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Mechanical and Thermal Properties of Goulmima's Earth Bricks

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Abstract. Earthen constructions are prevalent in the Drâa-Tafilalet region of Morocco, yet there is a notable absence of comprehensive studies on the mud bricks used in these structures. This research endeavors to characterize a quarry utilized by Goulmima residents for mud brick production. Various techniques, including physico-chemical analysis (XRD, IR, FX, etc.), microscopic examination (SEM), and geotechnical assessments (Atterberg limits, grain size, etc.), were employed to analyze samples from the site. The bricks, formed at different firing temperatures, were blended with naturally crushed date palm seeds. The chemical composition, firing temperatures, and organic matter percentage directly influence mechanical properties and thermal conductivity. Material compressive strength exhibited a proportional increase with rising firing temperatures, peaking at 850°C. Conversely, elevating the percentage of crushed palm seed had an adverse impact on mechanical strength.

Introduction

The current global growth model faces challenges due to the concerning impacts of global warming. Historically, this model has prioritized profit and gain, often neglecting environmental consequences. In Morocco, building construction stands as a major contributor to energy consumption, representing approximately 33% of the country's total energy expenditures (26% for residential structures and 7% for tertiary buildings) [1].

Improving traditional approaches and utilizing naturally available resources can serve as a viable alternative for achieving sustainable development. Some advantages of constructing with earth include its abundance, nearly unlimited recyclability, cost-effective building methods, hygroscopic and thermal properties, and positive impacts on occupant health. [2–4].

Producing environmentally friendly building materials can involve utilizing waste materials instead of clay in the manufacturing process. [5,6].

By adopting this approach, the adverse environmental impacts associated with such waste can be alleviated, and the excessive exploitation of natural clay deposits can be curbed, preventing further harm to the ecosystem. This can lead to the creation of more environmentally friendly products. [7,8].

Per the European standard TS EN771-1, 2005, it is imperative that a brick maintains a compressive strength of no less than 7 MPa. Therefore, incorporating crushed palm seed (CPS) into clay bricks should not exceed 15%. Any surpassing of this threshold resulted in the creation

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of bricks lacking the necessary compressive strength, thus failing to meet the standards set for conventional bricks [9].

De Silva and Perera conducted a study on the water absorption characteristics of fired brick specimens that integrated waste rice husk ash [8]. When 10% rice husk ash was added, the water absorption value was 27%, while the reference samples had a water absorption percentage of 21%. When Eliche Quesada [10] Studied how clay bricks absorb water when infused with wood ash at a temperature of 900 °C. Findings indicated that the initial absorption value rose to 22% with a 30% additive content, contrasting with reference samples that had a water absorption rate of 15%. Put differently, the addition of CPS causes the pores and capillary channels of the material to open more, which allows water to penetrate the brick matrix and increases the water absorption values.

In this work, we are interested in earth construction techniques, and more specifically in characterizing samples from the Goulmima region using different analytical methods and determining the stabilization effect of the designed bricks with crushed palm seeds as additive. The stabilization effect was monitored through the mechanical and thermal characteristics of the materials to validate their use as a construction material.

Materials and methods

Raw materials

Crushed palm seeds used during this investigation were sourced from a regional producer in the Errachidia area, whereas the clay was acquired in the southern Moroccan Atlas (Goulmima). Standardized sieves were employed following the AFNOR procedure for the crushing of the raw materials, the length of the chosen particles is less than 0.5 cm, the percentages added were 0, 5, 10,15, 20%.

Characterization of the raw material

Evaluating the quality and suitability of clay materials for load-bearing, (and/or) non-load-bearing walls is essential through compressive strength testing. [11] and using a sedimentometry technique for the 80 μm portion [12].

The XRD patterns were recorded using a Shimadzu 6100 diffractometer, equipped with a diffracted beam monochromator and Ni-filtered CuKα radiation (λ= 1.5406Å), operating at 40 kV and 30 mA, the 2θ angle was swept between 2° and 70° with a counting time of 1 s in steps of 0.02°.

Using a TESWELL machine with a 20 KN capacity and a 0.5 mm/min speed, the mechanical resistance tests were performed on stabilized specimens.

Results and discussion

Grain Size Analysis

Fig. 1 illustrates the dispersion of particle sizes within the earthen components of Goulmima. The results indicate that our clay consists of 71.01% sand, 20.10% silt, and 8.15% clay. The literature claims that the final produced bricks' qualities are directly impacted by the raw materials particle size distribution [13–15] .

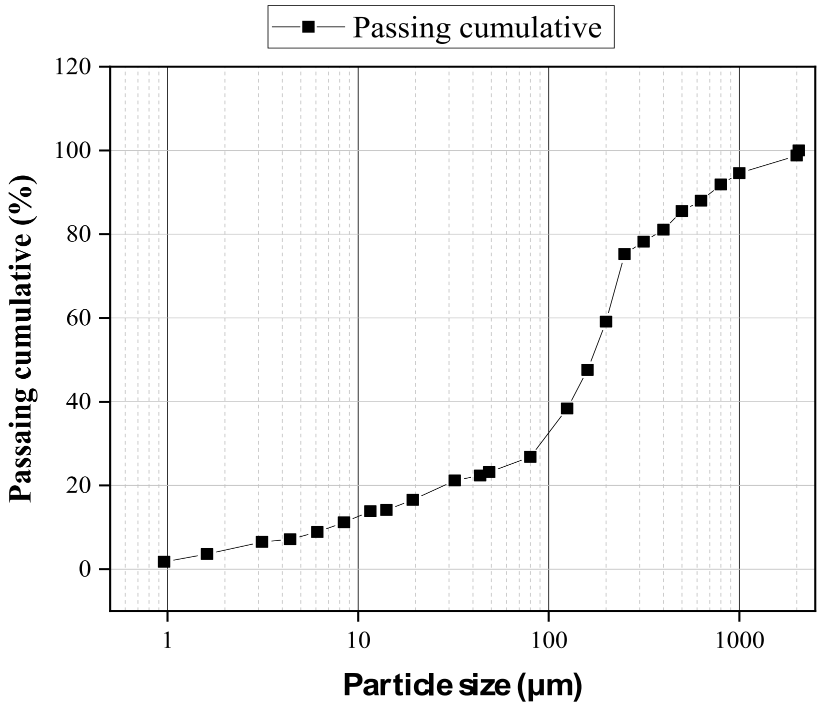


Fig. 1. Particle size analysis curve

Firing Shrinkage

Fig. 2 shows the progression of firing shrinkage with the proportion of CPS applied.
It was discovered that firing shrinkage reduces with increasing CPS concentration up to 20%, which is advantageous for building materials. Bricks containing 20% CPS shrunk by 0.5%, while the reference sample, which did not include CPS, shrank by 2.6%. Therefore, the mixture's plasticity limit is lowered when CPS is added to clay [16], Faria et al. [17] , Khoudja et al. [18] and Tjaronge et al. [19] discovered similar outcomes.

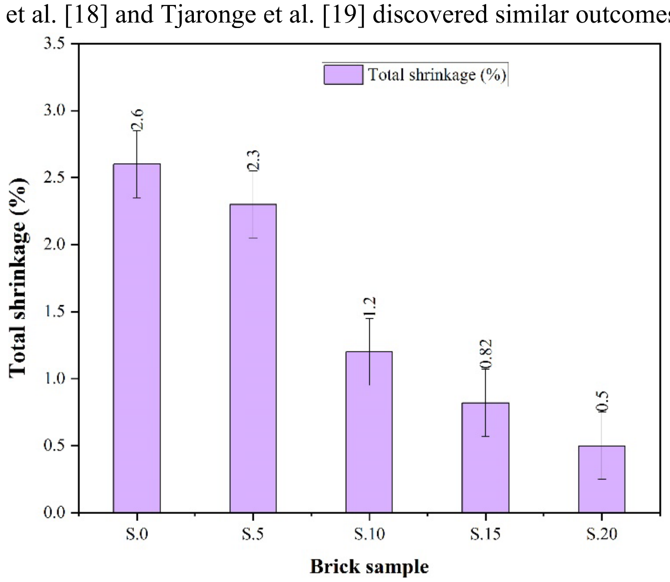


Fig. 2. Changes in overall shrinkage with the incorporation of Crushed Palm Seeds

The obtained shrinkage values for various CPS percentages ranged from 2.6% to 0.5%, demonstrating that all bricks fall within the specified clay brick limit of less than 8% [20].

Porosity, Water Absorption and Bulk Density

Fig. 3 and **4** show the changes in bulk density and porosity with the addition of CPS percentage, respectively. The quantity of CPS and bulk density were shown to be negatively correlated; that is, the brick samples became lighter as the amount of CPS increased. In actuality, the bulk density of the brick, with a 20% addition, increased from 2015 kg/m^3 in the reference clay brick to 1543 kg/m^3. On the other hand, porosity increases when CPS is added. Porosity specifically increases to 33% when 20% CPS is added, compared to the reference sample's 17.37%. The dehydroxylation reaction of carbonate in CPS and the burning of organic matter are responsible for the appreciable increase in porosity. As a result, brick samples become more porous and have less density. The findings exhibit an ideal relationship with earlier research. Eliche-Quesada et al.[10] , for example, examined the changes in bulk density and porosity of burned brick specimens when biomass ash was added. When 50% of waste additive was added, the density value decreased to 1270 kg/m^3 from 1754 kg/m^3 in the reference samples. The evolution of porosity with the addition of bottom ash was examined by Suctu et al.[21]. According to the results, the apparent porosity of the burnt brick samples increased when residual ash was added. Indeed, the porosity of the reference brick burned at 950 °C was 23.2%, and it increased to 26% with the addition of 30% of clinker. The bulk density of burned brick samples is reduced by the addition of biomass ash, as demonstrated by Casa and Castro [22] and other investigations [10,17,18,22–24].

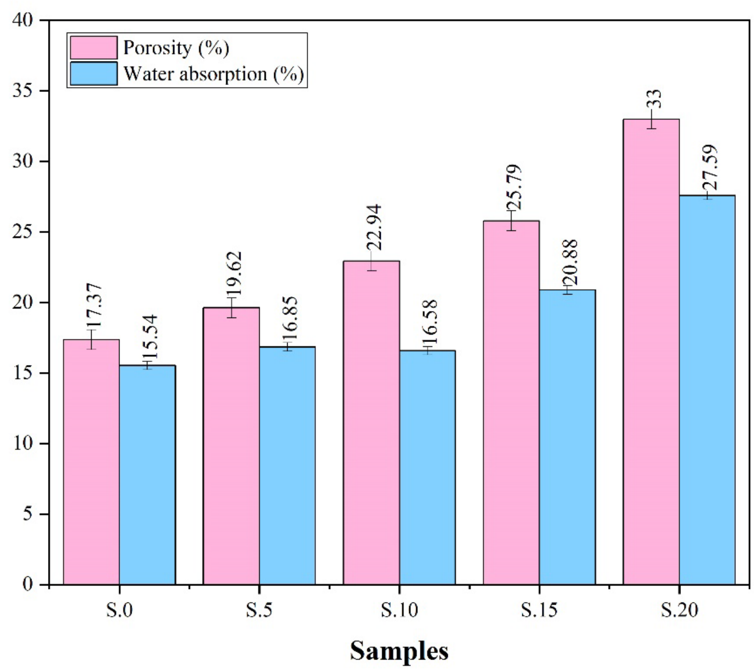


Fig. 3. Variation of open porosity, and water absorption with the addition of CPS

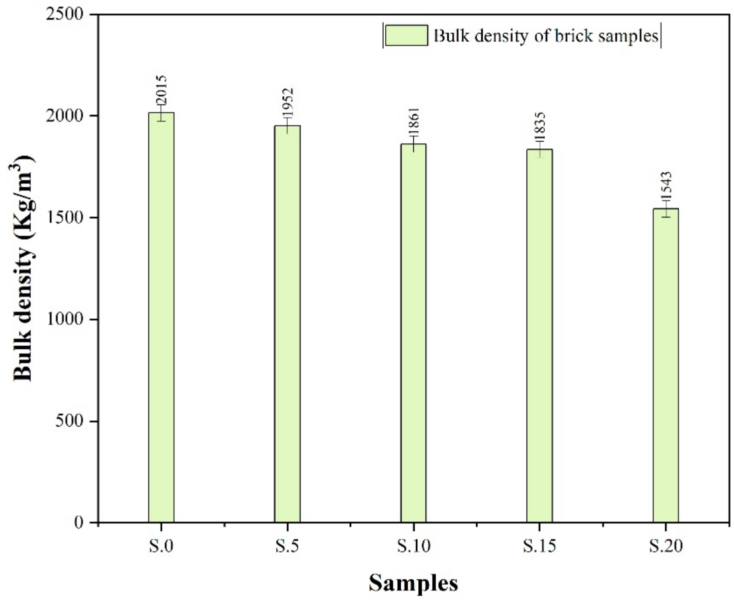


Fig. 2. Variation of bulk density with the addition of CPS

Fig. 3 shows the water absorption values of the brick samples. The addition of CPS appears to improve water absorption, as can be demonstrated. The brick without additives had the lowest value at 15.54%, while the brick with 20% CPS had the highest value at 27.59%. Since material porosity and water absorption are closely correlated, this conclusion is consistent with the bulk density figures. These conclusions are validated by the literature study. For example, the water absorption of burned brick specimens with waste rice husk ash addition was studied by De Silva et Perera [8]. When 10% rice husk ash was added, the water absorption value was 27%, while the reference samples had a water absorption percentage of 21%. The water absorption of bricks that are resistant to severe weather should not be more than 17%, and that of bricks that are resistant to moderate weather should not be greater than 22%, according to the ASTMC67-07a standards: 2003 [25]. When less than 10% of CPS was added to our samples, the water absorption results demonstrated that the samples met the strict requirements for weather-resistant bricks.

Compressive Strength

The compressive strength test is essential for assessing the quality of shaped bricks[10,26].

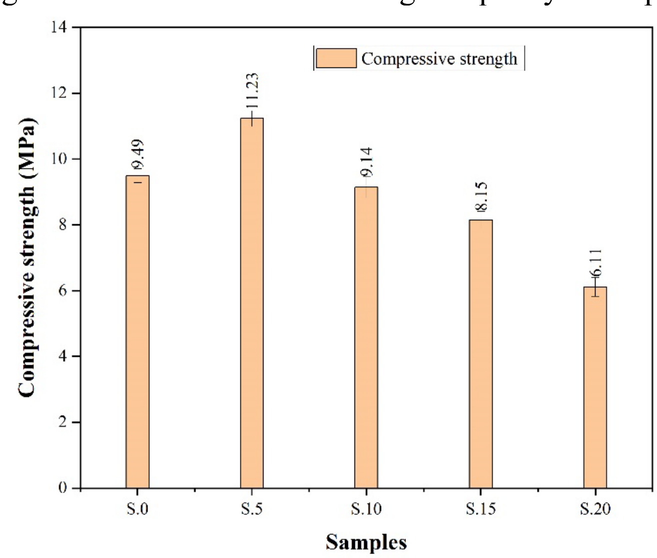
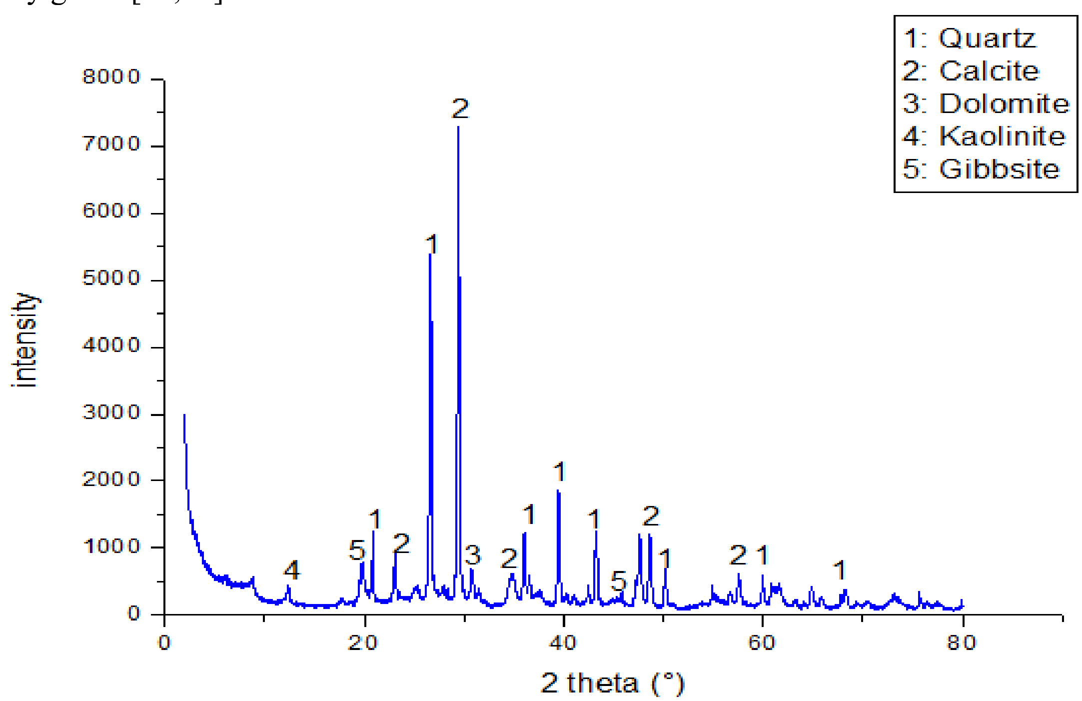


Fig. 3. Variation of compressive strength with the addition of CPS

The compaction resistance test results are displayed in **Fig. 5**. In this study, only 5% of CPS was added to bricks to improve their compressive strength by around 25The addition of CPS up to 5% results in an increase in compressive strength to a maximum of 11.23 MPa for S.5 sample. As a result, the compressive strength decreases below this rate. A significant amount of silica in the CPS used in this study may have contributed to the geopolymerization process, which forms a compact and strong geopolymer by hardening and forming a viscous cementitious slurry from aluminate and silicate [26–28]. However, it is best to avoid adding a lot of CPS as this can reduce the bricks' compressive strength. This might be the result of CPS breaking down, as it contains some organic material that burns when it is fired [18]. In accordance to the European Standard [29], The compressive strength outcomes for all bricks (excluding S.20) meet the necessary minimum threshold of 7 MPa, consistent with the conclusions drawn from previous literature [26–30].

X-Ray Diffraction
The bulk raw sample's XRD data are shown in Figure 6. It is evident that the primary constituents of Goulmima's sample include quartz, calcite, dolomite, kaolinite, and trace amounts of gibbsite. Because of its limited plasticity, low water absorption, and low shrinkage characteristics, kaolinite is regarded as a non-expandable clay. [31,32] . This is because their tetrahedral and octahedral sheets have strong interlayer bonds (Van Der Waals forces for kaolinite), which stop clay from expanding and absorbing water. This implies that the mechanical properties of this soil are generally good. [32,33].



Conclusion
This investigation establishes the viability of utilizing crushed date seeds as a clay additive to enhance the quality of clay bricks. The deliberate selection of date seeds is rooted in the prolific production of dates in the Errachidia region, resulting in a notable surplus of date stones as a byproduct. The study introduces a practical approach to systematically integrate date stone powder into the terracotta brick manufacturing process, effectively closing the recycling loop for this waste material. This integration not only addresses the waste predicament in the clay brick industry but also elevates the environmental sustainability profile of the resultant bricks.

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