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Investigation of Wood Biomass Ash on the Thermal Behaviour of Compressed Earth Bricks

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Abstract – The aim of this work is to study the effect of the incorporation of wood ash from the combustion of biomass waste on the thermal properties of compressed earth bricks (BWA). These bricks were obtained as a partial substitution of the soil with different contents (0, 5, 10, 15 and 20% wt). The specimens manufactured were compacted with a compaction stress at 10 MPa, conserved in the laboratory at a temperature of 20 ± 2 °C, then allowed to harden for 7 and 28 days. The results showed that the partial substitution of the soil leads to a decrease in thermal properties.Thermal conductivity values were decreased to different soil substitution proportions and with curing time. Minimum values were achieved for specimens containing 20% by weight of WA, with better thermal insulation, at thermal conductivity values ranging from 0.78 W/mK in BWA at 28 days and 1 W/mK in BWA at 7 days. This decrease was attributed firstly to the quantity of water consumed during the pozzolanic reaction that occurs between the soil components and the lime of the WA, secondly to the microstructure of this soil used.

Keywords Wood ash, Thermal properties, Compressed earth bricks, Thermal insulation.

Introduction

Since its existence, soil has been utilized in construction as a raw material, it has many advantages namely ecological, economic and environmental that allow it to be an important and main material in the construction of buildings (Rivera et al., 2021; Mansour et al., 2016). The performance of this earth depends mainly on its hygrothermal behavior, which is directly related to thermal and hydric properties and can be characterized by thermal conductivity (Mansour et al., 2016; Balasubramaniam et al., 2021; Omar Sore et al., 2018), but its disadvantage is that they suffer from a lack of mechanical strength, cracking due to shrinkage and sensitivity to water. To remedy these problems, the researchers used different stabilizers namely cement, lime, natural materials, biomass waste and industrial by-products (Felipe –Sesé et al., 2020; Eliche – Quesada et al., 2021).It hasseveralecological,economicandenvironmentalbenefits.

The current challenge in the champ of building materials is oriented towards the recovery of wood ashresulting of combustion of biomass waste to ensure on the one hand an improvement in thermal properties and on the other hand, an energy saving (Mansour et al., 2016; Felipe –Sesé et al., 2020; Çiçek et al., 2015). The main objective of this study is to develop new, cost-effective and environmentally friendly building materials based on wood ash from the calcination of biomass waste. In this context, BWA were carried out by partially replacing the soil with WA with different percentages (0, 5, 10, 15 and 20% wt) and then compacted at a compaction stress of

10 MPa. Before the thermal behaviour test, the bricks were left to cure for 7 and 28 days, then conserved in the laboratory at a temperature of 20 ± 2 °C.

Experimental Investigations

Characterizations of Materials Used

The materials utilized in this search are a silty clay soil collected from a local quarry in the Bejaia region (Algeria), wood ashmainly from biomass waste denoted WA. These materials are shown in Figure 1.

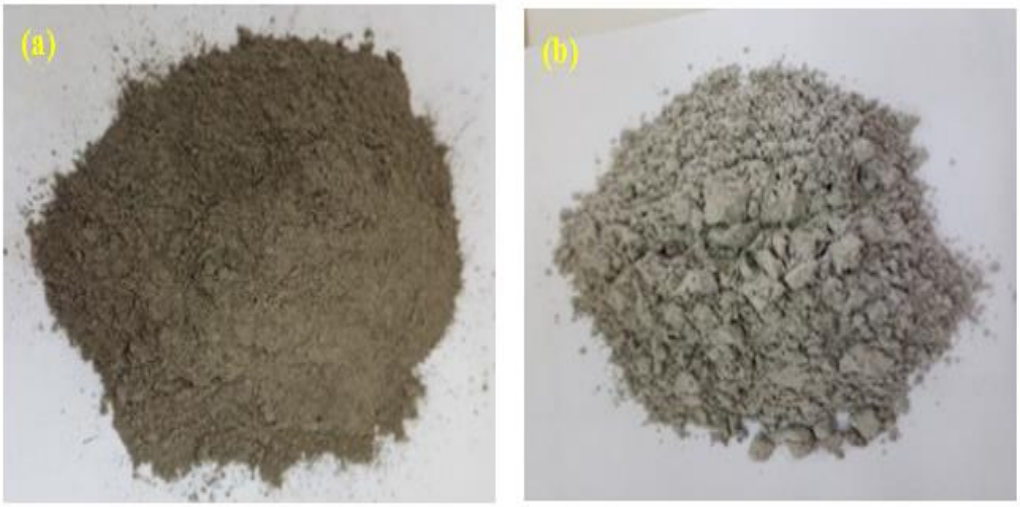

Figure 1. (a) Soil, (b) WA.

The chemical composition illustrated in Table 1 was determined by the X-ray fluorescence spectrometry (XRFS) technique. Elemental analysis of the soil yielded a high content of silica (SiO_2), alumina (Al_2O_3), iron oxide (Fe_2O_3) and calcium oxide (CaO). WA utilized as a source of lime in raw earth bricks contain a high CaO content.

Table 1. Chemical compositions of the materials used.

	Soil	WA
SiO_2	49.44	11.73
Al_2O_3	11.37	0.40
Fe_2O_3	5.31	0.02
CaO	14.63	43.74
MgO	1.70	1.58
K_2O	1.44	6.94
Na_2O	0.01	0.01
SO_3	0.70	0.82
LOI	15.38	34.55
Total	99.98	99.79

The mineralogical composition by X-ray diffraction (XRD) summarized in Figure 2 indicates that the principal phases existing in the earth are calcite, quartz and kaolinite. A laser particle size distribution (Figure 3) was performed on these materials indicates that the soil consists mainly of 87% silt and 12% clay. The clay content is low compared to the lower limits of the granular specifications proposed by the AFNOR NF XP 13-901 standard for a soil destined for the manufacture of compressed earth bricks.

The particle size of the WA revealed the presence of a high fine content of less than 20µm, of the order of 96%. The physical properties of the soil are thus evaluated (Table 2) i.e., the Atterberg limits determined according to standard NF P 94-051 and the methylene blue test was carried out according to standard NF-P18-592.

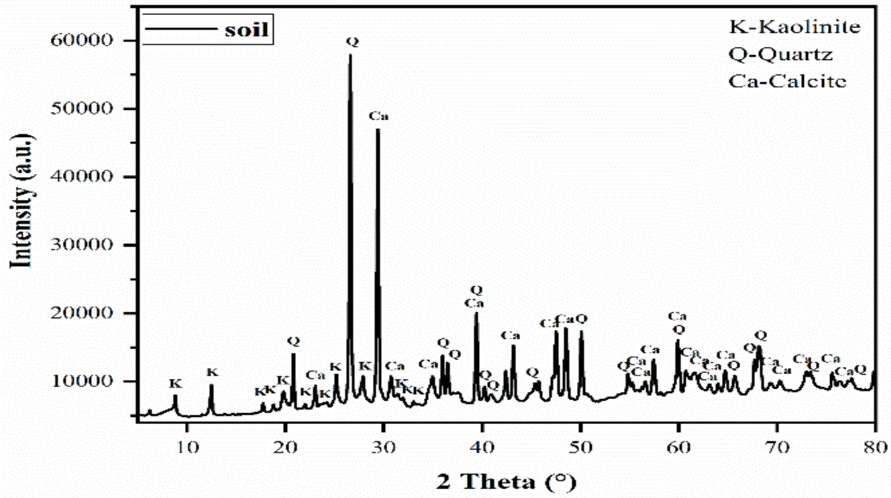

Figure 2. XRD of soil.

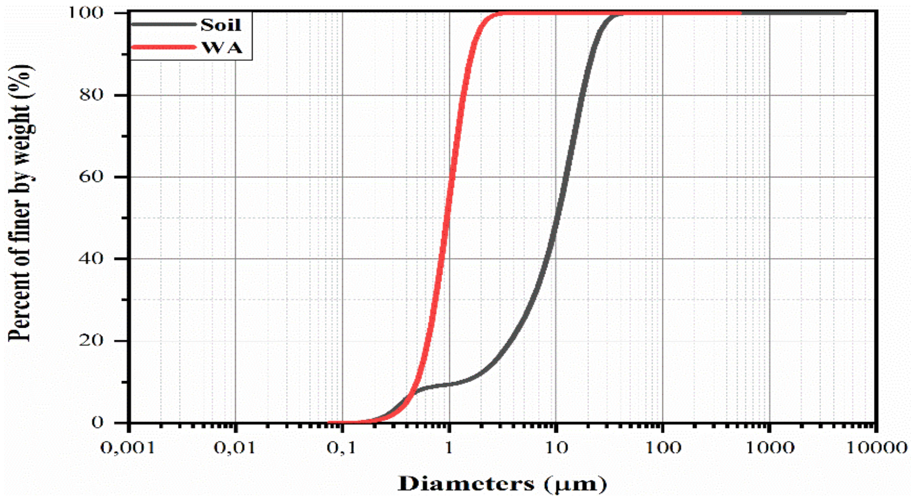

Figure 3. Particle size analyses of raw materials.

Table 2. Physical properties of the materials used.

Physical properties	Soil
Methylene Blue Value	2.77
Limits of Atterberg	
Plasticity limit Wp (%)	19
Liquidity limit WL (%)	39
Plasticity index Ip (%)	20

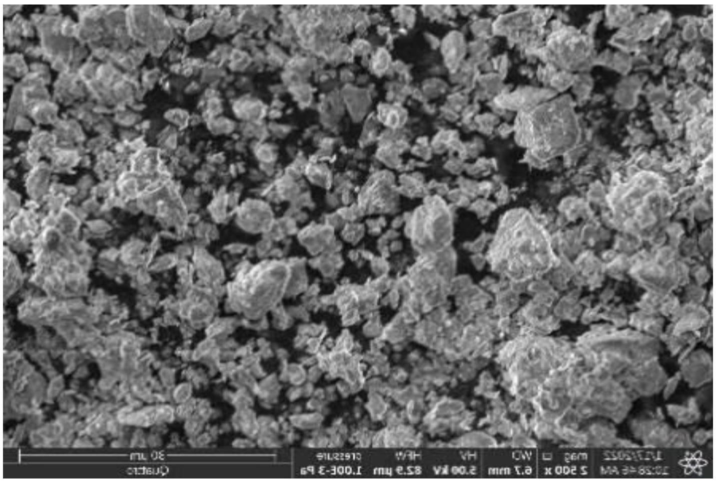

Figure 4. SEM image of soil used

The microstructure of these materials was characterized by scanning electron microscopy and SEM/EDX energy dispersion X-ray spectrometry using the high-resolution transmission electron microscope (Thermo Scientific™ Quattro ESEM). The microstructure of this soil is shown in Figure 4, has a dispersed particle size distribution with a concentration of small particles in the middle.

Preparation of BricksBWA(0-20%)

Four sets of BWA specimens were made for the different laboratory tests according to the fraction of WA added (0, 5, 10, 15 and 20% by weight). For each series three specimens were prepared. BWA(X%) are bricks mixed with WA with a partial substitution percentage X. The 0% WA reference specimens is denoted as BWA(0%). Before starting the preparation of the bricks, it is necessary to ensure that the materials are completely dry, for this, the soil and the WA have been dried in the oven at 105 °C for 24 h. The WA was first incorporated into the soil in a mixer, then the whole was mixed dry for 3 min to obtain a homogeneous mixture and that the grains of the soil were tightly mixed with those of the WA. The optimal water measured for each percentage of soil substituted by WAwas gradually added to the dry mixture and then the whole was mixed again in the mixer for 2 minutes. The assembly was then poured into steel molds of dimensions (16x5x2) cm^3, then compacted to 10 MPa utilizing a hydraulic press with a uni-axial load. After demoulding, the specimens were stored under standard laboratory conditions at a temperature of 20 ± 2°C for 7 and 28 days.

Results and Discussions

Thermal Conductivity

After curing, the thermal conductivities of manufactured specimens were evaluated in accordance with standard NF EN 993-15, measured using an CT-meter, with the hot wire method determined according to ISO 8894-1:1987. The results illustrated in Figure 5 show the decrease in the thermal conductivity of compacted earth bricks as a function of the increase in wood ash content and time cure. Thermal insulation was better in bricks stabilized with 20% of WA at 28 days, of the order of 0.78 W/mK, and 1 W/mK in BWA(20%) at 7 days compared to BWA(0%), which is in the order of 1.32W/mK. This decrease was attributed firstly to the quantity of water consumed during the pozzolanic reaction that occurs between the soil components and the lime of the wood ash, as well as the water evaporated during curing time from 7 to 28 days. Secondly to the microstructure of this soil used (Figure 4), which has a high porosity in their microstructure.

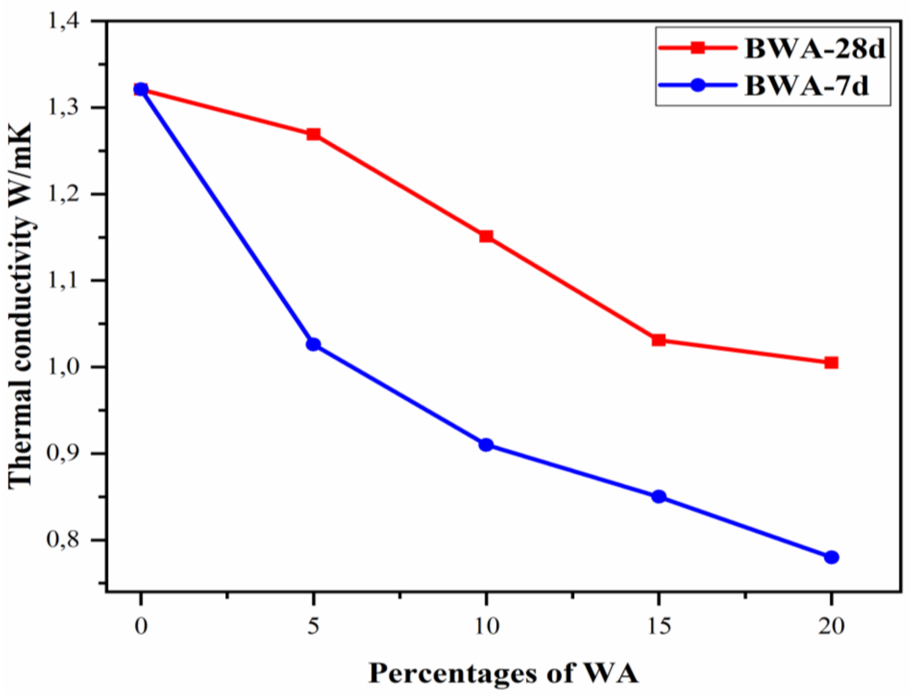

Figure 5.Thermal conductivity of raw bricks as a function of wood ash content.

This granular distribution (low clay percentages) causes pores connected to each other, forming thus a system and allowing the passage of flow between the pores of the brick. Similar results have been observed by other authors, the decrease in thermal conductivity related on the nature and amount of ash added to the mixture (Eliche – Quesadaet al., 2021; Çiçek et al., 2015; Minhaj Kazmia et al., 2018; Carrasco et al., 2014; Eliche – Quesada et al., 2018; Siddiqua et al., 2018; Rivera et al., 2021; Rivera et al., 2020; Leitão et al., 2017). The thermal conductivity values of BWA(0-20%) were below the minimum required by ASTM E2392M-10 it is of the order of 1.2W/mK.

Conclusion

Based on the results of this experimental study, it can be concluded that the recovery of wood ash as a partial substitution for silty earth was promising to produce compressed earth bricks. It's represented a sustainable solution with a good compromise between thermal, economic and environmental performance. WA are good chemical stabilizers for compacted earth bricks, they allow to achieve better thermal resistances (thermal conductivities) at 20% dosages. This experimental investigation gate on the advantage of recovering of wood ash from biomass waste to a high CaO content on the thermal properties of compressed earth bricks.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to authors.

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