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Research Article

Contribution to the Thermal and Mechanical Behavior of the Two Materials at the Base of Clay Reinforced by Fibers ALFA and of Straw Fibers

[1]Yassine El hamdouni, [1]Abdelhamid Khabbazi, [1]Chaimaa Benayad, [2]Abdellah Dadi and [3]Oumar Idriss Ahmid

[1]Université Med V-Agdal, Ecole Mohamedia d'Ingénieurs, Laboratoire Énergétique, Matériaux et Environnement, 227 Avenue Prince héritier EST-Salé, Maroc
[2]Institut Universitaire des Sciences et Techniques, Abeche, Tchad
[3]Faculté des Sciences Exactes et Appliques Université de N'djaud, N'djamud, Tchad

Abstract: This study is part of the valuation of local materials such as clay (earth) and alfa in the region of northern Morocco, with the aim of using them as building brick walls. These materials are abundant natural and renewable. Objective of this work is to study the thermal and mechanical behavior of a new material by mixing the Clay (chosen as linking) with different percentages of mass fiber alfa (0.5, 1, 2, 3, 4%, respectively) and to compare these results with those of material often used in the construction of individual houses in the rural area of Morocco (clay+straw). The results obtained, we will deduct that the incorporation of straw fibers can lower the thermal conductivity compared to fibers alfa which allows to have an energy economy of 2% to 7%., In part against the fibers alfa can improve the mechanical behavior of material to clay base in comparison with the material (clay+ straw) (An increase of 8% to 17% for the tractive resistance by bending and 6% to 18% for the resistance to compression).

Keywords: Alfa, clay, mechanical straw, propertie, thermal conductivity

INTRODUCTION

The clay and straw are the two most commonly used materials in the construction of the rural homes of Morocco, because of their abundance and their thermal insulation. However a small simple comparison between the Straw fibers and the fibers alfa has led us to point out that the rod of alfa is more hard than that of straw and that the surface of the stems of alfa is rough (Fig. 1) compared to the surface of the stems of straw which is thin, This will allow to create a very good connection between clay and fiber alfa.

By against the fiber alfa contains empty inside which will improve the behavior of thermal material clay based report by the material clay+alfa.

At the basis of these remark of departure it has begun to work on these two materials (clay+alfa and clay+ straw) and to compare Its results thermal and mechanical obtained. Certain studies have already established and published on materials at the root of clay and alfa.

Laaroussi *et al*. (2013) have carried out an experimental study of thermal a sample prepared using mixtures of clay bricks.

Also, Meukam (2004) studied the mechanical and thermal characteristics of the bricks of earth stabilized with the aim of use in building.

Bahloul and Bourzam (2009) had as objective to determine the effect of fibers alfa on the mechanical and thermal resistance of mortar of cement. After his studies on 3 samples of cement mortar with different percentages of fibers alfa (conservation in free air, conservation to freshwater, conservation of sea-water). They found that the tensile strength by bending of the sample retained in free air increases with the increase in the percentages of fibers alfa. It is for this reason also our choice is door to the fibers alfa.

Finally, Khabbazi *et al.* (2005) have worked on the mechanical and thermal properties of an insulating material to base of cork and cement mortar. These references show the interest that show the clay (earth) and the fibers, which are materials abundant in Morocco, likely to be of materials of first choice in applications of thermal insulation.

Several studies also of characterization of local materials have been completed and published by using the method of hot plan permanent and tests of compression and bending. We mention that Jannot *et al*. (2010) have used the method plan hot in permanent

Corresponding Author: Yassine El hamdouni, Université Med V-Agdal, Ecole Mohamedia d'Ingénieurs, Laboratoire Énergétique, Matériaux et Environnement, 227 Avenue Prince héritier EST-Salé, Maroc

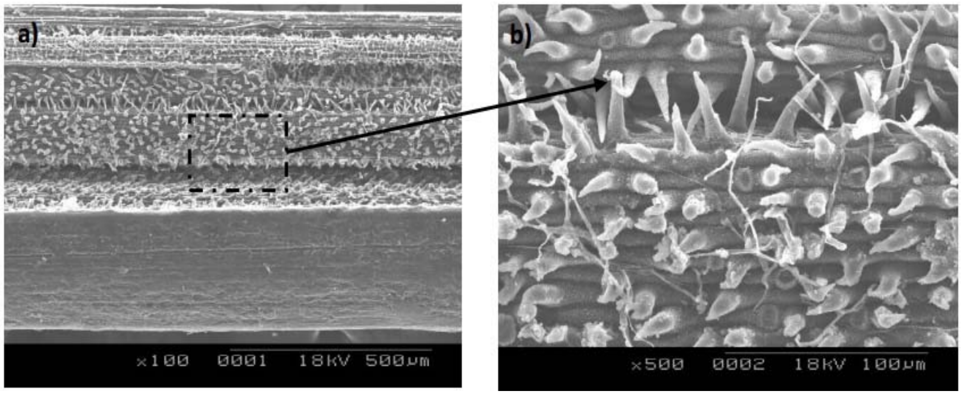

Fig. 1: Picture MEB of a surface of fiber alfa and its expansion (Dallel, 2012)

(a) (b)

Fig. 2: (a): Pictures and the different masses of alfa used; (b): Pictures and the different masses of straw used

Table 1: Chemical analysis of used clay

	Constituents											
	SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	P.F	Total
Teneur (%)	45.79	15.68	12.83	0.17	6.26	9.6	3.54	1.39	2.84	0.6	0.31	99.01

regime to determine the thermal conductivity of the insulating materials thin.

Gaye (2001) has described in detail the different methods of measurements of mechanical properties, Acoustic and thermal local materials in Senegal in its thesis of State in chapter 3, in particular the three methods of measuring the thermal conductivity in permanent regime and the two mechanical tests: test of compression strength and tensile strength by bending. This motivated us to adopt these methods and apply them to our new material.

USED MATERIALS

Clay (earth): In this study, we use clay from the region of Ksar Elkebir (northern Morocco) whose main chemical characteristics are given in Table 1.

Fibers: Alfa and Straw: The Straw fibers and alfa (Fig. 2a and b) are retained for reasons of availability and economy. The physical characteristics of these two fibers are shown in Table 2:

Table 2: Physical Characteristics of the fiber used

Caractéristics	Unit	Fibrs alfa	Straw fibrs
Apparent density	Kg/m^3	140	215
Diameter	Mm	0.9-1.2	1-4
Length	Mm	Natural state	10-50

Water of mixing: After several tries of estimate of the quantity of necessary water to thin the pate of clay and have a normal consistency, we found that the quantity of water must prove following relation:

$$\frac{E}{A} = 0.20 \quad (1)$$

With E and A are respectively the quantity of water (g) and the quantity of clay dryness (g).

EXPERIMENTAL APPROACH AND PRINCIPLE OF METHODS USED

Preparation of samples: The preparation of mixtures has been done manually by the see rustic in the laboratory LEME. The quantity of water added to the

Fig. 3: Example of samples parallelepipeds

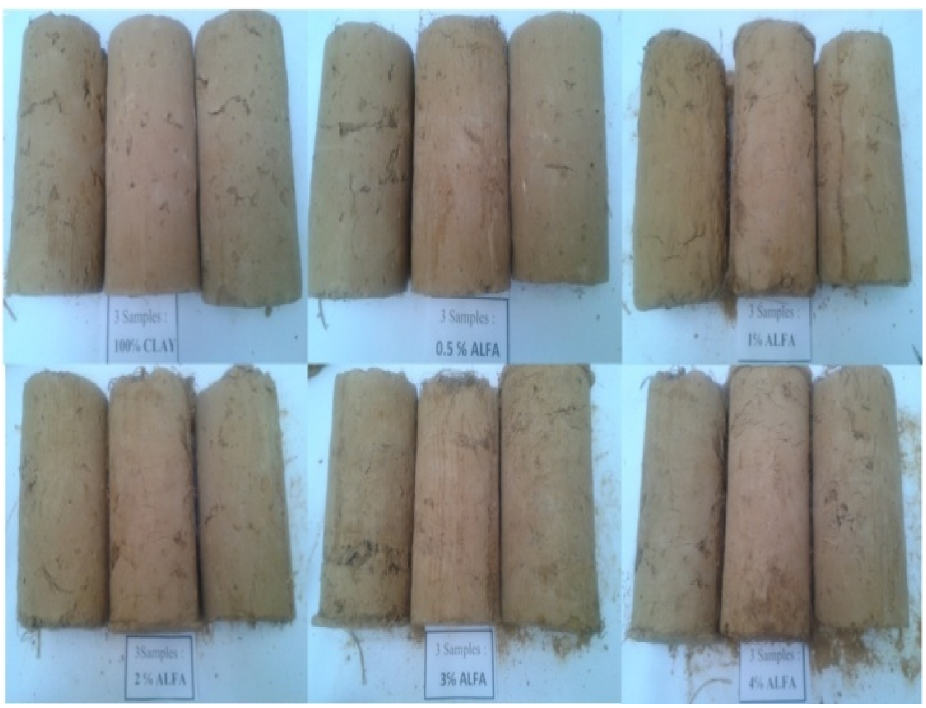

Fig. 4: Examples of cylindrical samples

mixture has been chosen in such a way that it will lead to a normal consistency. We took a quantity of clay and it has varied the percentage of fibers (0- 0.5- 1- 2- 3- 4%, respectively).

The test specimens used in this study are of three types:

- Parallelepipeds of dimensions (11 cm×11 cm×3 cm) to perform thermal testing (Fig. 3).
- Cylindrical dimensions of (11 cm×22 cm) to perform the tests of compression following the standard NF P18-406 (Fig. 4).

Fig. 5: Examples of prismatic samples

Table 3: The different compositions used

Samples	Numbers of samples for the thermal test	Numbers of samples for the tests of compression	Numbers of samples for tensile testing
ER: 100%Clay	3	3	3
EA1: 0.5%Alfa	3	3	3
EA2: 1% Alfa	3	3	3
EA3: 2%Alfa	3	3	3
EA4: 3%Alfa	3	3	3
EA5: 4% Alfa	3	3	3
EP1: 0.5%Straw	3	3	3
EP2: 1%Straw	3	3	3
EP3: 2%Straw	3	3	3
EP4: 3% Straw	3	3	3
EP5: 4% Straw	3	3	3

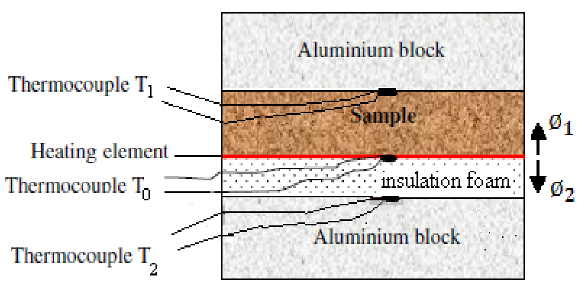

Fig. 6: Schema of the experimental implement of the hot plate

- Prismatic dimension (4 cm×4 cm×16 cm) to perform the bending test following the standard NF P18-40 (Fig. 5).

Samples is then kept in a etuve in a temperature of 60°C. They is dried up to a constant mass. Then the mass dried being measured and then they were wrapped in bags of plastic has at the end that they support a rate of humidity close to zero.

The different compositions of the material studied (clay+alfa) are presented in Table 3:
The total number of samples studied is 99 samples.

Asymmetrical method for determination of the thermal conductivity in permanent regime: Thermal conductivity was determined by method plate hot centered in permanent regime (Jannot *et al*., 2010). The method is based on the measure of the temperature in the centre of the heating element interposed between the sample and the foam of polyethylene, Fig. 6 illustrates the fundamental schema of method, the sample, of dimensions 30×100×100 mm^3 is put on a heating element of section 100×100 mm ² equal to that of the sample. They put, under the heating element, an insulating foam of dimensions 10×100×100 mm^3 and of conductivity of 0.04 W/m/K, so that the majority of the flux of warmth, issued by the heating element, pass towards the sample to be characterized (from above). The assembly sample, heating element and insulating foam is put between two blocks of aluminium of dimensions 50×100×100 mm^3, these last have as role, thanks to their big conductivity, to make attain the system towards thermal equilibrium as quickly as possible.

One thermocouple is glued together on the centre of the lower face of the heating up element to measure

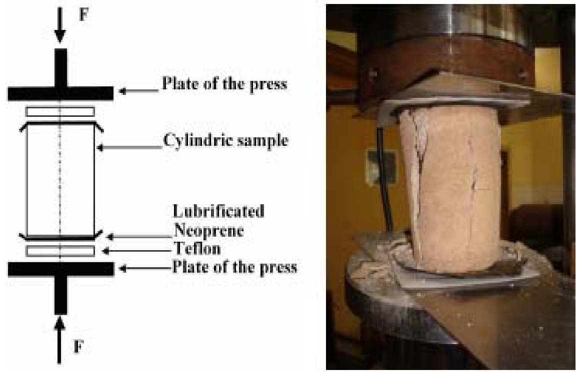

Fig. 7: Experimental device from the compression test

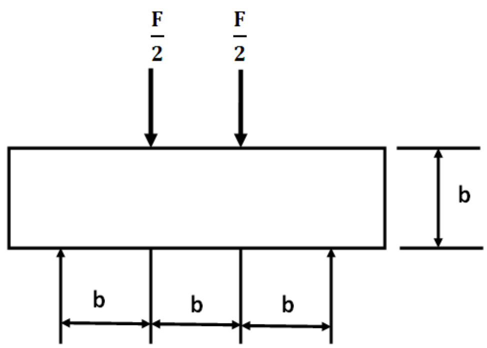

Fig. 8: Schematic drawing of tensile test by bending

the temperature T_0, other one to measure the temperature T_1 of the not heated face of the sample and a third to measure the temperature T_2 of the not heated face of the insulating foam. With this shape, we can write:

$$ø = ø1 + ø2\ ;\ ø1 = \frac{\lambda}{e1}(T0 - T1);$$
$$ø2 = \frac{\lambda}{e2}(T0 - T2) \quad (2)$$

where,
$Ø_1$: The Heat flux through the sample
$Ø_2$: The Heat flux through the insulation foam
$ø$: The Total flux emitted by the heating element
λ_1 : The Thermal conductivity of the sample as we seek to determine
e_1 : The thickness of the sample

$\lambda_2 = 0.04\ \mathrm{W.m^{-1}K^{-1}}$ and e_2= 10 mm are successively thermal conductivity and thickness of the insulating foam. But the heating element is an electrical resistance R dissipating a heat flux by Joule effect when it is crossed by an electric current électrique (I) under the effect of a voltage (U), so:

$$ø = \frac{U^2}{R.S} \quad (3)$$

Combining Eq. (2) and (3):

$$\lambda_1 = \frac{e_1}{T_0 - T_1}\left[\frac{U^2}{R.S} - \frac{\lambda_2}{e_2}(T_0 - T_2)\right] \quad (4)$$

Equation allows (4) us to determine the thermal conductivity of the sample once the system attains permanent regime.

Essai of simple compression: The apparatus for testing is a hydraulic press complies with the requirements of the AFNOR standard. The test is done according to the French standard NF P 18-406. The test tubes of cylindrical form (110 mm×220 mm) are centered between two metallic trays so that the vertical axle of test tubes coincides with the axle of the blocks of load (Fig. 7). The load is applied in a continuous manner with a speed of 5 KN/mn. The resistance in compression (Dallel, 2012) is calculated from the formula:

$$Rc = \frac{F}{S} = \frac{4xF}{\pi x D} \quad (5)$$

With:
F : Force applied during the breakdown in compression in Newtons
S : π D2/4 Section of transversal of the test piece in mm^2
R : Compression strength in MPa

Tensile test by bending: The charging is carried out by hydraulic pressure which is move the upper part down until contact with the loading device located in the upper part of the test piece at the center of the support. The value of the charge is read directly on the device. The loading is applied in a continuous manner with a speed of 0.5 KN/mn up to the rupture (Fig. 8).

The tensile strength by bending (Meukam, 2004; Gaye, 2001) is given by:

$$Rt = \frac{F \times L}{b \times d^2} = \frac{F \times 4}{b^2} \quad (6)$$

With,
Rt : Tensile strength (Mpa)
F : Maximum load applied (N)
L : Scope (160 mm)
d : Average thickness of the sample prismatic (40 mm)
b : Transverse dimension of the sample prismatic (40 mm)
F : Maximum load applied (N)

RESULTS AND INTERPRETATION

Thermal conductivity by asymmetrical method in permanent regime: Figure 9 presents the evolution of

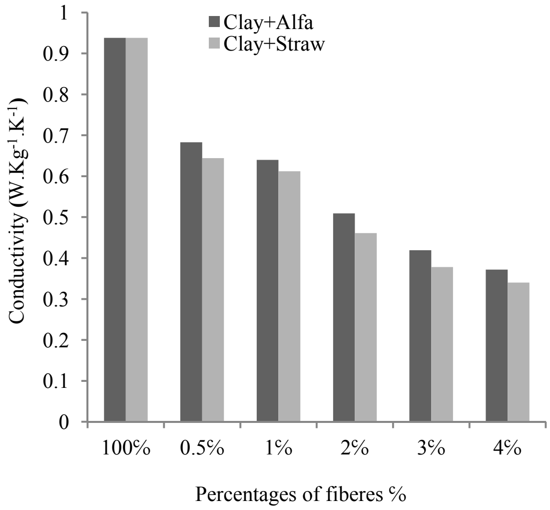

Fig. 9: Evolution of thermal conductivity based on the percentages of fibers

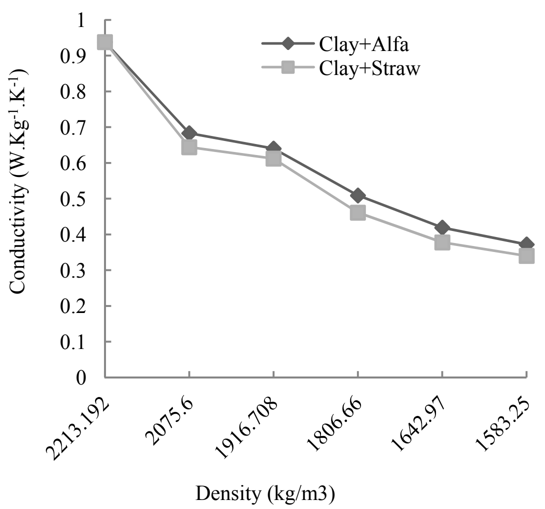

Fig. 10: The thermal conductivity of different samples studied in function of volumetric weights

the two thermal conductivities depending on the fiber percentages.

The thermal conductivities tend to decrease as a function of the percentage of fibers, this is perfectly logical Since more than the percentage of fibers is high, more than the material contains pores which are the origin of this decrease.

The thermal conductivity is decreased significantly as a function of the density of the sample, so that the sample becomes less insulation with the growth of its density (Fig. 10).

We also point out that the thermal conductivity of our material (clay+paille) is always lower than that of clay with alfa (Table 4) this is due to the shape of the stems of the straw which will store a large quantity of empty has the inside of the straw fiber. The presence of alfa fibers improves so the thermal insulation of the samples compared to straw fiber.

The error of measure been calculated by applying method to three resumptions for every sample and then we take the average of these three experiments (he does not exceed 1%).

To determine the economy of energy which can bring the straw fiber compared to fiber alfa. We will consider 2 exterior walls formed by (the material clay+alfa and the other in clay+straw) having the same thickness and are subjected to the same temperature gradient, It can be deduced from the report of the flow of heat which passes through two of these walls:

$$\frac{\o_{clay+straw}}{\o_{clay+alfa}} = \frac{\lambda_{clay+straw}}{\lambda_{clay+alfa}} \tag{7}$$

This allows the calculation of the energy saving by using the new hardware as exterior wall:

$$Energie_{saving} = 100x\left(1 - \frac{\o_{clay+straw}}{\o_{clay+alfa}}\right) \tag{8}$$

Table 4: The thermal conductivity of various compositions used

Samples	The thermal conductivity: $\lambda_{clay+alfa}$ (W.m^{-1}.K^{-1})	The thermal conductivity: $\lambda_{clay+paille}$ (W.m^{-1}.K^{-1})	Measurement Error $\lambda_{clay+ALFA}$ (%)	Measurement Error $\lambda_{clay+paille}$ (%)	Decrease the thermal conductivity $\lambda_{clay+paille}$ (%) compared to $\lambda_{clay+alfa}$ (%)
ER : 100% Clay	0.938	0.938	0.72	1.08	-
0.5% fibre (EA1 et EP1)	0.683	0.644	0.95	0.95	5.71
1% fibre (EA2 et EP2)	0.640	0.612	0.75	0.80	4.37
2% fibre (EA3 et EP3)	0.509	0.461	0.93	0.78	9.43
3% fibre (EA4 et EP4)	0.419	0.378	0.99	0.85	9.78
4% fibre (EA5 et EP5)	0.372	0.340	0.89	0.79	8.60

Table 5: The values of the tensile strength of the various samples

Samples	Tensile Strength average clay+alfa (MPA)	Tensile Strength average clay+straw (MPA)	Gap to tensile strength of clay+alfa compared to that of clay+ straw (%)
ER : 100% clay	1.15	1.15	-
0.5% fibre (EA1 et EP1)	1.38	1.24	10.14
1% fibre (EA2 et EP2)	1.58	1.3	17.72
2% fibre (EA3 et EP3)	2.01	1.66	17.41
3% fibre (EA4 et EP4)	1.75	1.53	12.57
4% fibre (EA5 et EP5)	1.59	1.46	8.17

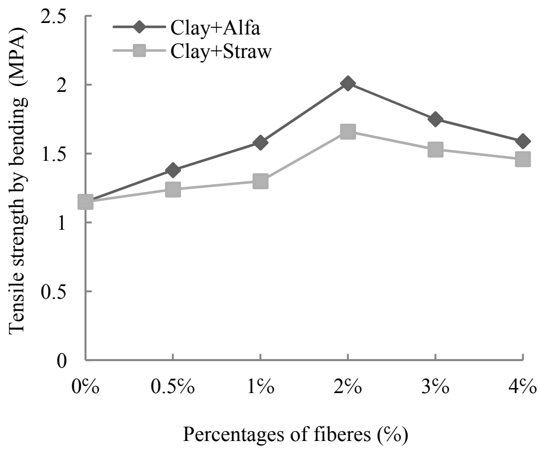

Fig. 11: Evolution of the tensile strength of samples based on the percentages of fibers

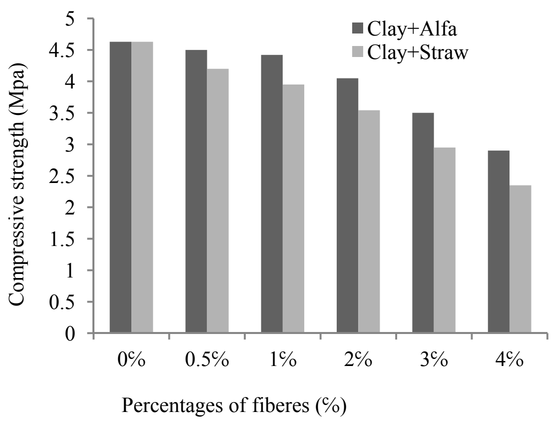

Fig. 12: Evolution of the resistance to compression of samples based on the percentages of fibers

Table 6: Energy savings compared to the material clay+straw

Samples	Energie_saving (%)
EP1: 0.5% Straw	5.71
EP2 : 1% Straw	4.37
EP3: 2% Straw	9.43
EP4 : 3% Straw	9.78
EP5 : 4% Straw	8.60

We are applying the relations (7) and (8) for the different samples and we get the economy of energy depending on the percentages of fibers (Table 5).

According to the Table 6, we can conclude that the use of material (clay+straw) like bricks on the exterior wall can give an energy saving of 4% to 9% compared to material (clay+alfa).

Tensile Test by bending: Figure 11 presents the evolution of the resistance has the traction by bending of the samples studied.

From 0 to 2% of fiber, we observed an increase of the tensile strength by bending, this increase is of the role played by the fibers (fibers alfa resists traction effort and also the good adhesion between fibers and clay). From 2% of the fibers, the tensile strength begins to decrease, because of the adhesion between fibers and pate of clay, which becomes low (increase in the percentages of fibers). In addition, the samples that contain fiber alfa have a tensile strength greater than that of clay with straw (Table 6). This is due to the hardness of rod of alfa compared to that of straw.

The fiber of alfa therefore is better than fiber straw in terms of mechanical resistance (a gap of two resistors can arrive up to 17.72%).

Compression test: We apply the method on three occasions, for each sample and then we adopt the average of these three experiences. The results of resistors in compression for each sample are presented in Table 7.

Figure 12 presents the evolution of the resistance to compression of samples based on the percentages of fibers. Figure 12, the increase in the rate of fibers in the samples of clay negatively affects the resistance of Compression, this is due to the incorporation of fibers which have created the empty which are the origin of this decrease.

In addition, the samples that contain fiber alfa have a compression resistance greater than that of clay with straw (Table 7), this is due to the better adhesion between the clay and fiber alfa which reduces the voids between the fiber alfa and the Clay.

CONCLUSION

This study represents a comparative study of thermophysical and mechanical properties of two materials: clay+alfa and clay$_+$ straw. We have shown that the increase in the percentages of fibers (alfa or straw) improves the thermal and mechanical properties of the two samples (a decrease of the thermal conductivity with an increase of tensile strength by bending), provided that the percentage of fiber alfa does not exceed 2%, beyond this values the adhesion

Table 7: The values of the resistance to compression of different samples

Samples	Resistance to the average compression clay+alfa (MPA)	Resistance to the average compression clay+straw (MPA)	Gap to tensile strength of clay+alfa compared to that of clay+straw (%)
ER: 100% clay	4.63	4.63	-
0.5% fibre (EA1 et EP1)	4.5	4.2	6.66
1% fibre (EA2 et EP2)	4.42	3.95	10.63
2% fibre (EA3 et EP3)	4.05	3.54	12.59
3% fibre (EA4 et EP4)	3.5	2.95	15.71
4% fibre (EA5 et EP5)	2.9	2.35	18.96

between fiber and clay becomes very low which in turn adversely affect the mechanical behavior of these two materials. In other we found that straw fiber can bring to the material clay an energy economy of 4 to 9% compared to the material (clay+alfa), by against the fiber alfa can increases the mechanical strength compared to the straw fiber of 8 to 17% for the tractive resistance by bending and 6 to 18% for the resistance to compression.

The fiber alfa can be an alternative in relation to the fiber straw which is sauvant uses in the rural construction in northern morocco), view their abundance (casement unusable with a very low price compared to the straw) and also view the report: mechanical behavior/thermal behavior (an increase of mechanical resistance of 8% to18% with a small decrease in thermal resistance of 4 to 9%).

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