change in density value when changing the ratio of lime and water.

4.2.2. Water Absorption Rate Measurement

The samples are placed in a water basin, as shown in **Figure 4**.

The samples are weighed before and after being placed in water for 60 minutes.

The water absorption rate is measured according to Equation (2).

$$m\ (\%) = \frac{m2 - m1}{m2} \tag{2}$$

The relationship between the dry (m1) and damp mass (m2) of earthen bricks is utilized to decide the water assimilation rate, a vital marker of brick quality. To begin with, the brick's dry mass is measured after it has been kiln-dried to evacuate dampness. The bricks are submerged in water for a certain period, and the damp mass after immersion is measured. The water retention rate is calculated by separating the contrast between the damp and dry mass by the dry mass and is communicated as a rate. A low water absorption rate indicates a denser, less porous brick, suitable for use in humid areas, while a high absorption rate indicates the opposite

The results of the water absorption rate measurement are shown in **Figure 5**.

Figure 4. Capillary water absorption experiment.

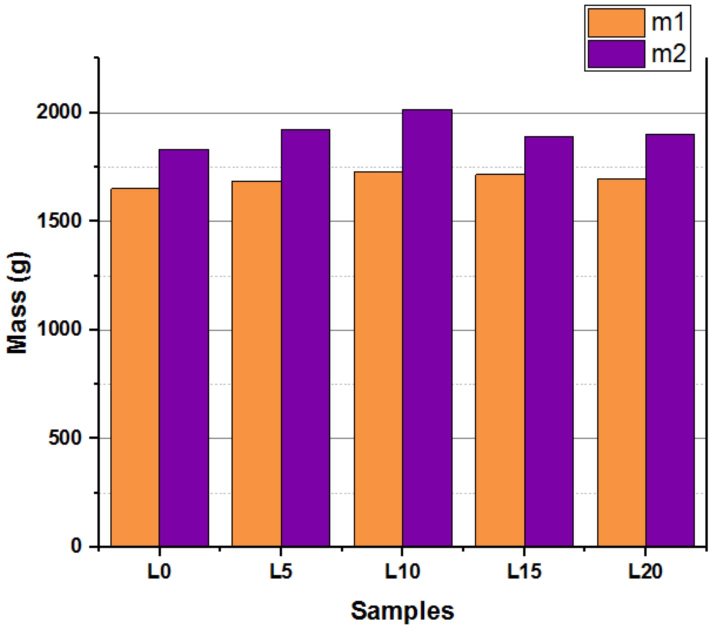

Figure 5. The change in the rate of water absorption when the ratio of lime to water changes.

4.2.3. Compressive Force Measurement

The samples are placed inside a 3000 kN hydraulic press. Vertical pressure starting from 10 kN is applied to the specimen over an area of 20 × 10 cm². Stress values are measured according to Equation (3):

$$\sigma = \frac{F}{A} \quad (3)$$

The test stops when the specimen breaks. The results of the compressive strength measurement are shown in **Figure 6.**

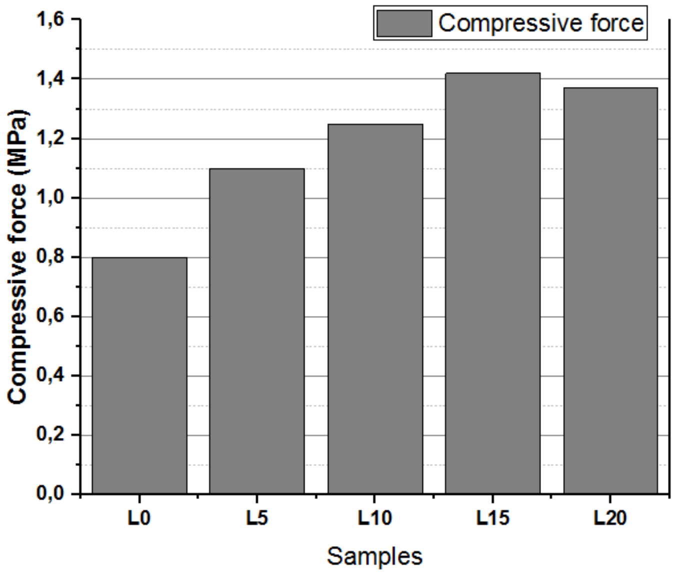

Figure 6. Change in compressive force when changing the ratio of lime and water.

4.2.4. Measurement of the Modulus of Elasticity

This test is performed by placing the specimens in a hydraulic compression machine. Probes are attached to the sides of the specimens, and the device provides direct values of the modulus of elasticity when the specimens break. Hook's law is used, as shown in Equation (4):

$$E = \frac{\sigma}{\varepsilon} \quad (4)$$

The results of the compressive strength measurement are shown in **Figure 7**.

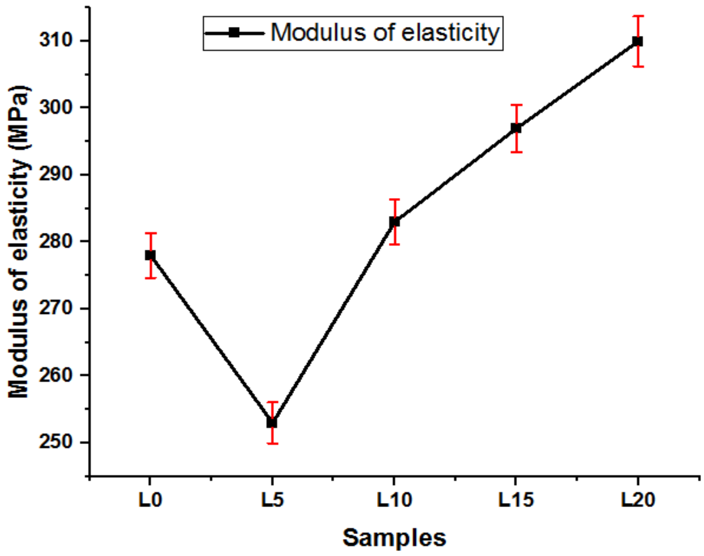

Figure 7. The modulus of elasticity changes when the ratio of lime and water changes.

5. Analysis and Discussion of Results

5.1. Density

Figure 3 shows the change in density value when the lime-to-water ratio changes. It is noted that the density value is 1653 kg cm^{-3} before adding lime, increases by 2.13% when 5% lime is added, and further increases by 4.56% when 10% lime is added. The density value increases when lime is added to earthen bricks. This is consistent with previous research [21,22].

The change in the amount of water added explains the fluctuation in density value. It is assumed that the density of earthen bricks decreases with increasing water content, as this increases air spaces during drying. Excess water evaporates, leaving voids that decrease the final density of the bricks. However, the amount of lime added is greater than that of water. Therefore, the density increases unevenly. The addition of lime to earthen bricks is of great importance in increasing density. It fills the spaces between soil particles and enhances the cohesion of the components. This increases the overall density of the bricks [23].

Lime fills the tiny spaces between particles, reducing porosity and increasing density. Furthermore, the lime components react with the clay materials to form new compounds, which increase their weight and reduce their relative volume. Lime also improves the cohesion between clay particles, making the structure more cohesive and stable. These improvements in structure and cohesion contribute to increased brick density, making it more durable and suitable for construction.

5.2. Water Absorption Rate

Figure 5 shows the change in the water absorption rate in earthen bricks when lime and water are added. We consider sample L0 the reference sample for the other samples. When exposed to water for 60 minutes, its mass increases by 11%. While the mass of sample L5 increases by 14% and sample L10 by 16.5%, it increases by 10.3% and 12% in samples L15 and L20, respectively. The curve analysis shows that the water absorption rate increases as the amount of lime increases.

From previous experiments, when lime is added to earthen bricks, the water absorption rate decreases because the lime reacts with the clay components, thus increasing hardness and decreasing permeability [24,25].

The results of this research differ from those of other studies due to the change in the amount of water and its instability. The percentage of water used in mixing clay bricks is important in determining the absorption rate. Excessive water content leads to increased voids after drying, and these voids increase the water absorption rate [26]. To achieve optimal results, we chose sample L15 because it has the highest density among the samples shown in **Figure 2**. This occurs when the mixture contains 15% lime, 12% water, 51% clay, and 22% sand. Comparing this sample to the reference sample L0, we conclude that the water absorption rate decreased by 6.36%. Sample L0 (1831.5 g – 1650 g) = 11% absorption rate. Sample L15 (1891.3 g – 1715 g) = 10.3% absorption, so 11 – 10.3 / 11 = 6.36% according to Equation (2). These results are consistent with studies in which the water content is constant.

Lime helps reduce the water absorption rate of clay bricks. The lime reacts with clay minerals to form compounds that reduce the porosity within the brick. These compounds block the microscopic pores within the brick, reducing the ability of water to penetrate. To achieve an adequate water absorption rate, the amount of water used in the mix must be sufficient, as this amount directly affects the water absorption rate of the samples. If insufficient water is used, a complete chemical reaction between the lime and clay may not occur, resulting in increased water retention. This typically occurred in the L0, L5, L10, and L20 samples. The L15 sample test showed a 6.36% decrease in water retention rate compared to the sample without lime.

5.3. Compressive Force

When analyzing **Figure 6**, which represents the change in the compressive force applied to bricks when lime and water are added, it is noted that the compressive strength increases with the addition of lime and then decreases slightly. Compared to the sample without lime, the compressive force increases by 27.3%, 36%, 43.66% and 41.6% in samples L5, L10, L15 and L20, respectively. When lime is added to soil, chemical reactions occur (calcium oxide with water), and the silica or alumina in the clay forms compounds called “calcium silicates.” These compounds enhance the bonding strength between the particles [27].

Lime acts as an additional binding agent in the bricks, reducing the pores and voids within the bricks and increasing density and hardness [28]. These results are consistent with previous research in this field [29,30].The decrease in compressive strength in sample L20 is explained by a 20% increase in the amount of water. From previous experiments, it can be concluded that the decrease in hardness of clay bricks when large amounts of water are added to the mix causes increased porosity and the formation of voids as the water evaporates during drying. These pores weaken the structure, making the brick less cohesive, and consequently, the bonding force between soil particles is weakened [31].

5.4. Modulus of Elasticity

Figure 7 shows the change in the modulus of elasticity in clay bricks when lime and water are added. It is noted that the modulus of elasticity decreases and then increases compared to the reference sample. The decrease is explained by insufficient water in sample L5, as the lime absorbs most of the water used in the mix. This causes cracks in the bricks during drying. The modulus of elasticity increases with increasing amounts of water and lime. The reference sample without lime has the lowest hardness (278 MPa), and the modulus of elasticity increases between 1.8% and 11.5%. The lime reacts with clay to form chemical compounds that improve molecular bonding. This enhances the brick’s ability to withstand stress without cracking [32]. Lime fills the voids within the brick, distributing stresses evenly, increasing the brick’s elasticity and improving overall cohesion. In addition, it controls the shrinkage rate during drying, which prevents cracking that could reduce elasticity [33].

The modulus of flexibility diminishes in test L5 since this test contains a small sum of water (80 Cl). When a small sum of water is utilized in blending the clay and lime, this adversely impacts the quality of the coming brick. This is often because the inadequate sum of water leads to inadequate chemical responses between the lime and clay, hence debilitating the bond between the particles. The result could be a brick with breaks and destitute compressive quality. However, we note that the other samples withstand greater stresses because the ratio of water and lime is higher than the sample without lime.

6. The Importance of Research from a Sustainable Construction Perspective

The incorporation of lime into mud bricks (adobe) enhances the concept of sustainable construction from multiple perspectives:

1. From a mechanical perspective, adding lime improves strength and durability. It acts as a natural bonding material that enhances structural stability, reducing cracks and corrosion over time. This leads to increased building life and reduced need for ongoing maintenance or restoration.

Lime also contributes to enhancing the bricks’ resistance to water absorption, making walls more resilient to erosion caused by rain or humidity.

2. From an environmental perspective, using local, eco-friendly materials helps reduce the carbon footprint. In addition, the lime hardening process contributes to the absorption of carbon dioxide, which reduces emissions into the atmosphere.

3. Improving the thermal efficiency of buildings: Previous studies indicate that adding lime enhances the thermal insulation of mud buildings, enabling residents to reduce the use of heating or cooling systems, thus reducing energy consumption [34,35].

4. From a health and safety perspective, lime is effective against mold and bacteria. It limits the growth of fungi and mold, improves indoor air quality, and reduces health risks associated with humidity. Lime also lacks the additives found in cement.

5. From a recycling and sustainability perspective, clay bricks can be recycled from old, damaged bricks when the lime content is less than 30%. This makes them a reusable material, contributing to reducing waste from residual materials.

7. Cost Calculation

The authors' tests show that the ideal lime substance is 15%, proportionate to 300 grams per brick. This implies that the extra fetching of utilizing lime in development is evaluated as follows: a 3 × 3 m divider with a thickness of 10 cm requires 900 bricks measuring 20 × 10 × 5 cm, expending roughly 270 kg of lime (900 × 0.3 kg). Hence, the extra fetched amount of lime utilized is 2,700 DZD (270 kg × 10 DZD). In this manner, a room with four dividers would fetch up to 10,800 DZD. Lime is known to decrease vitality utilization by 20% to 30%, agreeing to consider this field [36], making it conceivable to counterbalance the included fetched through lower vitality bills.

8. Suggestions

Including lime in clay is one of the foremost noticeable alternatives within the field of maintainable building materials, requiring inventive advancements based on a few variables. To begin with, the rate of lime included can be balanced, agreeing to the soil sort to guarantee ideal execution in terms of hardness and decreased porosity, upgrading the quality of the bricks and their capacity to stand up to disintegration and dampness. Moment, lime can be combined with making strides materials such as volcanic fiery debris or common filaments. These materials improve quality and solidness while keeping costs low, making it a prudent choice. Third, progressing warm treatment techniques, such as utilizing economical vitality sources within the terminating or drying forms, contribute to moving forward the inner holding between the clay and lime particles, expanding the soundness of the fabric. In expansion, the warm separator of bricks can be upgraded by blending lime with added substances such as perlite, which decreases warm conductivity and increments warm cover productivity, emphatically affecting vitality utilization in buildings. Logical inquiry plays an urgent part, as careful considerations offer assistance in deciding the ideal proportion of lime and its interaction with the different clay components, guaranteeing substantial advancements. Besides, costs can be decreased depending on neighborhood lime sources, which spares transportation costs and improves financial reasonability. At last, creating ecologically neighborly techniques, such as utilizing low-emission generation strategies, contributes to upgrading natural maintainability and supporting the drift toward feasible development. Combining these strategies increases the esteem of clay bricks, making them more competitive within the development industry.

9. Conclusions

This study examined the effect of adding lime and water to clay-sand bricks. Lime was added gradually from 0% to 20%, coincidentally with a change in the water ratio used in the mixture from 4% to 20%. This soil is characterized by a high clay or silica content, which makes it respond better to lime stabilization, as a chemical reaction occurs between the lime and the clay components. It is also rich in reactive minerals that enhance the formation of compounds, such as silicates and calcium aluminates, which increase compressive strength and internal cohesion. The results showed that the optimal lime ratio was 15%, corresponding to a 12% water ratio. This resulted in a 3.38% increase in the density of the bricks compared to samples without lime. This was accompanied by a 6.36% decrease in water absorption. Furthermore, the hardness of the bricks increased by 43.66% in compressive strength. This resulted in a 6.8% increase in the modulus of elasticity. Adding lime to clay is a promising technology for improving the properties of clay materials in terms of hardness and durability. This is because the reaction of lime with the clay components produces new chemical compounds, which connect the clay particles more cohesively, increasing their durability and strength against corrosion and external factors. Lime stabilization is a sustainable alternative because it reduces its natural carbon footprint compared to cement and also improves soil properties. Furthermore, lime has lower production costs and energy consumption than gypsum, making it an ideal choice for construction projects. Lime also offers the potential to enhance thermal insulation, reducing the energy requirement for heating or cooling buildings. The improved mechanical properties of lime-treated clay also make it suitable for construction and engineering applications, such as sustainable construction. Therefore, adding lime is a sustainable option for clay-based materials and an ideal choice for sustainable development projects that aim to balance technical viability and environmental concerns.

Author Contributions

All authors contributed to the preparation of this manuscript as follows: Methodology, K.M.A.; Figure drawing, K.B.; Data processing, D.A.; Writing, R.M.; Review and editing, K.C.; Supervision, F.A. All authors have read and approved the published version of the manuscript.

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Institutional Review Board Statement

We, the research team responsible for studying this manuscript, declare that this research does not involve any experiments or the use of human or animal samples. The aim of this research is to investigate the effect of lime on improving clay bricks using scientific methods. This declaration has been prepared to demonstrate our commitment to scientific research ethics.

Informed Consent Statement

The authors of this manuscript declare that there are no conflicts of interest that may affect the conduct of this research, its results, or its interpretations. The authors are committed to complete transparency at all stages of the research and confirm that the work was conducted independently, without any external influence.

Data Availability Statement

We, the research team responsible for preparing this article, would like to clarify that data related to this topic are currently unavailable for reasons related to the research process. This is due to further experiments in this field. We emphasize that this lack of data does not affect the validity of the results or conclusions presented in the article. For further clarification, please contact the corresponding author's email address.

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Conflicts of Interest

The authors of this manuscript declare that there are no conflicts of interest that may affect the conduct of this research, its results, or its interpretations. The authors are committed to complete transparency at all stages of the research and confirm that the work was conducted independently, without any external influence.

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