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RESEARCH ARTICLE

THERMOMECHANICAL CHARACTERIZATION OF PLASTERBOARDS BASED ON BAOBAB TRUNK FIBERS (ADANSONIA DIGITATA L.)

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Abstract

This work deals with the characterization of a plasterboards based on baobab trunk fibers for thermal insulation in buildings. The aim of this study is, firstly, to evaluate the thermal insulating capacity of baobab trunk fibers and, secondly, to determine the thermophysical and mechanical properties of plasterboards reinforced with baobab fibers. The results indicate that the water absorption of plasterboards increases with increasing fibers content, while the thermal conductivity and density decrease with increasing fibers content. All plasterboards showed good thermo-physical and mechanical properties for thermal insulation of buildings.

Introduction:-

The building sector is, today, an energy-intensive sector with a high environmental impact for its exploitation. The main building material is cement concrete, which is also a good heat conductor. In order to reduce the energy consumption and environmental impact of building operation, it is necessary to develop new alternative building materials to conventional concrete. The energy efficiency of a building depends on the hygrothermal behaviour of the building envelope. This behaviour is related to the hygroscopic and thermal properties of building materials. Thus, several research studies have been carried out in the manufacture and characterisation of bio-based building materials by mixing plant fibres with a mineral matrix. These new types of materials can be used as thermal insulation boards (Wei et al. **[1]**, Tangjuank et al. **[2**], Collet et al. **[3])** or as filling bricks in building construction (Benmansour et al. **[4]**, Potiron et al. **[5]**).

In fact, vegetable fibers are, in general, a local and available resource with good thermal and acoustic properties. Their use in the reinforcement of a mineral matrix first requires knowledge of their hygroscopic, physical and thermal properties. In the bibliography, a lot of research work that consisted in determining the physical and thermal properties of vegetable fibres can be foun. For example, date palm fibers studied by Ali et al.**[6],** pineapple fibers with a thermal conductivity of 0.043 W/mK for a density of 232 kg/m^3 (Tangjuank et al.**[2]**), fibres extracted from coconuts, date palm nuts and sugarcane studied by Manohar et al **[7].** Their results showed that the thermal conductivities of these fibers are 0.048 W/mk for coconut, 0.055 W/m.K for date palm and 0.046 W/mk for sugarcane. Diatta et al.**[8]** characterised the fibers of Typha australis. The value of thermal conductivity is of the order of 0.045 W/m.K. Harbaoui et al.**[9],** studying the aggregates of the Alfa plant, showed that their thermal conductivity is 0.058 W/mK. Hamdaoui et al **[10]** determined the thermal conductivity of marine Posidonia oceanica

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fibers. Thermal conductivity of rice straw panels and kapok fibres were respectively determined by Wei et al.**[1]** and Voumbo et al.**[11].**

All these studies have shown that vegetable fibers are materials with low thermal conductivity and density. Therefore, plant fibres are good candidates for the manufacture of concrete to solve the problem of thermal efficiency in buildings**.** In this context, some researchers have developed and determined the physical, thermal and mechanical properties of mineral matrix composites reinforced with vegetable fibres (Benmansour et al.**[4],** Bal et al.**[12]).** The most important properties of a building material are thermal conductivity and compressive strength. However, these properties are strongly influenced by parameters such as fibers content, density, fibers type, fibers size, matrix-fibers contact etc. Several works have been carried out on the thermal and mechanical characterization of composites based on gypsum board or cement concrete reinforced with plant fibres. Gypsum is currently receiving particular attention in the manufacture of thermal insulation materials for buildings.

In order to reduce the thermal conductivity and weight of the set gypsum, Ashour et al.**[13**] and Belayachi et al.**[14]** studied the effect of fibers content in gypsum composites reinforced with wheat straw, barley straw and wood shavings. Both studies noted a decrease in the density and thermal conductivity of the composites as the fibre content in the gypsum paste increased. Also, Abani et al.**[15]** manufactured gypsum boards reinforced with date palm fibers. Other authors have been interested in determining the compressive strength of bio-based gypsum boards. This is the case of Rachidi et al.**[16]** who worked on plasterboards containing date palm fibers and Lucolano et al.**[17]** who produced plasterboards reinforced with hemp fibers. Their studies revealed that the addition of the fibers to the plasterboard improves the compressive and flexural strength. This literature review shows that many plant fibers are used in the manufacture of thermal insulation materials.

To the best of our knowledge, there is no study yet on the determination of the mechanical and thermo-physical properties of plasterboards reinforced with fibers from the trunk of the baobab (Adansonia digitata L.). The baobab is a gigantic tree that grows in Sahelian and Sudano-Sahelian areas of Africa and in particular in central, south-eastern and southern regions of Senegal **[18].** This tree has long been used for food (leaves and fruit) and traditional medicine (leaves and bark). The trunk and branches of the baobab are very fibrous and are used for making ropes and weaving mats. The extraction of fibers from these parts does not affect the health of the tree because these parts can regenerate every 6 months after exploitation **[19].**

The aim of this paper is to first determine the thermal properties of baobab trunk fibers and then to develop and determine the physical, mechanical and thermal properties of plasterboards reinforced with these fibers. The properties studied are density, compressive strength, thermal conductivity and thermal effusivity. The originality of this work compared to the work mentioned above is the use of baobab trunk fibers in the production of composite plasterboards with a low environmental impact.

Materials and Methods:

Baobab trunk fibers:

The fibers used in this study were extracted from the trunk of a local tree, the Baobab (Adansonia digitata L.). After extraction, the fibers were washed clean and dried during two weeks at room temperature.

In order to strengthen the adhesion at the interface between the plaster matrix and the fibers, but also to reduce the water absorption of the fibers, a thermochemical treatment was applied to the fibers. This treatment consists of boiling the fibers for at least four hours and rinsing them thoroughly with distilled water. The boiled fibers were then chemically treated by immersion in a 5% sodium hydroxide solution for 4 hours. Cleanly washed with distilled water, they were dried at room temperature for 72 hours. The water absorption and bulk density values of these fibers are 226.08% and 220 $kg.m^{-3}$ respectively **[20].** For the measurement of thermal conductivity and thermal diffusivity, we used a dial with dimensions of 27 x 27 x 5 cm^3 with Plexiglas lateral faces (figure 1).

Figure 1:- Fibers samples for thermal testing.

Preparation of plasterboards:

Plasterboard is made from a mixture of plaster and treated baobab trunk fibers. The gypsum used is the commercial gypsum used in housing construction. The ratio of fibers mass to plaster mass (W/ P) is 0.6 for all boards. The fibers were cut into lengths of about 1/2 cm by hand. For each formulation, the fibers were immersed in water for 1h 30 min to allow for the amount of water that could be absorbed until they were saturated. The fibers contents of the plasterboards are 5%, 10%, 15% and 20%. After mixing the mixture (gypsum + fibres + water), the homogeneous paste is placed in moulds of dimensions 10 cm x 10 cm x 2 cm for thermal tests or in moulds of dimensions 4 cm x 4 cm x 16 cm for mechanical tests. After 24 hours, boards were removed from the moulds and placed in plastic bags to even out the water content. The samples are shown in Figure 2.

Figure 2:- Left: Thermal test samples, right: Mechanical test samples.

Methods:-

Water absorption of composites:

First, the concretes were dried in an oven for 24 hours before being weighed. Then they were introduced into distilled water at room temperature. By performing successive weighings, we found that after 24 hours of immersion, the concretes reached their water saturation point when the difference between two successive weighings is less than 0.01g ($\Delta m \leq 0.01g$). The expression for water absorption is given by:

$$\omega = \frac{m_h - m_o}{m_o} x\, 100 \qquad (1)$$

$\mathbf{m_s}$: Mass of gypsum plasterboard saturated with water.

$\mathbf{m_o}$: Mass of the plasterboard in dry state.

Bulk Density and Porosity:

The **bulk density** is the ratio of the mass (mo) to the apparent volume of the sample. The sample mass was weighed with a 0.01g precision scale. The size of the sample were measured with a caliper. The bulk density of the sample was obtained by the equation:

$$\rho = \frac{m_0}{V} (2)$$

Porosity is the ratio of pore volume to sample volume. The pore volume in the sample is the difference between its mass in the water saturated state ($\mathbf{m_h}$) and its mass in the dry state ($\mathbf{m_o}$). Porosity is given by the equation :

$$n = \frac{m_h - m_0}{\rho_e V} 100 \qquad (3)$$

Thermal conductivity and thermal diffusivity of fibers:

The thermal conductivity and thermal diffusivity of the fibers were measured by the box method. The detailed description of the device is given in the work of Meukam **[21]** and Boumhaout **[22].** The principle is to send a constant heat flux (Φ) to one of the sample faces by means of a heating resistor (R). After the steady state is achieved, the temperatures of both sides of the sample are measured with a thermocouple. In order to minimise heat loss (C) through the box faces, a rheostat (R) is connected to regulate the voltage so that the temperature in the box is slightly higher than the ambient temperature($T_b - T_a$) $< 1\,°C$). The thermal conductivity is given by the equation:

$$\lambda = \frac{e}{S(T_c - T_f)}\left[\frac{U^2}{R} - C(T_b - T_a)\right] \qquad (4)$$

U: Electric voltage R: Heater film resistance

T_c: Temperature of the heated face T_b: Temperature in the box.

T_f: Temperature of the cooled face T_a: Ambient temperature

Thermal diffusivity of fibers:

The Flash (or pulse) method has been used to determine the thermal diffusivity of fibers. The device and principle of the method are detailed in the work of Cerezo **[23]** and Hayet **[24].** A flash of 500 W power was sent to one side of the sample for 30 seconds. With a thermocouple placed in the centre of the other side, the evolution of the temperature as a function of time was recorded. By applying the partial time method of Degiovanni [25] on the obtained thermo gram, the average value of the thermal diffusivity at the times ($t_{1/2}, t_{1/3}, t_{2/3}$) was determined by the equation:

$$a_{1/2} = \frac{e^2}{t_{5/6}}\left(0{,}954 - 1{,}581\frac{t_{1/2}}{t_{5/6}} + 0{,}558\frac{t_{1/2}}{t_{5/6}}\right) \qquad (5)$$

$$a_{1/3} = \frac{e^2}{t_{5/6}}\left(0{,}818 - 1{,}708\frac{t_{1/3}}{t_{5/6}} + 0{,}885\frac{t_{1/3}}{t_{5/6}}\right) (6)$$

$$a_{2/3} = \frac{e^2}{t_{5/6}}\left(1{,}131 - 1{,}222\frac{t_{2/3}}{t_{5/6}}\right) (7)$$

Thermal conductivity of the samples:

The thermal conductivity of the samples was determined by the asymmetric hot plane method shown in Fig 3. The principle of this method and the modelling have been described in detail by Bal et al **[12]**. During the measurement, a constant heat flow is sent through the heating element onto a sample face of dimensions 10 cm x 10 cm x 2 cm**.** A thermocouple, placed in the centre of the heating element, is used to record the evolution of the temperature Ts(t). The principle consists in determining the values of the thermal conductivity and the thermal effusivity of the sample in order to minimise the square deviation between the experimental and theoretical curves. The expression for the square deviation is:

$$\psi = \sum_i^n [T_{exp}\,(t_i) - T_{mod}\,(t_i)]^2 (8)$$

ψ: Squared deviation between experimental and theoretical values

T_{exp} : Experimental temperature

T_{mod} : Temperature of theoretical model

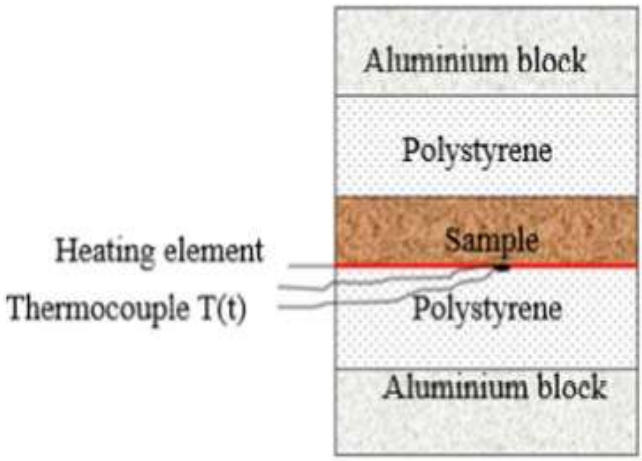

Figure 3:- Asymmetrical hot-plane device.

Compressive strength:

Mechanical characterisation focused on determining the compressive strength of the composites. This was measured using a Controlab Cyber-plus C0049FS press machine with a capacity of 2000 kN. The tests were carried out on composites of dimensions 4 cm x 4 cm x 16 cm with a displacement speed of 11.25 kN/s.

The compressive strength is calculated by the relation:

$$\sigma_{max} = \frac{F}{S} \quad (9)$$

F: Force applied (N)

S: samble section (m^2)

σ_{max} : the tress in MP_a

Results And Discussion:

Thermal properties of the fibers:

Thermal conductivity of fibers :

The thermal conductivity values of untreated (FNT) and treated (FT) fibers, determined by the box method, for different densities are grouped in Table 1. These values are the average of three measurements made on each sample.

Table 1:- Apparent density and thermal conductivity of fibers.

$\rho_{app}(kg/m^3)$	96,022	123.458	150.891	178.329
$\lambda - FNT\ (W.m^{-1}K^{-1})$	0.038	0.041	0.045	0.046
$\lambda - FT\ (W.m^{-1}K^{-1})$	0.043	0.045	0.047	0.055

The thermal conductivity of the raw fibers (FNT) and the treated fibers (FT) as a function of bulk density are shown in Figure 4 and Figure 5.

First, we notice that the thermal conductivity of the fibers increases when the bulk density increases for both types of fibers. Indeed, in a constant volume of the dial, when we increase the mass of the vegetal fibers, we also increase the compaction pressure to fill the dial. This results in a decrease in the amount of air contained in the pores and voids between the vegetable particles. Since air has a low thermal conductivity, its decrease in the sample volume leads to a decrease in the sample's porosity. This explains the increase in the thermal conductivity of the sample as the density increases.

In Figure 6, it can also be seen that treated fibers have higher thermal conductivities than raw fibers. In fact, the treatment of plant fibers leads to the reduction of the amount of amorphous components (lignin and hemicellulose) **[26].** A measurement of the density of both types of fibers showed that the treated fibers were denser, i.e. less porous than the raw fibers **[20].** This decrease in the porosity of treated fibres explains the increase in their thermal conductivity compared to raw fibers.

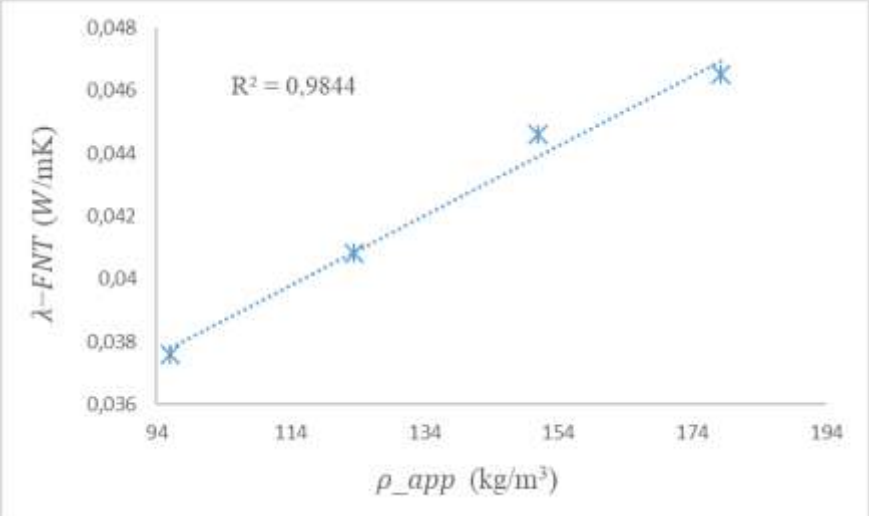

Figure 4:- Thermal conductivity of raw fibers (FNT).

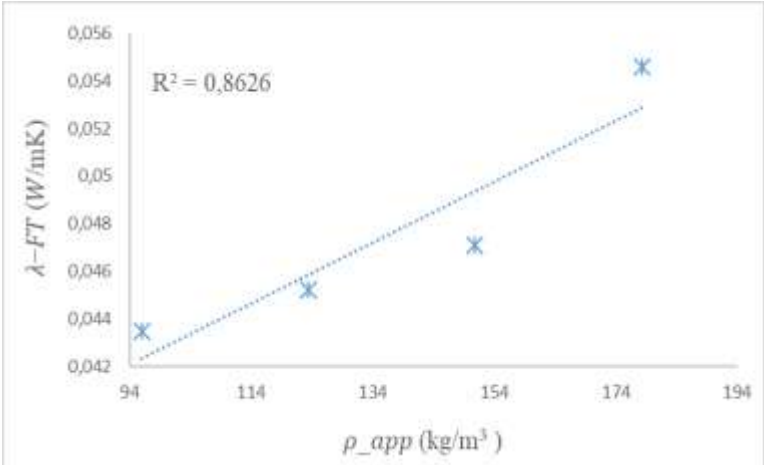

Figure 5:- Thermal conductivity of treated fibers (FT).

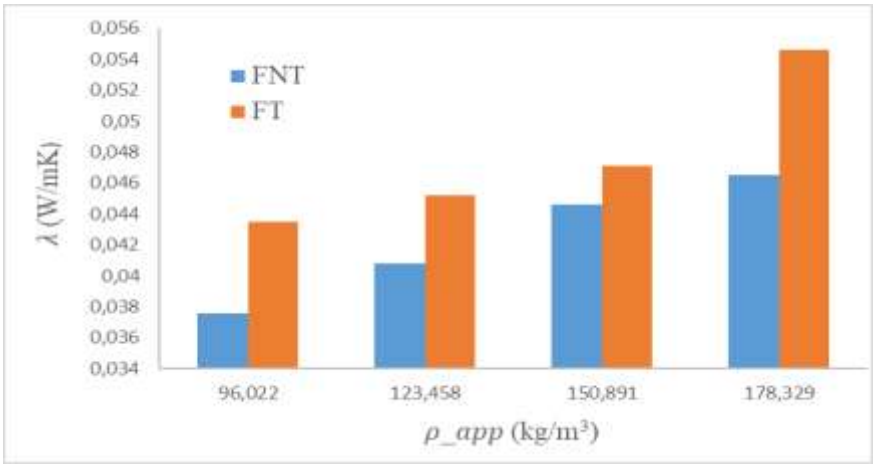

Figure 6:- Comparison of thermal conductivity of raw and treated fibers.

Thermal diffusivity of the fibers:

The thermal diffusivity values of the samples, measured by the flash method, are shown in table 2 for different densities.

Table 2 : Thermal diffusivities of raw and treated fibers.

$\rho_{app}(kg/m^3)$	96,022	123.458	150.891	178.329
a –FNT (m^2/s)	4,067. 10^{-7}	3,492. 10^{-7}	2,822. 10^{-7}	3,066. 10^{-7}
a -FT (m^2/s)	3,366. 10^{-7}	2,085. 10^{-7}	3,214. 10^{-7}	2,556. 10^{-7}

From Table 3, it can be seen that the thermal diffusivity of the fibers (raw and treated) is a function of bulk density. The thermal diffusivity values of the raw fibers range from 2.822 10^{-7} m^2/s to 4.067 10^{-7} m^2/s while those of the treated fibers range from 2.085 10^{-7} m^2/s to 3.366 10^{-7} m^2/s. For thermal diffusivity, we did not observe the same evolution as thermal conductivity as a function of density. The thermal diffusivity values are scattered and it is believed that this is due to the fact that diffusivity is a complex property that depends on the thermal conductivity and the heat capacity of the composite.

On the other hand, it was found that, except for the sample with a density of 150.891 kg/m^3, the thermal diffusivity of the treated fibres decreased compared to that of the raw fibres. This is due to the same effects as mentioned for the thermal conductivity.

Properties of composite plasterboards:
Considering the poor adhesion at the interface between the mineral matrix and the raw fibres, only concretes based on treated fibres were made and characterised. The obtained results are presented in Tables 3 and 4.

Table 3:- Physical and thermal proprieties of composites.

φ (%)	ω (%)	ρ (kg. m^{-1})	η (%)	$\lambda\ (W.m^{-1}.K^{-1})$	$E(J.m^{-1}.K^{-1}.s^{-1/2})$
0	29	1150.309	39.5	0,309 $\pm$0.012	641,331$\pm$ 0.011
5	42.24	1024,598	50.22	0,227$\pm$0.004	556,777$\pm$0.002
10	55.00	872,229	54.33	0,184$\pm$0.01	450,024$\pm$0.01
15	62.09	845,827	59.17	0,169$\pm$0.014	444,457$\pm$0.001
20	64.75	825,742	60.00	0,154 $\pm$0.003	422,121$\pm$0.012

Table 4:- Compressive strength of plasterboard.

φ (%)	0	5	10	15	20
σ (MP_a)	9.853	10.167	10.464	10.547	11.517

Effect of fibers content on water absorption and density:
Figure 7 shows the evolution of water absorption of plasterboards as a function of fibers content. It can be seen that increasing the fibre content leads to a significant increase in the water absorption of the plasterboards. For example, with a fibre content of 5% by mass, the water absorption of the plasterboard increased by 42.65 %. In fact, baobab trunk fiberss are hygroscopic materials with a high water absorption coefficient **[20].** Thus, their incorporation in a gypsum matrix would explain the increase in water absorption of the plasterboards when their content increases. A similar result is reported by Chikhi et al **[27]** on date palm fibers reinforced gypsum composite. They concluded that this behaviour depends on the capacity of the fiberss to absorb significant amounts of water.

Figure 8 shows the variation of the density as a function of the plasterboard porosity. It can be seen from Fig 8 that the density decreases with increasing porosity of the boards. For a fibers content of 15%, the density of the composite board decreased by 26.47% compared to that of the gypsum board. This is because vegetable fibres are light materials, i.e. they are highly porous. Their incorporation therefore leads to an increase in the porosity of the plasterboard. This may explain the lower density of fibers-based plasterboards. Several studies (Benmansour et al **[4],** Hernandez-Olivares **[28]** et al, Xie et al **[29])** have already shown that the addition of plant fibers to a mineral matrix leads to an increase in porosity and, inversely, to a decrease in the density of the composite material.

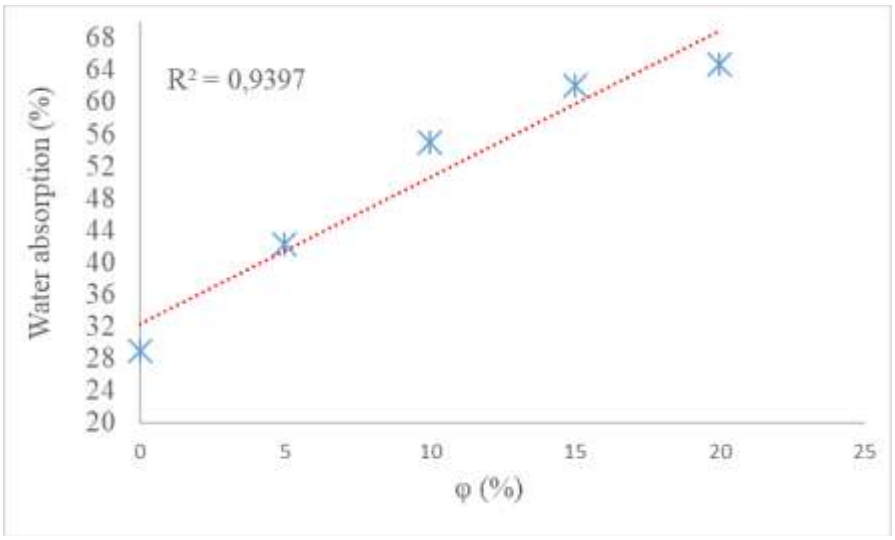

Figure 7:- Water absorption as a function of fibers content.

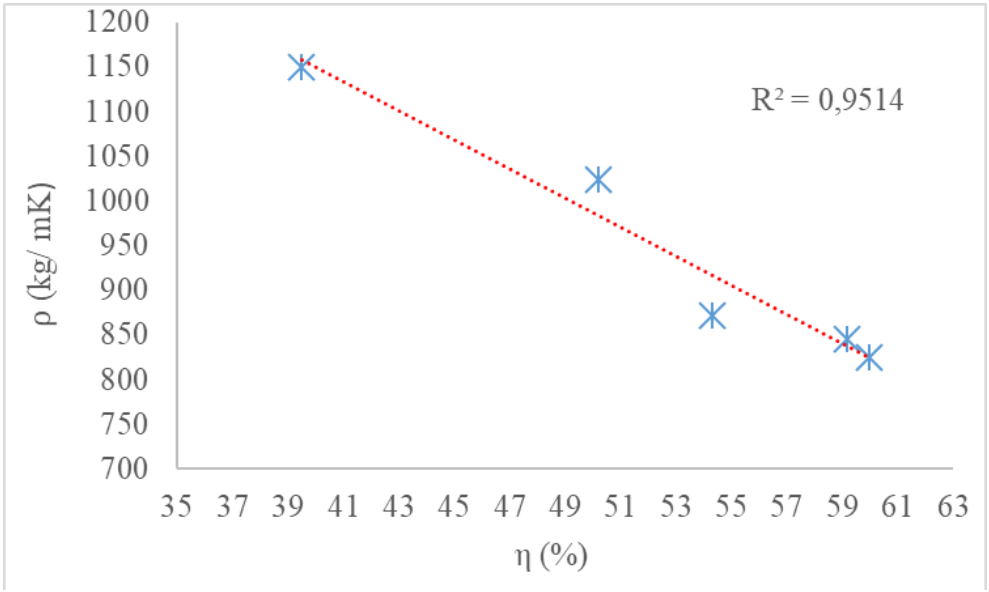

Figure 8:- Density versus porosity of plasterboard.

Effect of content and density on thermal conductivity:

The evolution of the thermal conductivity of the boards as a function of the fibers content is shown in Figure 9. It can be observed that the thermal conductivity of the plasterboards decreases as the fibers content increases. This can be explained by the fact that the addition of fibres to a gypsum matrix contributes to an increase in the porosity of the composite board.

The increase in porosity in the composite board can explain the decrease in thermal conductivity. Figure 10 shows the variation of the thermal conductivity with the density of the plasterboards.

It can be seen in Figure 10, that the thermal conductivity increases with increasing density of the composite boards. This is due to the fact that the increase in density corresponds to the decrease in porosity in the board. This explains the increase in thermal conductivity as a function of density. Other studies (Osseni et al **[30],** Abani et al **[15],** Ashour et al **[13],** Thieblesson et al **[31])** have also observed the same type of behaviour when adding vegetable fiberss in a mineral matrix.

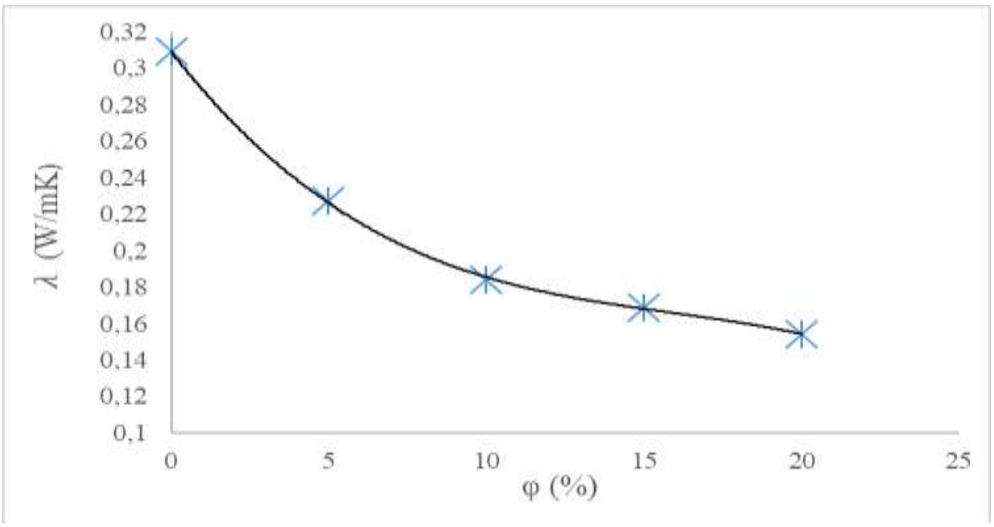

Figure 9:- Thermal conductivity as a function of fibers content.

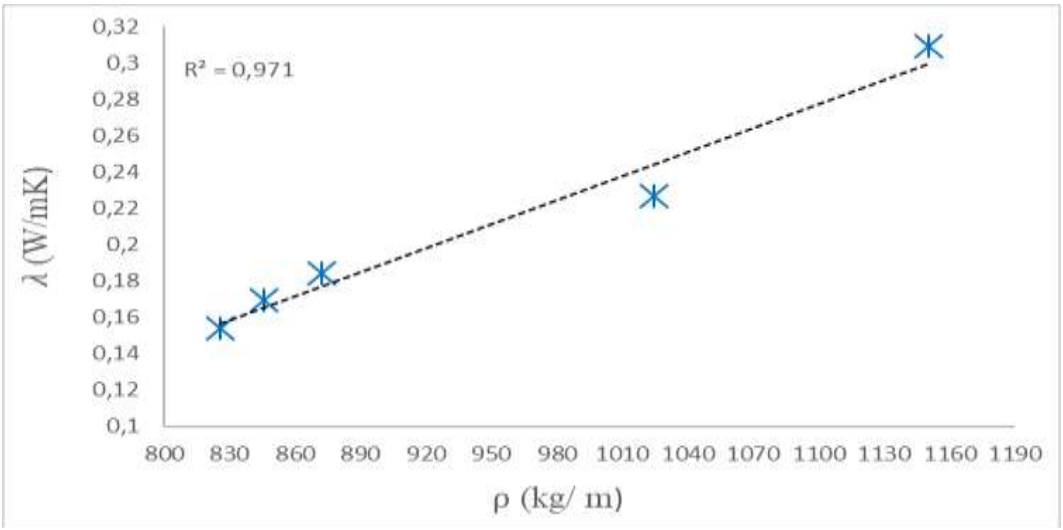

Figure 10:- Thermal conductivity as a function of density.

Compressive strength:-

Figure 11: shows the variation of the compressive strength of plasterboards as a function of the fibers content. An increase in compressive strength was noted when the amount of fibers was added to the plaster. For an addition of 10 % by mass of fibers, an improvement in compressive strength of 7 % over that of the control plasterboard can be noted. Set gypsum is a brittle material in compression. The reinforcing fibers contribute to the absorption of the applied loads by acting as coarse aggregates in the gypsum matrix. This is the reason for the increase in compressive strength of plasterboards. A study carried out by Rachedi et al **[16]** on plasterboards reinforced with date palm fibers also shows that the compressive strength of the set plaster was improved by the addition of the fibers.

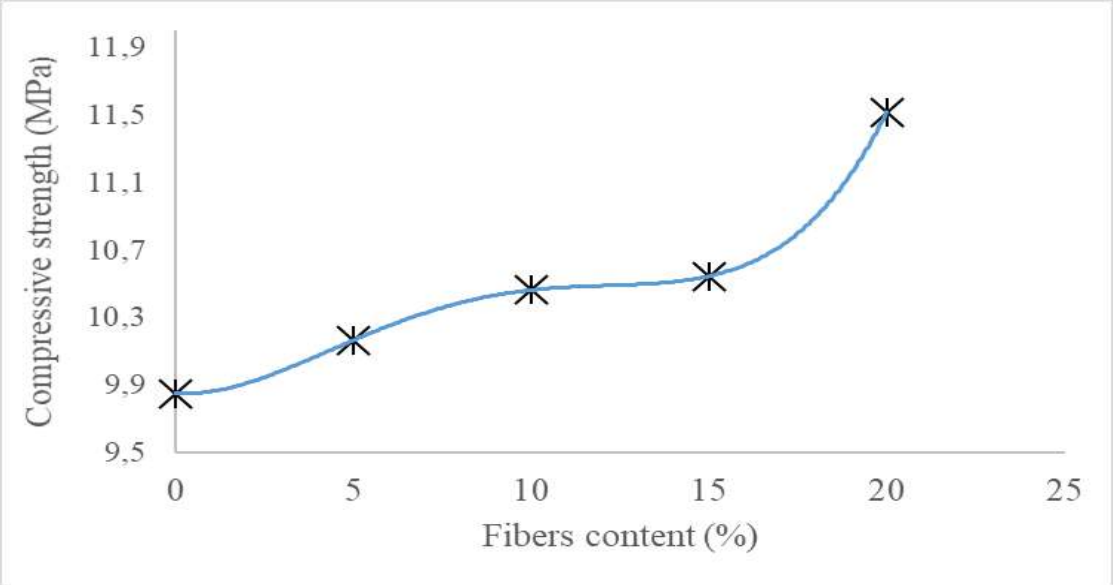

Figure 11:- Compressive strength as a function of fibre content.

Conclusion:-

This paper reports the results of an experimental investigation on thermophysical and mechanical properties of plasterboard reinforced with baobab trunk fibers. The aim of the study was to evaluate the thermal insulating capacity of plasterboards and to use them to reduce heat loss in buildings. The experimental results were analysed and it was concluded that:

1. baobab trunk fibers (raw or treated) have good heat insulating properties.
2. increasing the content of baobab fibers leads to a decrease in the weight and thermal conductivity of the plasterboard.
3. The compressive strength of the plasterboards has been improved by the addition of the fibers.

However, these plasterboards have a high water absorption capacity, which is a disadvantage for their application in humid regions. Nevertheless, the resulting plasterboards have good thermal and mechanical properties and can be used for thermal insulation of the building envelope.

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References:-

[1] Kangcheng Wei, Chenglong Lv, Minzhi Chen, Xiaoyan Zhou, Zhenyu Dai, Da Shen, Development and performance evaluation of a new thermal insulation material from rice straw using high frequency hot-pressing, Energy and Buildings 87 (2015) 116–122.

[2] S. Tangjuank, Thermal insulation and physical properties of particleboards from pineapple leaves, Department of Science, Faculty of Science and Technology, Uttaradit Rajabhat University Thailand, International Journal of Physical Sciences Vol. 6(19), pp. 4528-4532 (2011).

[3]F. Collet, S. Pretot, Thermal conductivity of hemp concretes: Variation with formulation, density and water content, Constr. Build. Mater. 65 (2014) 612 – 619.

[4] Nadia Benmansour, Boudjemaa Agoudjil, Abdelkader Gherabli, Abdelhak Kareche, Aberrahim Boudenne. Thermal and mechanical performance of natural mortar reinforced with date palm fibers for use as insulating materials in building, Energy and Buildings (2014) 98-108.

[5] Cristel Onesippe Potiron, Nady Passe-Coutrin, Fernando Toro, Silvio Delvasto, Ketty Bilba, Sugar cane bagasse fibres reinforced cement composite: Thermal considerations. Composites Part A: Applied Science and Manufacturing, Elsevier, 2010, 41 (4), pp.549-556.

[6] B. Agoudjil, A. Benchabane, A. Boudenne, L. Ibos, and and M. Fois, "Renewable materials to reduce buildings heat loss: characterization of date palm wood," Energy and Buildings, vol. 43, pp. 491-497, 2011.
[7] Krishpersad Manohar, Experimental Investigation of Building Thermal Insulation from Agricultural By-products, Mechanical and Manufacturing Engineering Department, The University of the West Indies, 2(3): 227-239, (2012)
[8] Marthe Tatiana Diatta, Salif GAYE, Ababacar THIAM, Dorothé AZILINON ; Détermination des propriétés thermo-physiques et mécaniques du typha australis, Laboratoire d'Energétique Appliquée, Ecole Supérieure Polytechnique – Université Cheikh Anta Diop, Dakar-Sénégal
[9] Mohamed Harbaoui, Marwen Bouasker, Pierre Mounanga, Nabil Benkahla, Mohamed Ben Hassen, Caractérisation thermo-physique des granulats végétaux d'Alfa en vue d'utilisation dans des bétons écologiques, Le Laboratoire de Systèmes et de Mécanique Appliquée, La Marsa, Tunisie.
[10] Ons Hamdaoui, Laurent Ibos, Atef Mazioud, Mohamed Safi, Oualid Limam: Thermophysical characterization of Posidonia Oceanica marine fibers intended to be used as an insulation material in Mediterranean buildings, Construction and Building Materials 180 (2018) 68–76.
[11] L. M. Voumbo, A. Wereme, S. Tamba, S. Gaye, M. Adj, G. Sissoko, Caractérisation des Propriétés Thermo physiques du kapok ; Ecole Nationale Supérieure Polytechnique, Université Marien Ngouabi, Congo Brazzaville et Laboratoire d'Energétique Appliquée, Ecole Supérieure Polytechnique, Université Cheikh Anta Diop de Dakar, Sénégal, J. Sci.Vol. 8**, N° 1** (2008) 33 – 43
[12] Bal H, Jannot Y, Gaye S, Demeurie F, Measurement and modélisation of the thermal conductivity of a wet composite porous medium: Laterite based bricks with millet waste additive, Construction and Building Materials 41 (2013) 586–593.
[13] T. Ashour, H. Georg, F.J. Bockisch, W. Wu, "The influence of natural reinforcement fibres on insulation values of earth plaster for straw bale buildings," Materials and Design, vol. 31, pp. 4676-4685, 2010.
[14] Naima Belayachi, Dashnor Hoxha, Marouen Slaimia, Impact of accelerated climatic aging on the behavior of gypsum plaster-straw material for building thermal insulation, Construction and Building Materials 125 (2016) 912–918
[15] Abani S., Hafsi F., Kriker A., Bali A. (2015), "Valorisation of Date Palm Fibers in Sahara Constructions". Energy Procedia, Vol. 74, pp. 289-293.
[16]M. Rachedi, A. Kriker et A. Mokhtari, Contribution à l'étude de la durabilité de mortier de plâtre à base de sable de dunes renforcé par des fibres de palmier dattier, Revue des Energies Renouvelables Vol. 20 N°2 (2017) 243 - 251
[17] Fabio Iucolano, Barbara Liguori, Paolo Aprea, Domenico Caputo, Thermo-mechanical behaviour of hemp fibers-reinforced gypsum plasters, Construction and Building Materials 185 (2018) 256-263.
[18] Sow Alioune, Cissé Mady, Ayessou Nicolas, Sakho Mama, Diop Codou Mar, Le baobab (Adansonia digitata L.) : Taxonomie, importance socio-économique et variabilité des caractéristiques physico-chimiques, International Journal of Innovation and Scientific Research, Vol. 39 No. 1 (2018) pp. 12-23.
[19] Aida Diop, Mama Sakho, Manuel Dornier, Mady Cisse, Max Reynes. Le baobab africain (Adansonia digitataL.) : principales caractéristiques et utilisations. Fruits, 2006, 61 (1), pp.55-69.
[20] Alphousseyni Ghabo, Younouss Dièye, Pape Moussa Touré, Vincent Sambou, Joseph Sarr, Physical and hygroscopic characterization of fibers extracted from the Baobab trunk for their use as reinforcement in a building material, International Journal of Engineering and Technical Research (IJETR) Volume 10, 2454-4698 (P), 2020.
[21] Pierre Meukam, valorisation des briques de terre stabilisées en vue de l'isolation thermique de bâtiments, Université de Yaoundé I, spécialités : Energétique-Génie Civil. (2004)
[22] Mustapha Boumhaout, Lahcen Boukhattem, Hassan Hamdi, Brahim Benhamou, Fatima Ait Nouh ; Mesure de la Conductivité Thermique des Matériaux de Construction de différentes Tailles par la Méthode des Boites ; laboratoire matériaux, procédés, environnement et qualité (LMPEQ), ENSA Safi ; Université Cadi Ayad, Marrakech, Maroc (2014)
[23] Véronique Cerezo, Propriétés mécaniques, thermiques et acoustiques d'un matériau à base de particules végétales : approche expérimentale et modélisation théorique, Thèse de doctorat, L'Institut National des Sciences Appliquées de Lyon, 2005.
[24]Khab Hayet, Etude du comportement hygrothermique d'éléments de construction : Application aux toitures, Université Mentouri de Constantine, Faculté des Sciences Exactes, option : photo thermique. (2007)
[25] Degiovanni, A. Diffusivité et méthode flash. Rev. Gen. Therm. Fr. N0 185, PP. 420-441. (1977).
[26] Mohamed DALLEL ; Evaluation du potentiel textile des fibres d'Alfa (Stipa Tenacissima L.) : Caractérisation physico-chimique de la fibre au fil ; Thèse de doctorat, Université de Haute Alsace; Discipline : Génie des Procédés 2012.

[27] M. Chikhi, B. Agoudjil, M. Haddadi, A. Boudenne, Numerical modelling of the effective thermal conductivity of heterogeneous materials, Journal of Thermoplastic Composite Materials 26 (2011) 336–345
[28] F. Hernandez-Olivaresa, M.R. Bollatib, M. del Rioc, B. Parga-Landad, Development of cork-gypsum composites for building applications, Construction and Building Materials 13 (1999) 179-186
[29] Xie X., Zhou Z., Jiang M., Xu X., Wang Z., Hui D. (2015), "Cellulosic fibers from rice straw and bamboo used as reinforcement of cement-based composites for remarkably improving mechanical properties". Composites Part B : Engineering, Vol.78, pp. 153-161.
[30] Sibiath O. G. OSSENI, Berléo D. APOVO, Clément Ahouannou, Emile A. Sanya et Yves Jannot, Caractérisation thermique des mortiers de ciment dopés en fibres de coco par la méthode du plan chaud asymétrique à une mesure de température, Afrique SCIENCE 12(6) (2016) 119 – 129.