Comparative Study on the Impact of Sand and Lime on the Physical and Mechanical Characteristics of Unfired and Fired Earth Bricks

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Abstracts: Earth bricks represent one of the most important and widely used building materials in current era, due to its unique physical and mechanical properties compared to other materials. Earth bricks are available in two main types: raw earth bricks and fired bricks. The physical and mechanical properties differ for each type, which affects their performance in various applications and their long-term durability. Several studies have been conducted to improve the properties of raw and fired bricks and address their weaknesses. In this research, we aim to investigate the effects of adding dune sand and lime on the physical and mechanical properties of raw earth and fired bricks, and compare the results. Sand was added by 25%, while lime was added by 0, 6, 8, 10, and 12% of the soil matrix weight. Initially, we determined the properties of the raw materials used. After creating the samples, they underwent tests for bulk density, longitudinal shrinkage, compressive strength, and flexural strength. The study revealed the positive impact of adding sand on the physical and mechanical properties of raw and fired bricks. It contributed to reducing the bulk density and longitudinal shrinkage of the samples, while increasing their compressive and flexural strength to varying extents. The results also showed the positive effect of lime on the physical and mechanical properties of raw bricks, as long as it was added at a ratio not exceeding 10%. However, the addition of lime to fired bricks affected the physical properties positively but it has a negative effect on the mechanical properties.

Keywords: Clay, Dune Sand, Lime, Fired Brick, Compressed Earth Brick, Physical Proprieties, Mechanical Proprieties.

1. INTRODUCTION

With the development of technology, various groups of bricks appeared that are diverse in their properties and composition. Among these different types of bricks, raw brick and burnt brick stand out as the two main types. Raw brick, as its name implies, is made only after forming and drying, without exposing it to the burning process, and is characterized by its distinctive physical properties such as its water absorption and ability to provide moderate thermal and sound insulation. However, raw brick has poor wear resistance as it wears out faster over time. As for fired bricks, they are made by exposing raw bricks to high temperatures in special furnaces. This process results in structural and chemical changes in the starting materials, which leads to the formation of crystallized substances and the improvement of the mechanical properties of the brick. Fired brick is characterized by very high compressive strength and resistance to environmental influences such as temperature changes, humidity, mechanical influences.

Many studies have been launched to improve the properties of bricks, whether raw or burnt, where the improvement processes aim to strengthen the weaknesses of bricks through new recipes for the manufacturing mixture or the addition of some raw or industrial elements and materials to address certain deficiencies. Dune sand is one of the raw materials that are added to bricks, where sand acts as an inert element to reduce the elasticity of the mixture, which helps in the mixing and molding process. It also acts as a degreasing element [1].

Lime is also one of the industrial materials that are added to bricks in order to improve its properties, as it works to increase the cohesion between the various components of the mixture and reduce the risk of cracks during the drying process, lime is one of the most suitable stabilizers for cohesive soils [1-3]. In this study ,we added a fixed percentage of sand of 25 % of the soil matrix ,based on the recommendations that the addition of sand should not exceed 30 % [1] ,as well as based on the studies of researchers Chaib, Mekhermeche and Hakkoum et al.[4-6] who proved that the optimal percentage of adding sand ranges between 20 and 30 % . We also added variable proportions of lime in the recommendations area [2].Through this mixture, we manufactured samples of compressed earth bricks and samples of fired bricks and subjected them to experiments: bulk density, longitudinal shrinkage, compressive strength and bending strength to evaluate the effect of these additives on the properties of the two types of bricks and compare their behavior.

2. MATERIEL AND METHODS

2.1. Clay

Figure 1. The Clay Used

The used clay is extracted from quarries in Balidat Ameur municipality, Touggourt state, Algeria (Figure 1), its characteristics are shown in table 1 and 2

Table 1. Physical Properties of Clay

Property	Apparent density	Absolute density	Liquidity limit	Limit plasticity	Plasticity index	Type of soil
Value	1258 kg/m^3	2828.57 kg/m^3	%67.75	23.98%	43.77%	Very plastic clays

Table 2. The Granular and Sedimentary Analysis of Clay

Particle size (mm)	2≥ D ≥0.2	0.2≥ D ≥0.02	0.02≥ D ≥0.002	0.002 ≥ D
Percentage passing (%)	2	20	42	36

2.2 Dune Sand

Figure. 2 The Dune Sand Used

The sand used is the dune sand of El Oued municipality, El Oued State, Algeria(Figure 2), Its characteristics are shown in table 3 and table 4

Table 3. Physical Properties of Dune Sand

Property	Apparent density	Absolute density	Sand equivalent	Fineness module Type of sand	Water absorption
Value	1732 kg/m^3	2511.09 kg/m^3	95.12% very clean sand	0.95 The sand is very fine and has a narrow grain gradient	0.91%

Table 4. The Granular Analysis of Dune Sand

Particle size (mm)	0.8≥D≥0.4	0.4≥D≥0.2	0.2≥D≥0.1	0.1≥D≥0.08	0.08≥ D
Percentage passing (%)	8.06	79.5	11.93	0.51	00

2.3. Lime

Figure. 3 The Lime Used

In this study, we used slaked lime Ca (OH) 2, (Figure 3), Its chemical and physical properties is shown in tables 5 and 6

Table 5. Physical Analysis

Fineness (% by Weight)	Bulk Density
98% passing 0.2 mm	555 kg/m^3

Table 6. Chemical Analysis

Element	CaO	CO2	K2O+NaO	SiO2	Al2O3	Fe2O3	SO3	H2O
Percentage (%)	73.12	15.23	0.05	0.32	0.05	0.06	0.02	0. 3

2.4 Samples Preparation and Tests

The clay was mixed with sand and lime, then water was added, the optimal amount of water (OMC) was estimated based on the results of the Proctor's Standard experiment based on standards NF P94-093 and NF EN 13286-2.

The mixture was placed in the piston mold ,then the sample was pressed by a hydraulic manual piston (Figure 4), which applies a static pressure force of up to a maximum of 1.2 MPa, as this pressure is considered close to what the commercial compaction machines applies such as Ausbildungsverbund AVM CINVA Ram (2Mpa) , Sheltertech block press (1 to 2 MPa) and TTera structure TPM (1.2Mpa) [7].

After extracting the sample, we left it to dry in the open air away from the sun for 30 days in order to complete the lime reaction process [2]. We manufactured samples with sizes 22 x10.5 x 6 cm^3 such as dimensions of commercial solid brick. The samples were subjected to tests: Bulk density, Longitudinal shrinkage ,Compressive strength based on standards NF P18-406 and Flexural strength (three point method) based on standards NF P18-407.

Figure. 4 The Manual pressing machine.

3. RESULTS AND DISCUSSION

3.1. Proctor's Test

The figure 5 shows the change in dry density depending on the water content of the soil consisting of the manufactured brick, mainly 75% clay, 25% dune sand and 10% lime of the soil matrix weight so that OMC corresponds to the maximum dry density obtained. According to the curve of figure 5, we can conclude that the OMC is 26% of the dry weight of the sample, which is consistent with the recommended range, which states that the water needed to form bricks ranges from 15 to 30% of the weight of the samples[1].

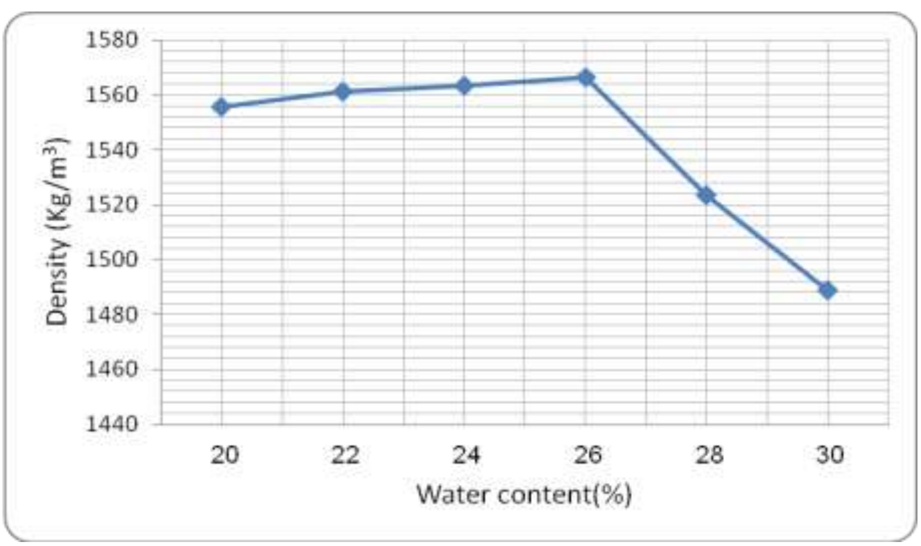

Figure. 5 Proctor Standard Test Curve

3.2 Bulk Density

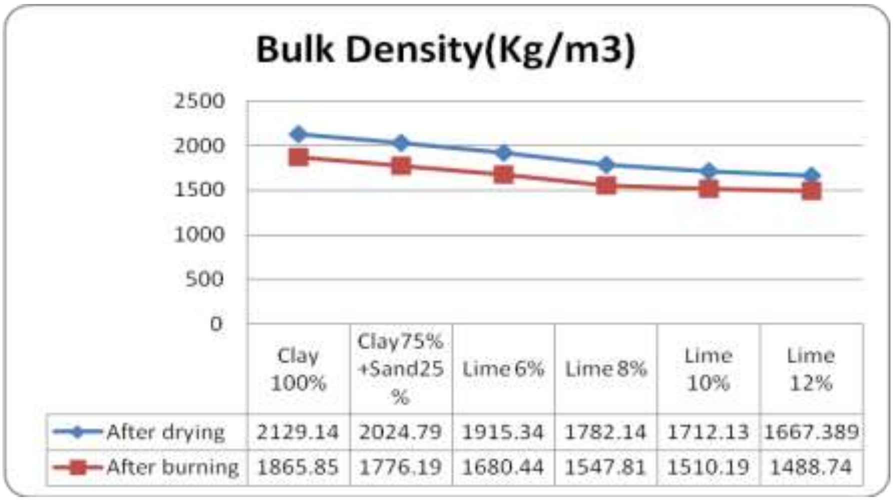

Figure. 6 Bulk density Curve

Through the curve shown in figure 6, we observe that the addition of sand has contributed to a reduction in the apparent density of both raw and fired bricks by 4.9% and 4.8%, respectively. This is because the absolute density of sand is lower than the absolute density of clay.

As for lime, its addition had an inverse effect on the apparent density of both unfired and fired samples. The addition of lime contributed to a decrease in the density of unfired brick samples by 5.4% and 17.65% when added in percentages ranging from 6% to 12%. This is due to the reaction of lime with the silica present in the sand and clay, as well as its contribution to increasing the porosity of the samples.

Lime also contributed to reducing the density of fired samples by percentages ranging from 5.39% to 16.88% when added in the same proportions. This is because lime helps increase the fusion speed of the components of the manufacturing mixture during firing and also increases the porosity of the final product, in addition to consuming the water present in the mixture during its reaction.

Furthermore, we notice that the apparent density of fired samples is always lower than that of unfired samples. This is due to the changes in the internal structure of the bricks, the breaking of mineral bonds, and the expulsion of most of the water present in the samples.

3.3 Longitudinal Shrinkage

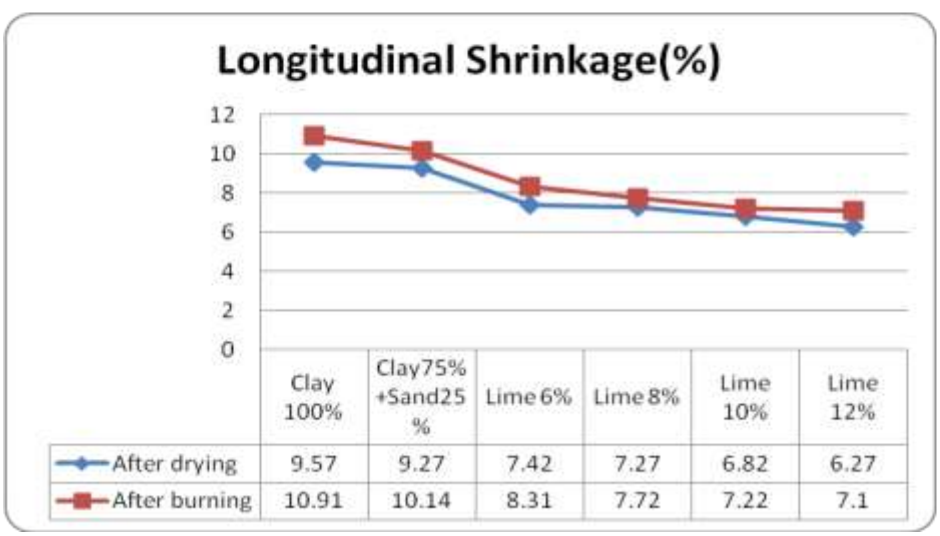

Figure. 7 Longitudinal Shrinkage Curve

Through the curve shown in figure 7, we observe that the addition of sand has worked to reduce the shrinkage ratio of both raw and fired brick samples. This is due to its low water absorption capacity. It is known that the shrinkage process is closely related to the extent of water absorption by the components of the mixture.The addition of 25% sand has contributed to a reduction in longitudinal shrinkage ratio by 3.13% and 7.05% for raw and fired bricks, respectively, as demonstrated by researcher[1]. The addition of lime has also contributed to reducing the longitudinal shrinkage ratio of raw bricks by percentages ranging from 19.95% to 32.36% when added in proportions of 6% to 12% of the soil matrix weight.

The same addition proportions have also resulted in a reduction in shrinkage of fired brick samples by percentages ranging from 18.04% to 30%. We notice from the curve that, in all cases, the shrinkage of fired bricks is greater than that of raw bricks. This is due to the expulsion of most of the water in the sample during the burning process.

3.4 Compressive Strength

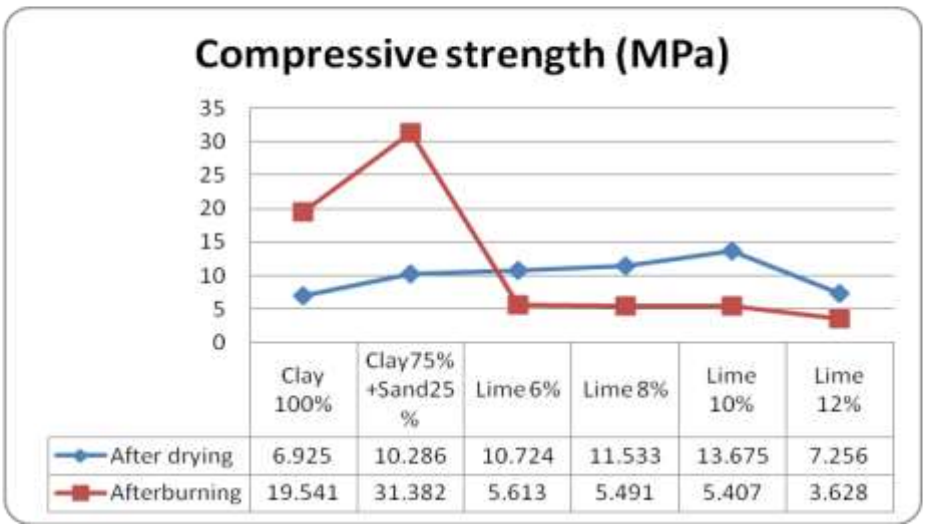

Figure. 8 Compressive Strength Curve

Through the curve shown in figure 8, we observe that the addition of sand has contributed to an increase in the compressive strength of both raw and fired brick samples. Sand has increased the compressive strength by 48.53% for raw bricks and 60.59% for fired bricks. This is due to the unique characteristics of the sand structure in its resistance to compressive forces. The burning of the samples has also contributed to an increase in the compressive strength of samples containing only clay, reaching up to 182.18%. The compressive strength also increased by 205% for the fired sample that contained both sand and clay. The addition of lime has contributed to an increase in the compressive strength of raw brick samples. Increasing the lime content from 6% to 10% led to an increase in compressive strength by percentages ranging from 4.25% to 32.94%.

However, if the lime content exceeds 10%, it has a negative effect on the compressive strength of raw brick samples. This increase in compressive strength is attributed to the reaction between the calcium in lime and the silica in sand and clay, resulting in the formation of calcium silicate hydrated $CaSiO_3$, which forms a high-strength structure. This is known as pozzolanic reaction. [8],[9].

As for fired brick samples, the addition of lime had an inverse effect on their compressive strength. The compressive strength decreased in proportion to the lime content added. This is because lime, when fired, contributes to increasing the porosity of the final product, as mentioned earlier.

3.5 Flexural Strength

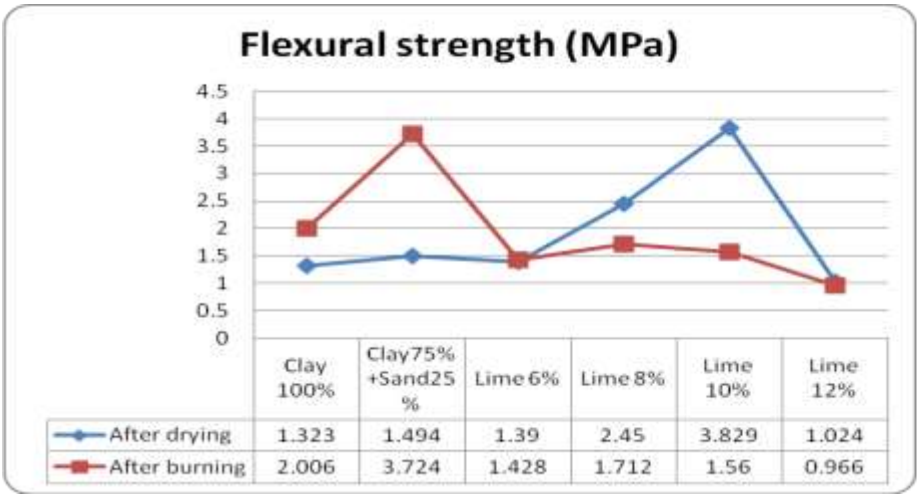

Figure. 9 Flexural Strength Curve

Through the curve shown in figure 9, we observed that sand and lime have played similar roles as they did in compressive strength. Sand has contributed to an increase in the flexural strength of both raw and fired bricks. Similarly, lime has contributed to an increase in the flexural strength of raw bricks, as long as it is added in proportions not exceeding 10% of the soil matrix weight. The corresponding flexural strength for this proportion reached 3.829 MPa, with an increase of 156.29%.However, the addition of lime had an inverse effect on the flexural strength of fired bricks. The burning process has also contributed to an increase in the flexural strength by 51.62% for the sample containing only clay and 149.26% for the sample containing clay and sand.

CONCLUSIONS

In conclusion, based on the findings from the provided curves and graphs:

- The addition of sand has resulted in a decrease in the apparent density of both raw and fired bricks. This is attributed to the lower absolute density of sand compared to clay. Additionally, the sand has contributed to a reduction in shrinkage ratio and an increase in compressive strength and flexural strength of the bricks.

- The addition of lime has shown mixed effects on the properties of the bricks. It has contributed to a decrease in the apparent density and shrinkage ratio of raw bricks, but it had an inverse effect on the compressive strength and flexural strength of fired bricks. Lime has shown a positive influence on the compressive strength and flexural strength of raw bricks, but only when added in proportions not exceeding 10% of the soil matrix weight.

- The burning process has generally resulted in an increase in the compressive strength and flexural strength of fired bricks. The increase in strength is attributed to the reactions that occur during the firing process, leading to the formation of compounds with higher hardness and strength.

- Overall, it can be observed that the properties of fired bricks are different from those of raw bricks due to changes in their internal structure and the expulsion of water during the firing process.

These findings provide valuable insights into the effects of sand, lime, and firing on the density, shrink-age, and strength properties of bricks. They can be useful in optimizing the manufacturing process and en-hancing the quality of brick products.

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