Properties of extruded clay bricks reinforced by date palm fibers following the same industrial production steps.

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ABSTRACT.*In arid zones of Algeria the climate is characterized by hot and dry in summer, very cold in winter. Construction materials used in these zones are concrete and clay bricks. These materials have poor insulating properties and are not adapted to this climate. In order to improve thermal comfort in the building and saving energy, it is necessary to ameliorate the performance of construction materials used which must be good insulators while having an acceptable mechanical strength. In this study, we have elaborated extruded clay bricks with good mechanical and thermal properties. We tested (07) seven sample compositions of dimension 40x40x160 mm^3. The percentage of dune sand was set at 20% according to the optimal ratio used in the Brickyard for all compositions with clay / fiber ratios of (78% / 2%) to (68% / 12%) respectively.*

Results showed that as the fiber content increase, the bulk density decrease, providing a light-weight construction material combined with low conductivity with acceptable mechanical strength. The optimum is obtained for a composition with 20% dune sand, 68% clay and 12% fiber. For this composition the weight reduction has exceeded 22% for an energy saving impact of more than 42% in normal state of conservation of samples..

RÉSUMÉ *Dans les zones arides de l'Algérie, le climat est caractérisé par un climat chaud et sec en été et très froid en hiver. Les matériaux de construction utilisés dans ces zones sont du béton et des briques d'argile. Ces matériaux ont de faibles propriétés isolantes et ne sont pas adaptés à ce climat. Afin d'améliorer le confort thermique dans le bâtiment et d'économiser de l'énergie, il est nécessaire d'améliorer les performances des matériaux de construction utilisés qui doivent être de bons isolants tout en ayant une résistance mécanique acceptable. Dans cette étude, on a élaboré des briques d'argile extrudées avec de bonnes propriétés mécaniques et thermiques. Nous avons testé (07) sept compositions d'échantillons de dimensions 40x40x160 mm^3. Le pourcentage de sable de dune a été fixé à 20% selon le taux optimal utilisé à la Briqueterie pour toutes les compositions avec des taux d'argile / fibres pris égaux respectivement de (78% / 2%) à (68% / 12%). .*

Les résultats ont montré que lorsque la teneur en fibres augmente, la densité apparente diminue, fournissant un matériau de construction léger combinée à une faible conductivité avec une résistance mécanique acceptable. L'optimum est obtenu pour une composition avec 20% de sable de dunes, 68% d'argile et 12% de fibres. Pour cette composition la réduction de poids a dépassé 22% pour une incidence sur l'économie d'énergie de plus de 42% en état de conservation normal des échantillons

KEY WORDS: extruded clay bricks, thermal insulation, date palm fibers, sand dune, mechanicals and thermo-physical properties of extruded clay bricks.

1. Introduction

In arid zones of Algeria, the most used construction materials are concrete and clay bricks manufactured by Brickyard that have poor thermal insulation power and are not adapted to the local climate. Indeed, the building envelope mainly fulfills two thermal functions; the first is a thermal storage function and the second is an insulating function, which is consists of minimizing the thermal flow that passes through the walls. This second function is generally not satisfied for the industrial clay brick, thus causing a thermal discomfort difficult to restore. In order to improve thermal comfort of building and saving energy, a new clay bricks elaborated by extrusion following industrial production is proposed for study. The objective of this research is to prepare and test for mechanical, physical and thermal properties of this new extruded clay bricks reinforced by date palm fibers.

2. Materials and Procedures

2.1 Used materials

2.1.1 Clay (earth): In this study we use clay from Blidet Amor Town in Algeria. The Physical characterization was carried out in (Ouargla) LTPS laboratory. The results are presented in Table 1.

Table 1. *Physical characteristics of clay.*

Characteristics	Results
The dry bulk density (NF 94- 064)	ρ_b =1920 kg/m^3
Methylene blue (NF 933-9)	ρ_b =1920 kg/m^3
Limit of Atterberg (NF 94-051)	WL= 86,73 % WP= 33,17 % IP= 53,56 %

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The main chemical experimentations were performed in(Boumerdes)CETIM.The results are grouped in table 2.

Table 2. *Chemical analysis of clay performed in CETIM by x-ray fluorescence spectrometry***.**

Constituents	Fe_2O_3	MnO	SiO_2	CaO	MgO	K_2O	Na_2O	P_2O_5	Al_2O_3	TiO_2	Cl	PF
Pourcentages (%)	4.66	0.05	50.62	11.61	2.39	2.06	0.91	0.18	12.18	0.60	0.66	14.6

The table shows that the mainly consists of this clay are SiO_2, $Al2O3$, and CaO .Minor contents in clay consist of Na_2O, SO_3 and Cl.

2.1.2. The sand dune: The used sand dune was from Blidet Amor town in Ouargla Algeria.The physical and chemical analysis were carried out in (Ouargla) LTPS laboratory The results are summarize**d** in table 3.

Table 3. *Physical and chemical analysis of sand dune.*

Characteristics	ρ_b (Kg/m^3)	ρ_a (Kg/m^3)	ESP ('%)	$CaSO_4$ 2 H_2O('%)	SO_4 (%)	SO_4 (%)	$CaCO_3$ (%)	Cl (%)	NaCl (%)	Insoluble (%)
Results	2606.43	1496.72	80.53	2.95	0.73	1.44	1.34	0.16	0.27	93.49

Regarding the poor percentage of $CaSO_4$, SO_4 , the sand is considering as a not aggressive one.

2.1.3. The date palm fibers: The natural fibers used in this study as reinforcement is the date palm fibers collected from the oasis of Touggourt.The physical, mechanical and mineralogical analyses of fibers are taken from a previous study of KRIKER and al [KRI 2005].The results are presented in tables 4&5.

Table 4. *The physical, mechanical and mineralogical compositions of date palm fibers* [KRI 2005].

Characteristics	ρ_b (Kg/m^3)	ρ_a (Kg/m^3)	Fiber length (mm) Tensile Strength (Mpa) 100	60	20	Deformation at break of fiber (Ø 0,8 mm)	Natural moisture (%)	Rate of absorption (%)	Diameter of used fibers (mm)
Results	2606.43	1496.72	170±40	240±30	290±2	0.232	9,5-10	96,83-202.64	0.14-1.7

The mineralogical compositions of date palm were determinate from the powder of fibers after calcinations at 400°C [KRI 2005].

Table 5. *The mineralogical compositions of date palm fibers* [KRI 2005].

Constituents	Fe_2O_3	MnO	SiO_2	CaO	MgO	K_2O	Na_2O	P_2O_5	Al_2O_3	TiO_2	PF
Percentages (%)	2.51	0.05	48.04	14.2	4.88	2.80	1.81	50.45	6.12	20.42	18.08

The major mineralogical compositions of date palm fibers are extremely similar to clay.

*2.1.4. Samples preparation***:** The samples of dimensions (40x40x160) mm^3 were prepared with seven (7) different weight fractions (0,2,4,6,8,10 and 12%) of date palm fibers , (80,78,76,74,72,70 and 68%) of clay and the Percentage of sand dunes set at 20% according to the optimal ratio used in the Brickyard, which were labeled as C_2, C_4C_6,C_8, C_{10}, C_{12} and C_0 taken as reference . For each composition, Three (3) samples were necessary to retain the average of the property studied for mechanical (flexural and compressive strengths) , and thermo-physicals (thermal conductivity, Linear shrinkage and bulk density) properties. It is noted that the same steps, used in Brickyard, were followed for preparation of samples.

3. Procedures

3.1 Mechanical characterization: The flexural and compressive strengths are tested according to standard EN 196-1.The mechanical properties obtained from tests performed on three brick samples testing machine three points test configuration, the max flexural strength of samples determined from the maximum load until the rupture of the prism and after flexing, we reuse each half-prism for testing compressive strength of samples determined from the maximum load until the rupture.

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3.2 Thermo-physicals characterization

3.2.1 The physical characterization: linear shrinkage and bulk density were considered in our study.

Linear shrinkage: The total shrinkage was obtained by measuring the length of sample before and after firing, using a caliper with a precision of ± 0.01 mm, according to the standard ASTM C326-09 standard.

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Bulk density: The bulk density of a specimen is the quotient of its dry mass divided by the exterior volume.

3.2.2 The thermal characterization: The samples were tested for thermal conductivity and specific heat according to NFE 993-15, by the use of CT Meter device, equipment developed by the Scientific and Technical Center for Building (CSTB) of Grenoble, to determine with precision the thermo-physical properties of certain number of materials .The brick samples were tested under the different climatic conditions. At first, the samples were tested in the normal state where they were permanently in the open air (with natural conditions of temperature, pressure and humidity of the measuring room).Then the measurements of the thermal conductivity were carried out at different rates of saturation (in the dry state 0 %, 35%, 70% saturated state of 100 %). Successive water contents were obtained by first saturating the samples tested and then gradually dewatering by drying in a ventilated oven.

3. Results and discussion

3.1. Mechanical properties: Figure 1 shows that increasing fibers percentage decreases flexural and compressive strengths. The lower value of compressive strength (5 MPa) is obtained for 12% of fibers content, which is the minimum strength recommended by British Standard specification for clay brick BS 3921, the standard deviations on the results obtained in fluxion and compression vary between (0.049- 0.293) and (0.026- 0.193) respectively.

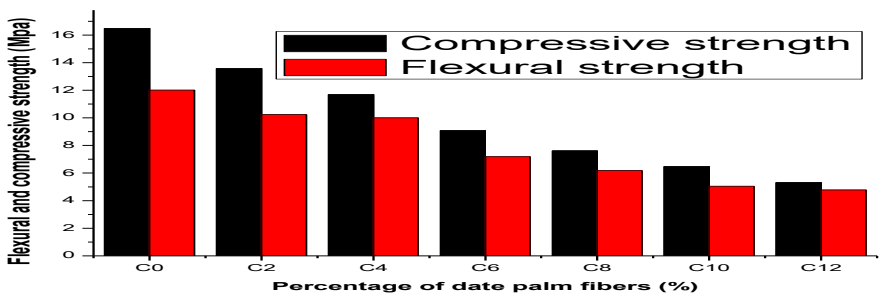

Figure 1. *The compressive and flexural strengths.*

3.2. Thermo-physical properties:

3.2.1 The thermal conductivity: The results presented in figures 2 and 3 show that the thermal conductivity of extruded clay bricks decrease with the increasing of percentage of date palm fibers and ameliorates its thermal insulation by saving energy over 42% in normal state and an increase in the thermal conductivity with the increase in the water content. This result is strongly impacted by the micro-structural nature of the material and its high moisture storage capacity. Indeed, in the dry state, the thermal conductivity only depends on those of the solid matrix and the air (about 0.26 W / m K at 20°C), this last one is much lower than the thermal conductivity of water (approximately 0.60W / m K at 20 ° C), which will gradually replace the air contained in the pores, during the humidification. This phenomenon allows an increase in the thermal conductivity of the material, which has a negative influence on the insulating power of these materials, the results obtained by using CT meter with a precision of ± 5%.

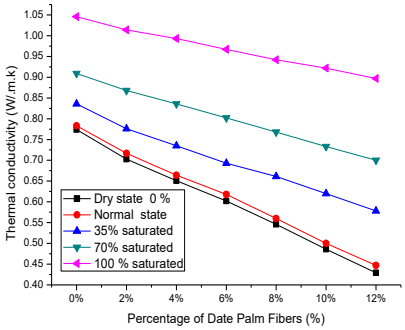

Figure 2. *Thermal conductivity in function of fibers.*

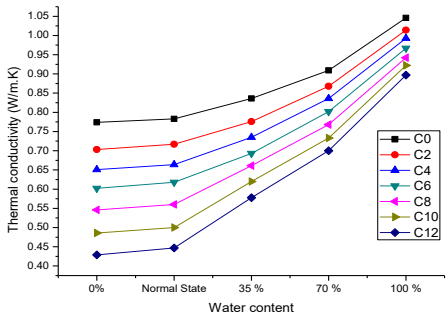

Figure 3. *Thermal conductivity in function of water content.*

3.2.2 Firing Shrinkage: Firing Shrinkage was directly affected by firing temperature. All the samples studied in this paper were prepared and following the same process (extrusion, drying and firing at 870 °C).According to the literature, this value must be below 8% and the result presented in figure 4 are in accordance with ASTM C326 – 09 standard requirements.

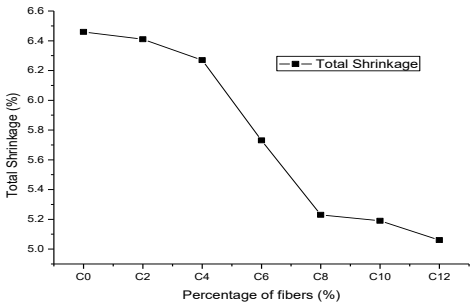

Figure 4. *Total shrinkage in function of fibers*

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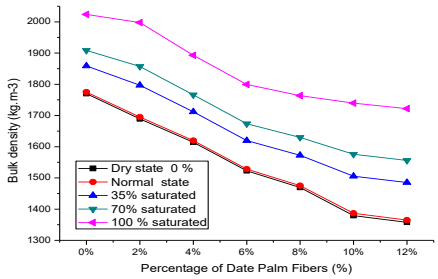

Figure 5. *Bulk density in function of fibers.*

3.2.3 The Bulk density: The results presented in figure 5 show that as fiber content increase, bulk density decreases which provide a light-weight construction material. For 12% fibers content, the composed is lighting by more than 22% compared to the reference 0%.

4. Conclusion

After this experimental study, we conclude that the addition of date palm fibers to a clay matrix for the fabrication of extruded bricks improves their thermo-physical properties. Experimental results show that whatever the saturation state of the material, apparent density and thermal conductivity decrease with increasing fiber percentage in the clay matrix. The optimum is obtained for composition C_{12} with 20% dune sand, 68% clay and 12% date fibers and for which a weight reduction of more than 22% is retained with an improvement in the insulating power of more than 42% in normal state of conservation (not dry and not saturated) compared to the reference C_0 (without fiber) actually manufactured by the Brickyard.

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