Thermal Performance and Environmental Analysis of a Brick Based on Traditional Gypsum Plaster Reinforced with Date Palm fibres

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Abstract: Timchemt is a traditional plaster that has been used for a long time and until today in the construction of the Ksar of Ouargla through their facility of obtaining and realization. In addition to that, because of the use of industrial building materials, nature is carried out by the toxic gases that are produced in factories when these materials are manufactured. So to minimize these negative effects on our planet and to encourage the use of local materials from the Saharan region, we have studied this material to improve its characteristics and to replace the others, especially because it is natural and does not harm the environment. The main objective of this paper is the improvement of the thermal properties of gypsum plaster by mixing it with date palm fibres in order to be used in wall and ceiling mortars. The thermal conductivity, thermal diffusivity, and thermal effusivity of the studied samples were measured using a steady hot plate. The obtained results show that the increase in the mass fraction of date palm fibres resulted in a significant improvement consisting of a reduction of the material's thermal properties. This reduction was up to 36% for the thermal conductivity, 13% for the thermal diffusivity, 23% for the thermal effusivity, and 16% for the volumetric thermal capacity.

Keywords: Brick, Traditional plaster, Date palm fibres, Thermal properties, Mechanical properties.

1. INTRODUCTION

Algeria contains a variety of local products utilized in the construction field that should be valued. For example, those situated in the southern part of the country, Namely: Sand dunes, gypsum, clay, palm wood, etc. that are still undervalued. The building materials currently used in the Saharan regions are not well-adapted to the

climatic and environmental conditions, sustainability, and economics.
Moreover, in order to better comprehend how local materials behave in the context of civil engineering and building construction. Estimating their resources and researching their physical, chemical, mechanical, and thermal characteristics are crucial. This area is also characterized by a very large number of remnants of date palms and plaster. Where this current work contributes to the development and valuation of local resources and their inclusion in the field of construction.
Which is the original plaster known as "Timchemt", which improves the mechanical properties of bricks made with Timchemt, and to study the effect of adding cement in specific proportions up to 5%. These new environmental compounds have very important thermal and mechanical properties.
The following literature shows a range of research projects that have been conducted to include natural additives in building materials to enhance their thermal properties.

A study on surface date palm fibers was undertaken by KRIKER A. et al[5] . in 2005. These fibers appear to be the most ideal for exploitation, the authors said to support their decision. The four varieties of date palm surface fibers (FSPD) used in this study are male date palm, Deglette-Nour, Degla-Bida, and El-ghers (local names). The findings showed that the male date palm's surface fibers (FSPDM) have more tensile strength than the other types of fibers under investigation. and Benmansour et al[15] , who produced a new material consisting of natural cement, sand, and date palm fibers (DPF), and a study on the possibility of using this new material as a thermal insulation building material. Where they discovered the results that the incorporation of DPF reduces the thermal conductivity and compressive strength of the composite while reducing the weight. Khoudja et al [16]. A study on a bio-sourced composite material, in the form of raw ground bricks, cemented with lime and mixed with date palm residues. The addition of residues with different contents had a positive effect on the physical and thermal properties of the obtained bricks and on its mechanical behavior and a significant improvement in thermal insulation. Ouakarrouch et al [17]: Adding chicken feather droppings to gypsum plaster to improve its thermal qualities and use it as a wall and ceiling mortar. The static hot plate method, the flash method, and the transient hot plate method, respectively, were used to assess the thermal conductivity, thermal diffusivity, and thermal reactivity of the samples under study.

The obtained results demonstrated that the material's thermal characteristics significantly improved as the mass percentage of chicken feathers increased. The decrease in heat conductivity was up to 36%.

2. STUDY PROBLEM AND QUESTIONS

It is our observation that most researchers in this field have important results. The two main targets in this work were intriguing. The first is to measure the thermophysical properties of gypsum composites by adding local palm fibers. Secondly, the new products created by local materials like plaster and palm fiber are used directly in construction.
The main aim of this article is to study how to improve the thermal performance of bricks made of traditional plaster mixed with date palm fibres. As a new composite construction material, "brick" is compatible with the demands and climate in desert areas and achieves thermal comfort while reducing energy consumption and environmental preservation. The experimental characterization of palm fiber reinforced gypsum's thermal properties was carried out to determine its bulk density, thermal conductivity, thermal diffusivity, thermal efficiency, and volumetric heat capacity.

2.1. Objectives of the study

The study aims to achieve the following:

- ✓ Promote local materials in southern Algeria.
- ✓ Utilization of plaster and date palm fibers in construction and the trend towards environmentally friendly buildings.

3. Methods and materials

3.1. The Traditional plaster “Timchemnt”

Traditional ovens are used to burn the plaster. These ovens are simple structures with a vertical oven that is 1.5 meters high and 1 meters in diameter and a horizontal oven that is 1 meters high and 4 meters in diameter in a courtyard. They are made of thick timchent [2]. For this, a worker goes down into the hole and places a row of large blocks of timchemt around the bottom (wait in front of the opening). Then he places a second row, a little set back towards the center, fills the sides with smaller pieces, and climbs on this second seat; a third is placed in the same way, and then, with a large block, the middle is blocked; in short, a vault has been built; the worker continues to fill the oven until it is above ground level, where it ends up in a dome, a dome almost one meter high in the center, above ground level.

At Kasdi Merbah Ouargla University's civil engineering laboratory, we are analyzing this material physically and chemically. The results of the physical tests are shown in table 1 as follows:

Table 1. Results of the Timchemt's physical tests.

Tests	Results
Apparent density	1.39 g/cm^3
Absolute density	2.18 g/cm^3
Methylene blue	0.68
Atterberg limit	WL=41.10
	WP=34.42
	IP=6.68
Sand equivalent	Esv=38.80 Esp=37.17

Our sample is between 0.2 and 2.5, which suggests that it is not extremely plastic, not very adsorbent, and sensitive to water, according to the NF P 94-068 standard.

Our Timchemt can be categorized based on Atterberg and Burmister's plasticity index IP=6.68. Due to the conventional plaster's less plastic nature and its natural density of 1.51 g/cm3, the result falls within the classification range of 1.4 to 1.8. Despite the differences that may be seen between them, this material is considered to be loose.

3.1.1 X-ray diffraction (XRD)

Utilizing x-ray diffraction (XRD), Timchemt's mineralogical makeup was examined. With the help of this method, you may pinpoint the crystalline phases contained in this conventional plaster and figure out the mesh parameters related to it.

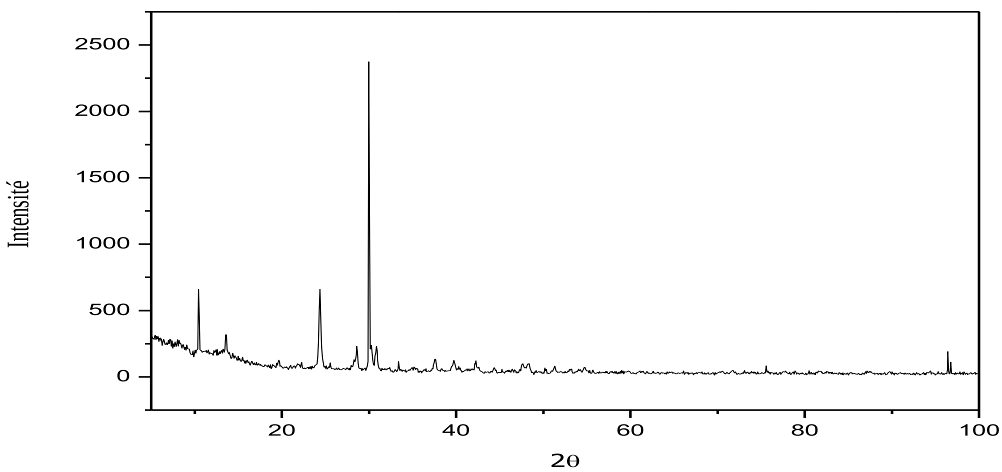

Figure 1. The X-ray diffraction (XRD) of Timchemt

Figure 1 Electromagnetic waves with a wavelength of between 0.01 nm and 10 nm are referred to as X-rays. They typically come out when fast-moving particles suddenly slow down. When electrons from an incandescent tungsten filament (cathode) are accelerated in the tube's vacuum at voltages typically between 15 and 60 kV and impact a metallic target (anode), X-ray emission is produced in an X-ray tube for diffractometry. The electrons collide with a lot of other electrons when they hit the target, The electrons abruptly decelerate as a result of colliding with a huge number of additional electrons during their impact with the target. The energy released when an atom returns to its ground state manifests as secondary radiation that is specific to each element and can either be radiative (X-rays) or non-radiative (Auger electrons) [2].

The fact that our Timchemt is sulfated over the course of the peaks observed in this diffractogram must be kept in mind. What we observe is as follows: Sulphate $CaSO_4$ makes up a sizable portion of the minerals, with a 96% NaOH content and low percentages of around 4%.Table 2 presents the results of the chemical analyses.

Table.2 Results of Chemistry tests on traditional gypsum (Timchemt)

	The Components	the Valuers
Insolubles NF P 15 - 461	Insolubles	27 %
	SO_3^{-2}	14.09 %
	$CaSO_4 / 2H_2O$	75.71 %
Sulfates BS 1377	SO_4^{-2}	16.93 %
Carbonates NF P 15 - 461	$CaCO_3$	2 %
Chlorides MOHR method	Cl^-	0.845 %
	NaCl	1.385 %

Gypsum makes up approximately 75.71% of the sample's constituents, according to the data in table 2, with a 27% insoluble content. Sulfates and chlorides are present in extremely small amounts.

3.2. Date Palm Fibres

The palm is a tree found in desert oases; it is characterized by its ability to withstand higher temperatures; its height can exceed 20 meters; and it can live 100 years. There are about 9 million date palms in Algeria.

Palm trees have more than 130 uses, for example:

- Manufacture of baskets and hats from these fibres.
- The extraction of therapeutic oils from its nuclei.
- Its barter used as beams for roofs in the construction of houses.
- Provide shade to create orchards in warm areas.
- Its dates used in the manufacture of date honey.

Figure 2. Date Palm Fibres [5]. **Figure 3. Lif enveloped trunk of date palm [5].**

The fibers that we have added to the compositions of the bricks in our work are the fibers of date palm. The couchequi envelops the palm bart

er, located between the barter and the Kenaf. These fibers have the form of entanglement. Chan is the name of these fibers in the local language of the Ouargla region. The two figures (2, 3) above illustrate the shape of the latter and their location in the palm barter.

In this study, they also studied fibre morphology and structure using scanning electron microscopy (SEM). The SEM images shown in the figures 4. (a) , (b) and (c), show a typical cross-section, a typical longitudinal cross-section and a longitudinal view of the FSPDM fibres.

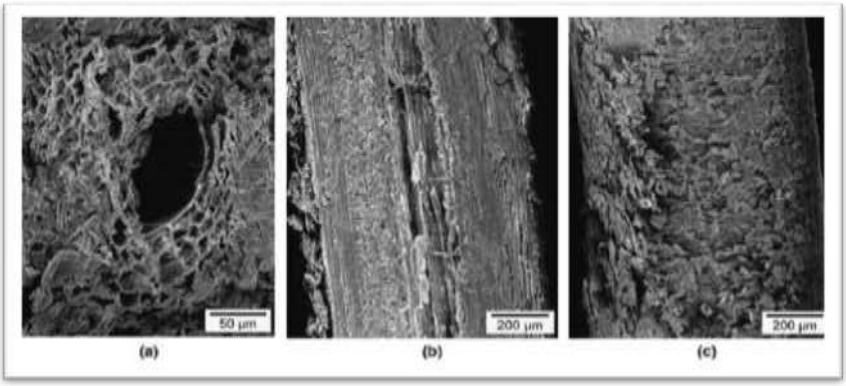

Figure 4. Observation under SEM of surface male date palm fibres: (a) typical cross-section; (b) typical longitudinal section; (c) longitudinal view of the fibre [8].

Figure 4 (a), (b) show that the fiber section is dense with a small channel and many small pores that allow saliva to circulate. This confirms that the structure is porous and that the fibres behave hydrophilically. Figure 4.(c) shows that FSPDM fibres have some roughness on their surface, which ensures good matrix fibre adhesion [5].

3.2.1 General Characteristics of Date Palm Fibres

The tests carried out have made it possible to characterize Ouargla date palm fibres as follows:

Apparent density: ρa=512,21-1088,81 kg/m^3

Absolute density ρs=1300-1450Kg/m^3

Tensile breaking load Ft = 85 N (8 mm diameter fibres)

Deformation at break 0.232

Moisture content w = 9.5 - 10.5%

Absorption rate (after 24 hours) TA = 96.83 - 202.64 %

Diameter (of fibres used): d = varied between 0.2 - 1 mm Length (of fibres used) L = 1 cm. [7]

4. Results and Interpretations

Five variants of the sample sizes (40x40x160) mm^3 de (Timchemt percentage plus a percentage of Date Palm Fibres) were prepared, using an initial weight, we then calculate the mass compositions shown in Table 3 which presents the percentages of the following brick components: calculate the weight of fibres and timchemt for each sample by applying the math to find the equivalent weight for each percentage.

Table 3: Brick components (Timchemt + fibres) in percentage (%)

Compositions	Percentage of traditional plaster	Percentage of fibres
C1	100%	00%
C2	99%	01%
C3	98%	02%
C4	97%	03%
C5	96%	04%
C6	95%	05%
C7	94%	06%

For each composition we added 36% water, this percentage representing a suitable volume for each variant. The following steps describe how to prepare the test pieces. The operation consists of weighing the materials used (Timchemt, fibres, and water) using a balance specified up to predetermined values, Then mixing these compositions, After gluing the mould is passed through the vibration apparatus to take out the area and decrease the number of voids, After hardening; the bricks are diced and stay 48 hours in the area to dry well figure 5.

Figure 5. Specimens of (traditional plaster + palm fibres)

We did not take the compositions C6 and C7 because, during the preparations, we observed that these two variants contain a high percentage of fibres, which impedes the handling of the mixture show figure 6**.**

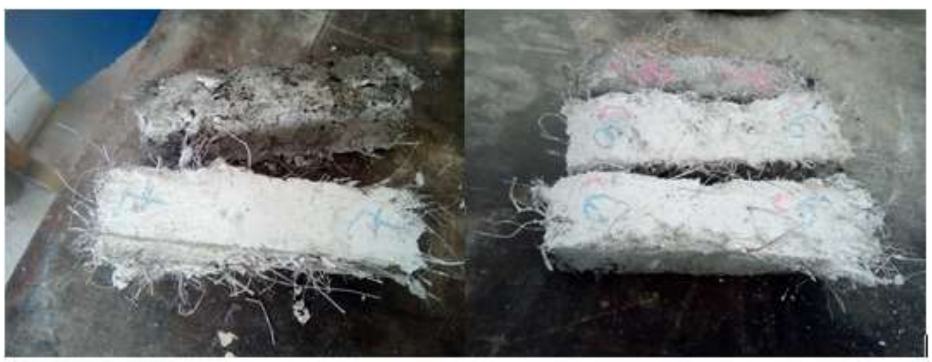

Figure 6. Photos of C6 and C7.

In this experimental and numerical study, the thickness of the plate, the diameter of the circular cutout, the distance between the circular cutouts, and the rowing orientation effect on the critical buckling behavior of pultruded E-glass/vinylester composite beams with single or double circular cutouts were investigated. From the results of this study, the following conclusions can be drawn:

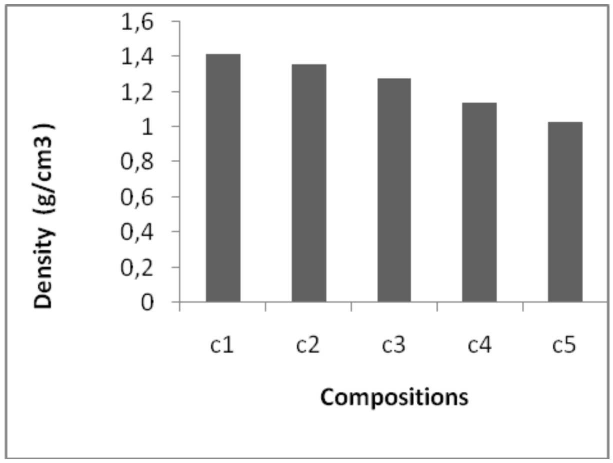

Figure 7. Density (g/cm^3).

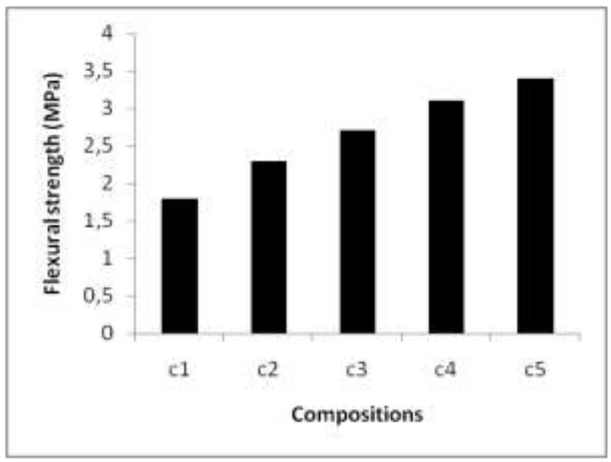

Figure 8. Flexural strength (MPa).

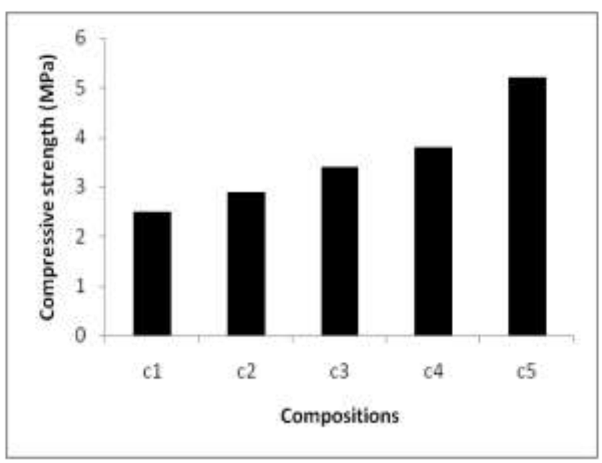

Figure 9. Compressive strength (MPa)

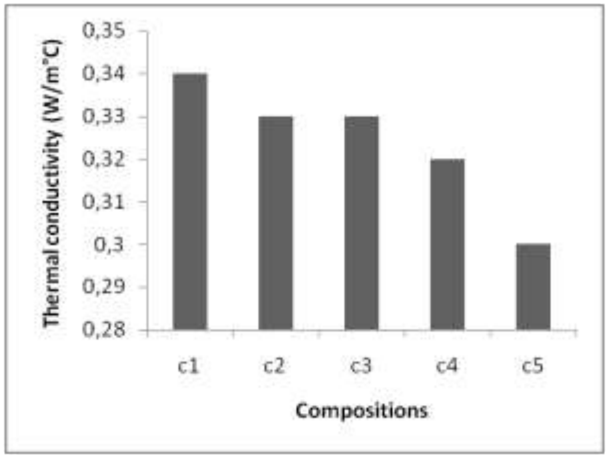

Figure 10. Thermal conductivity (W/m°C).

Based on these results, the following are noted:

- The following graph shown in Figure 9 gives the resistance of the bricks to compression, it is observed that this resistance increases gradually according to the increase of % of the fibres, it is noted that C1 which contains only traditional plaster gives a higher value, this is due to the compactness that was produced because of the absence of the fibres, the decrease in this resistance that was recorded for, C2, C3, C4, C5can be caused by the existence of porosity, because we have observed that the fracture zone is the one where the fibres are present, this porosity increases by the increase of % of the fibres, that which negatively affects the compressive strength.
- The following figure shows the velocities of the waves obtained by the ultrasonic test; a decrease of this velocity is shown here, this decrease saying that the fibres created from the voids inside the test specimens.
- The following Figure 7 shows that composition C1 marked with the maximum density value and C4 gives the minimum, that is, the fibres decrease the density of the bricks, This decrease can be produced by the low weight of the fibres as well as the agglomeration of the fibres which created by inadequate vibration. Very dense materials (which have a high density) are particularly resistant to compression, that is to say when the compactness is important. But here we have observed that compositions which have low values of density give bad values on the other hand to compression, which conforms to the hypothesis of existence of porosity.
- Figure 8 shows the results of the bending tensile test, the histogram shows that there is an increase in the resistance to successive bending from C1 to C5, This explains that the addition of fibres to the compositions of bricks with well-defined values is positively influenced to bending, especially as the latter work well at the traction.

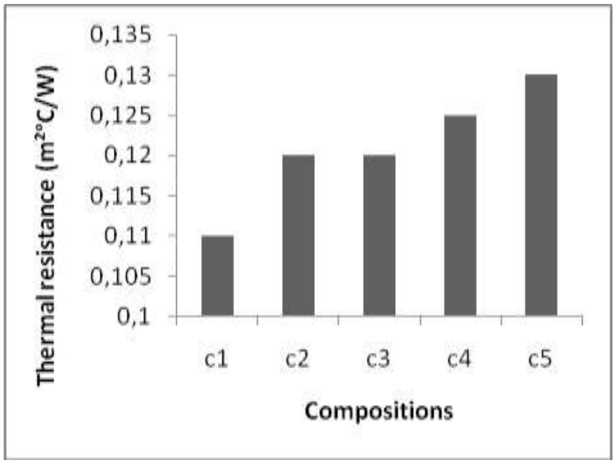

Figure 11. Thermal resistance

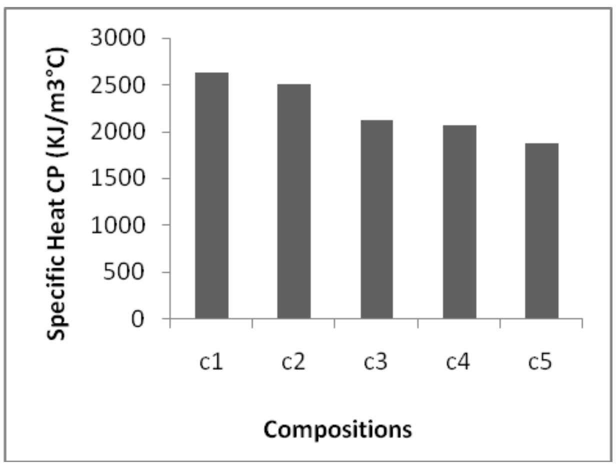

Figure 12. Specific Heat CP (KJ/m3°C).

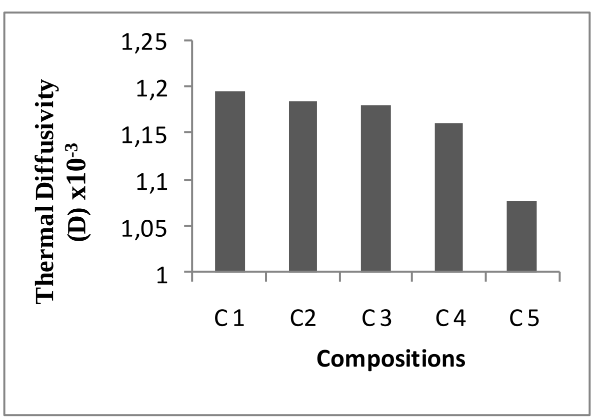

Figure 13. Thermal Diffusivity (D)

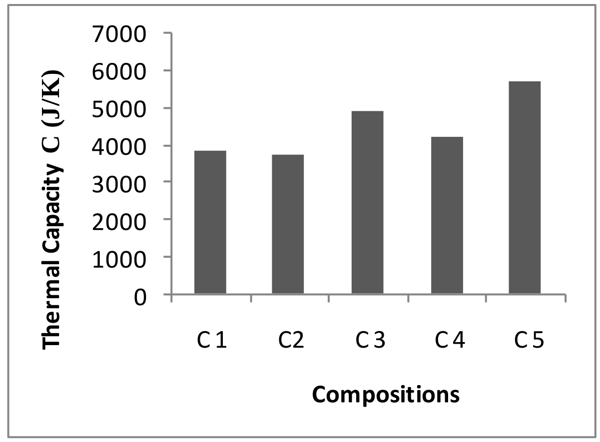

Figure 14. Thermal Capacity(C).

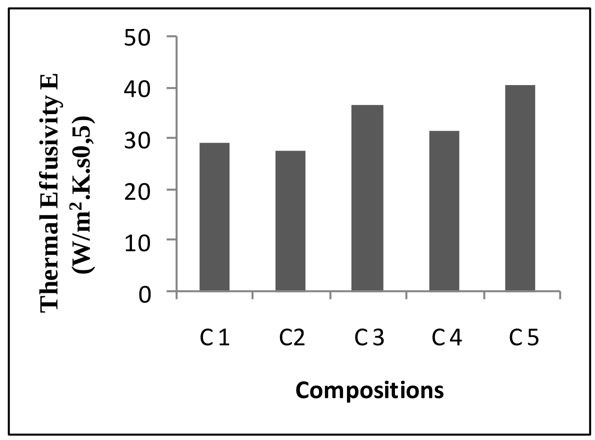

Figure15. Thermal Effusivity (E).

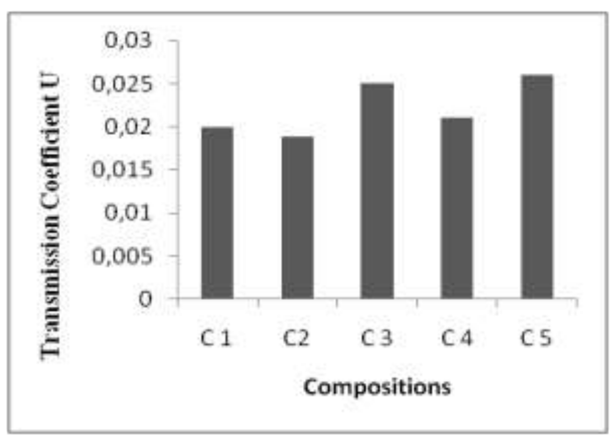

Figure16. Transmission Coefficient U (E).

• Thermal conductivity is the ability of a material to transfer heat. Minerals have high thermal conductivity in contrast to wood and plastics, for building materials the lower the thermal conductivity the more the material has good thermal conductivity, because we will ensure that the external heat does not penetrate the interior of the structure, the results obtained indicate that the compositions of the bricks have acceptable thermal conductivities, we notice an increase in conductivity as a function of the increase in the percentage of fibres in the mixture. The best value marked 0.3 (W/m K_o) of variant C2.

- Since the thermal resistance (R_{th}) is meant the ability of the element to isolate heat, we notice across the curve a decrease in the values of this resistance as a function of decrease of % of traditional plaster and increase of % of fibres, the best value is 0,53(W/m^2.K°) of the C2 composition.

- According to the curve in Figure 12, the values of specific heat (Cp) are varied between 2000 and 2625(J /Kg. K°), showing that the heat transfer between the particles of the material is very low and requires a large amount of heat for the transfer. This is because the element does not retain heat, which increases thermal insulation and strengthens thermal resistance.

- The histogram in Figure 14 indicates that the Transmission Coefficient (U) is automatically increased as it is the inverse of the thermal resistance.

- The thermal capacity (C) is a coefficient that shows the capacity of an object to conserve thermal energy (the greater the amount of material, the greater the thermal capacity), in our case, we must take the smallest value, which equals 3744.18 (joule per kelvin) which belongs to composition C2.

- Figure15 shows the histogram showing the results of the Thermal effusivity (E) which was expressed in (J/K1 m^2 s1/2), the values of this properties increase with the increase in fibre content, This indicates that the existence of the capacity to exchange thermal energy with the environment is possible for this type of brick, then the minimum value equal to 27,5 (J/K1 m^2 s1/2) of the composition C2 is taken. It can also be concluded that the % increase in fibre decreases the value of this characteristic.

- The values of thermal diffusivity (D) presented in the graph of the last figure decrease successively from C1 to C5, these values vary between 1,197x10^{-3} and 1,078 x10^{-4}(m^2/s). We said earlier that materials with high thermal diffusion values quickly adjust their temperature to suit the ambient temperature, so from these results it can be concluded that this type of brick has this particularity.

5. Conclusions

Through the definitions presented in the first chapter, we say that gypsum is the raw material for producing traditional plaster. To prepare the traditional plaster with the traditional method, we must add wood or city gas for the help of cooking.

White cement is gray cement are different because the existence of iron oxide and magnesium in lime used in cement manufacturing allocates the color of this material.

Traditional plaster is a link like industrial plaster and cement, so it works well at compression but does not work at traction, according to KRIKER (2005) the breaking load at the fiber traction: Ft = 85 N (8 mm diameter fiber). Our material will use for making insulation bricks, the addition of fibers helps to increase the tensile strength of these bricks.

The following chapter presents the physical and chemical characterization of traditional plaster

6. Funding statement

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7. Availability of data and materials

The “Experimental Research” data used to support the findings of this study are available from the corresponding author upon request .

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