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Thermal Study Prototypes Effected by Earth Bricks Reinforced by Date Palm Fibers

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Abstract: Algeria is located in an area with a high solar potentiality and presents nearly 90% of arid and semi-arid lands of this fact it is important to look at the current situation of Saharan cities. The objective in the context of this work is the achievement of a level of thermal comfort with a lower energy consumption and a mechanical resistance acceptable with a reduced cost. For this, we have tried to make bricks with good thermal characteristics and mechanical basis of three local materials: namely the clay of baldet amer the sand dune of sidi khouiled and fibers of date palm. The construction materials used in the Saharan regions of Algeria are often concrete or cementitious products such as cinder blocks that have rather poor thermal properties. Yet, these areas have several local materials (Clay, gypsum ...) that have historically proven their thermal and mechanical efficiencies. The purpose of this study is to carry out a thermal study of prototypes made of bricks that are made from local materials. After analyzing and interpreting the obtained results, the most appropriate choice was made on the bricks that meet the requirements of good thermal isolation.

INTRODUCTION

The price of construction material used therefore, depends on the international market constantly destabilized by the economic crisis coupled with the energy crisis in recent times. To produce a framework of life at a lower cost, it is important, therefore, to circumvent the influence of the cost of energy by upgrading the local materials of construction.

The Saharan regions of Algeria have several local materials (clay, gypsum, etc.) which are formerly proved their thermal efficiency. It is important to enhance these resources by bringing in new technologies in order to comply with the requirements of time, cost and quality.

In this objective, this study is launched. Of a global point of view, the aim of our research is to fabricate a brick at the base of three local materials: namely the clay, sand dune and the fibers of the date palm. In later proceed with its characterizations thermal and mechanical.

Conditioning in each room to ensure comfort summery. The Saharan regions of Algeria which are characterized by a hot and dry climate have long suffered from several problems in terms of habitats and constructions. Yet these regions have several local materials (Clay, gypsum …) who have formerly proved their thermal efficiencies and mechanical.

In this objective this study is launched. The purpose of our research is to the thermal study prototypes carried out by bricks manufactured on the basis of local materials.

According to the analyzes and interpretations of the results obtained, we thing the bricks which meet the requirements of heat.

MATERIALS AND METHODS

The sand dunes: For our study, we used the sand dunes of Sidi-Khouiled (Ouargla). We performed the following tests:

- The mass density absolute
- The apparent density
- Equivalent of sand
- Chemical analysis
- Test X-Ray Diffraction (XRD)

The results obtained are the following (Table 1).

Chemical analysis: Table 2 shows the percentages of the chemical components of sand dunes. We note that the percentage of the ($CaSO_4$), (SO_4) is lower than the recommended limit. Of this fact, the sand used is non-aggressive.

Test X-Ray Diffraction (XRD): The curve shows the results obtained for the sand dune (Fig. 1). Next steps undertaken from diffractrogramme, we can see that:

- Quartz forms a large proportion of minerals with a percentage of 80%
- The gypsum is in the form of whitish fine grains with a percentage of about 3%
- Feldspar and calcite are present with low percentages in round 10%

The clay: For this research, we have used the clay of Ouargla. We performed the following tests on the clay:

- Dry density
- Methylene Blue
- Limit of Atterberg
- Chemical analysis
- Test X-Ray Diffraction (XRD)
- The results presented in Table 3

Chemical analysis: The main results of the chemical analysis performed are grouped in Table 4. Table 4 shows that the elements of this clay are insoluble in percentage of approximately 64%, the levels in sulfates and chlorides are very low.

Test X-Ray Diffraction (XRD): Figure 2 represents the results for the clay of Ouargla. The sample consists essentially of associated minerals quartz and montmorillonite and other phases which are not

Table 1: Physical characteristics of sand dunes

Test	Results
The mass density absolute	$\rho_a = 2560\ kg\ m^{-3}$
The apparent density	$\rho_a = 1512.5\ kg\ m^{-3}$
Equivalent of sand	ESP = 98%

Table 2: Chemical compositions of sand

Components	Percentage
Fe_2O_3-$AL_2\ O_3$	0.25
$Ca\ SO_4$, $2H_2O$	2.78
SO_4	0.51
$Ca\ CO_3$	1.30
Insoluble	93.23
NaCl	Trace
Loss to Fire	1.16

Table 3: Physical characteristics of clay

Characteristics	Results
The dry bulk density (NF P 94/064)	$P = 2.03\ g\ cm^{-3}$
Methylene blue (NF 933-9)	VBS = 8
Limit of Atterberg (NF P 94-051)	WL = 69.58%
	WP = 24.71%
	IP = 44.87%

Table 4: Chemical compositions of the clay

Chemical characteristics	Components	Percentage
Insoluble (NF P 15-461)	Insoluble	63.18
Sulphates (BS 1377)	SO_3	0.45
	$Ca\ SO_4/2H_2O$	2.46
Carbonates (NF P 15-461)	$CaCO_3$	18.00
Chlorides (MOHR'S method)	Cl^-	0.42
	NaCl	0.68

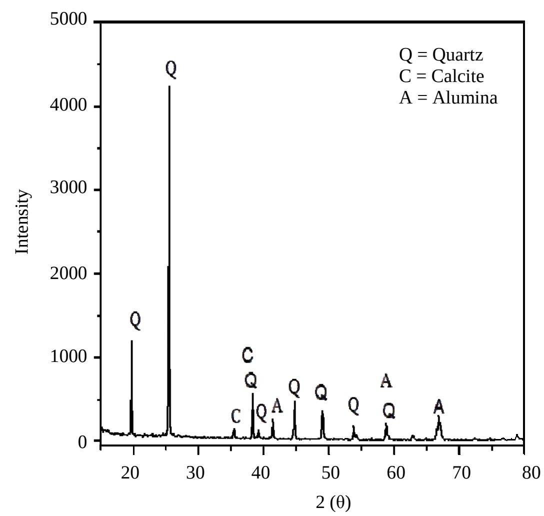

Fig. 1: Diffractometry analyses of dune sand

Table 5: The physical and mechanical characteristics of fibers used

Characteristics	Results
Apparent density	ρ_a = 512.21 - 1088.81 kg m^{-3}
Mass density absolute	ρ_a = 1300 - 1450 kg m^{-3}
Tensile Strength (MPa)	L= 100mm L= 60 mm L = 20 mm 170, 240, 290
Deformation at the rupture	E = 0.232 (fiber diameter 0. 8 mm)
Humidity	W = 9.5-10.5%
Rate of absorption in water (after 24 h)	TA = 96.8-202.6%
Diameter (of fibers used)	D = varies between 0.1-1 mm

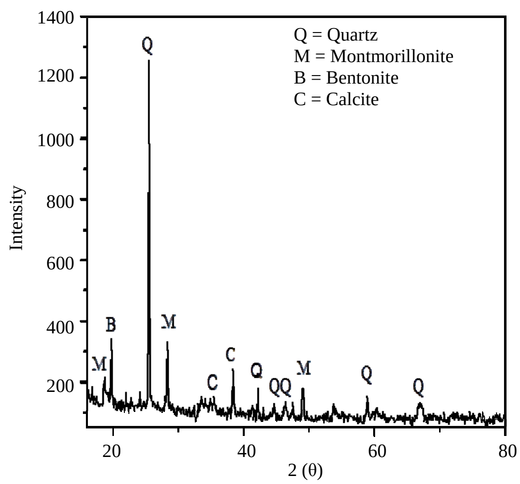

Fig. 2: Diffractometry analysis of clay Beldet Amor

discarded. The intensities of the diffractogram show that the quartz is the dominant phase in fact the peaks 42.20, 55.02, 60.36, 76.04 (2 θ) are characteristic of this material, even for montmorillonite, its presence in the sample is determined by the main peaks at 19.76, 24.11, 35.53 and 53.87 (2 θ).

The fibers: The fibers used in this study are of vegetable fiber of date palm of dokar. Bledzki and Gassan[1] after the se-studies carried out on four types of fiber surface of the palm (the fibers of dokar, deglette nour, degla bida and elghers), it was found that the fibers of dokar give the best result of point of view to tensile strength. It is for this reason our choice is the door to the fibers of dokar.

Fiber characteristics of date palm: The tests carried out on the fibers by Pr KRIKER have allowed us to characterize the fibers of palm of Ouargla as result in Table 5.

Tea date palm fibers have average strength high tensile strength. In addition, thesis fibers classified among the fibers which have weak modulus of elasticity. However, it should be mentioned that the high tensile strength depends on the specimen length which is of prime importance regarding reinforcing efficiency. As shown in Table 5, the high tensile strength increases with decreasing specimen length. The latter observation also

Table 6: The major constituents of organic fibers

Regards	Proportion (%)
Ash	1.2 ±0.3
Cellulose	43±2
Hemicellulose	8±2
Lignin	35±5

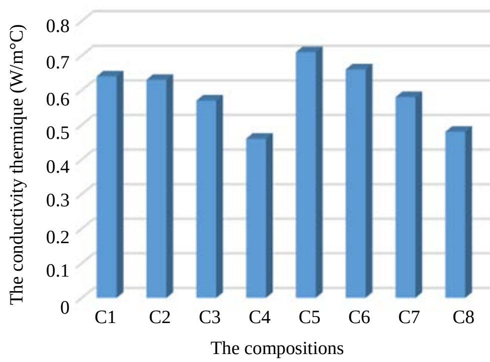

Fig. 3: The thermal conductivity

reported by Bledzki and Gassan[1] who calculated the actual high tensile strength of a single fiber by extrapolation to zero length of the curve of high tensile strength, VS fiber length. This estimation method indicates a high tensile strength of 320 MPa for thesis fibers.

Comparatively with other results, thesis fibers are not so dependent on the fiber test length than for the case of other natural fiber[2-7].

Analysis of organic materials: The analysis of organic materials of fibers of dokar has given on the following table the proportions of cellulose, hemicellulose and lignin.

We find that these fibers have higher rates in cellulose and hemicellulose relatively low compared to that of the fibers of sisal. By contrast, rates of cellulose and lignin move closer to that of coconut fibers given by the literature (Table 6).

Remember that the cellulose is the essential element from the point of view resistance. We have proposed to our work the eight compositions (clay+sand+fiber) following in addition the composition of reference (Fig. 3-7):

- Composition C1 :70% clay+30% sand+00% fiber (composition of reference)
- Composition C2: 69% clay+30% sand+01% fiber
- Composition C3: 68% clay+30% sand+02% fiber
- Composition C4: 67% clay+30% sand+03% fiber
- Composition C5 :80% clay+20% sand+00% fiber (composition of reference)
- Composition C6 : 79% clay+20% sand+01% fiber
- Composition C7: 78% clay+20% sand+02% fiber
- Composition C8: 77% clay+20% sand+03% fiber

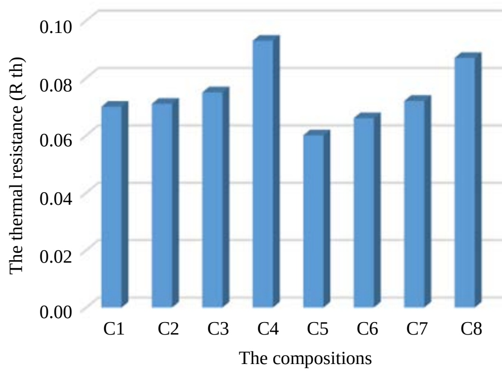

Fig. 4: The thermal resistance

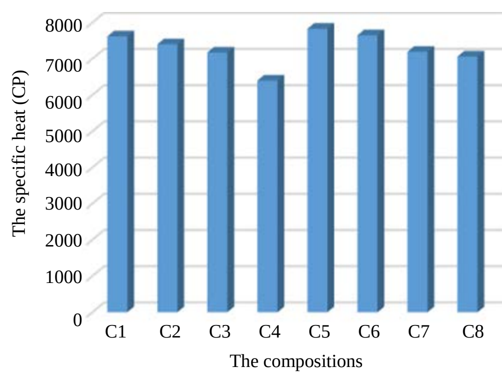

Fig. 5: The specific heat

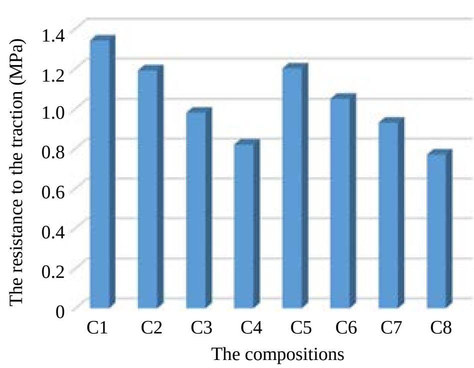

Fig. 6: The resistance to traction

After the results obtained, we note that: a decrease of the conductivity as a function of the percentage increase of fibers in the mixture. The compositions (C4) and (C8) give the best results of the conductivity and the thermal resistance and this is due to the presence of the fibers which creates empty on the inside of the brick after cooking. A decrease of the thermal conductivity depending on the increase of the percentage of sand in the mixture. The thermal resistance will automatically increase with the increase of the percentage of sand. The

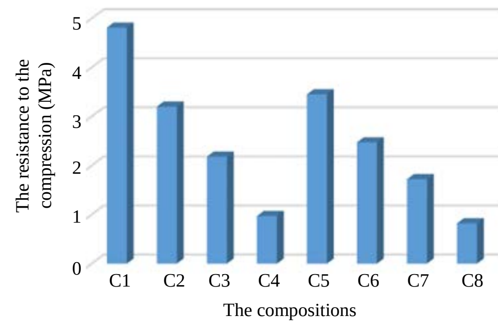

Fig. 7: The resistance to compression

specific heat decreased in function of the increase in the percentage of sand. This is logical in view of the fact that theoretically the specific heat varies in the same direction as the thermal conductivity.

A decrease of the mass and the mass density as a function of the increase percentage of fibers in the mixture (1700 kg m^{-3} and mass density of intoxicating fiber 512.12 kg m^{-3}).

The resistance to bending the most high is that of the composition (C1) is ca is due to the absence of fibers and the good cohesion of the matrix of the mixture. The resistance to bending of the compositions (C1, C2, C3 and C4) is higher than that of the individual flower arrangements and (C5-C8) and ca is due to the increase in the percentage of sand.

The resistance to compression of compositions (C4) and (C8) is low and ca is due to the influence of voids created by the fibers. The resistance to compression of compositions (C1-C4) is higher than that of the individual flower arrangements and (C5-C8) and ca is due to the increase in the percentage of sand.

Realization of prototypes: In order to enhance the value of our bricks in the construction, we produced a few realized prototypes by the bricks which have presented good thermal and mechanical properties. The prototypes are put in the actual conditions in the open air. The location and directions the prototypes are N-S-E-W. The floors that we have chosen are among the floors more used in construction:

- Slab composed by a hourdi in terracotta with a slab of compression in the concrete (4-5) cm
- Slab composed by a hourdi in terracotta with a slab of compression in the clay (4-5) cm

Composition of prototypes: We proposes the thermal behavior of the walls of different compositions in order to identify those which allow the largest economy of energy in the case of air conditioning for the Saharan context. The composition of these walls is given in Table 7. We note the studies are carried out in the coldest month (December), at the University of Kasdi Merbah Ouargla.

Table 7: The composition of the elements of the prototypes

The prototypes	Dimensions	Type of the slab	Brick in the wall
P1	(1×1×1) m^3	In concrete	Industrial brick 12 holes
P2	(1×1×1) m^3	In clay	C1
P3	(1×1×1) m^3	In clay	C2

C1 = 70% clay and 30% sand and 00% fiber; C2 = 67% clay and 30% sand and 03% fiber

Table 8: Variation of temperature during the days of 20, 21 and 22/12/2017 of prototypes (P1-P3)

Hours	T ext °C	T Int °C P1	T Int °C P2	T Int °C P3	T Conf °C min	T Conf °C max	HR%
07 PM	5.8	7.8	7.6	8.4	24	30	51
08 PM	7.3	8.2	8.8	10	24	30	49
12 PM	24.7	25.1	27.3	28.3	24	30	43
01 PM	25.1	26.5	28.1	28.8	24	30	44
02 PM	23.8	25.2	26.6	28.2	24	30	46
05 PM	17.6	18.8	20.1	22.8	24	30	50.5
06 PM	16.4	17.5	18.1	19.3	24	30	50.5
07 PM	15.1	16.8	17.3	18.7	24	30	53

Thermal study prototypes

The measurement of the external temperature and internal and the humidity of the prototypes: After the realization of prototypes, we measured the external temperature and internal and the moisture of these prototypes.

Variation of the temperature during the day of prototypes: According to recommendations of Algerian DTR thermal regulation of building C3.2 and C3.4 The requirement hygrothermique comfort for a humidity varies between 30 and 60% are: t Comfort Min = 24°C, T ComfortTmax = 30°C. Using a digital thermometer and hygrometer, we have measured the climate data that data during the days of 20, 21 and 22/12/2017.

Variation of the temperature of the prototypes (P1-P3): Table 8 presents the variation of the temperature during the days of 20, 21 and 22/12/2017 of prototypes (P1-P3).

RESULTS AND DISCUSSION

Prototype P1: Figure 8 summarizes the graph of variation of the interior temperature, exterior and moisture. From Fig. 8 presents the curves Variation of the temperature inside the prototype P1, the external temperature and the humidity of the air as a function of the time chosen. During the period of the day, we have noticed that the difference of indoor and outdoor temperature (2-3)°C. This is due to the hollow bricks and the concrete slab.

Between the hours 12-02 PM. We have noticed that the inside of the prototype P1 is in comfort (Table 9). The effect of storage of the heat by the concrete slab always affects this prototype. The moisture increases as a function of the decrease of the temperature. Figure 9 summarizes the graph of the difference of indoor and outdoor temperature of the prototype P1.

According to Fig. 9 which presents the results of the prototype P1, we have noticed that the gap of indoor and outdoor temperature is positive between (2-3)°C. Also, we would note that on the 7 AM and 07 PM, the

Table 9: The difference of the interior temperature and the exterior of the prototype P1

Hours	T ext °C	Tint °C P1	ΔP1
07 PM	4.80	7.80	3.0
08 PM	6.30	8.20	1.9
12 PM	23.7	25.1	1.4
01 PM	24.1	26.5	2.4
02 PM	22.8	25.2	2.4
05 PM	16.6	18.8	2.2
06 PM	15.4	17.5	2.1
07 PM	14.1	16.8	2.7

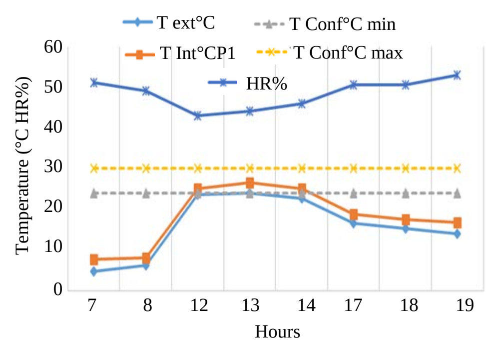

Fig. 8: The influence of temperature on the prototype P1

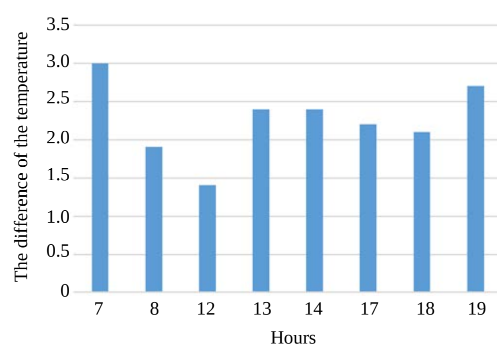

Fig. 9: The difference between the interior temperature and the external temperature of the prototype P1

Table 10: The difference of the interior temperature and the exterior of the prototype P2

Hours	T ext °C	Tint °C P2	ΔP2
07 PM	4.80	7.60	2.8
08 PM	6.30	8.80	2.5
12 PM	23.7	27.3	3.6
01 PM	24.1	28.1	4.0
02 PM	22.8	26.6	3.8
05 PM	16.6	20.1	3.5
06 PM	15.4	18.1	2.7
07 PM	14.1	17.3	3.2

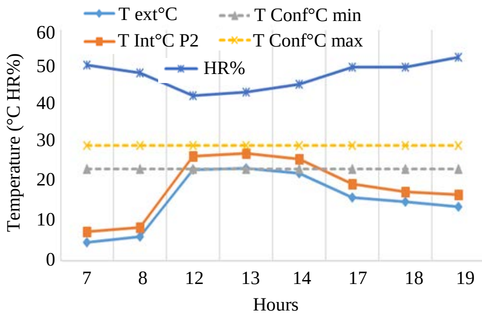

Fig. 10: The influence of temperature on the prototype P2

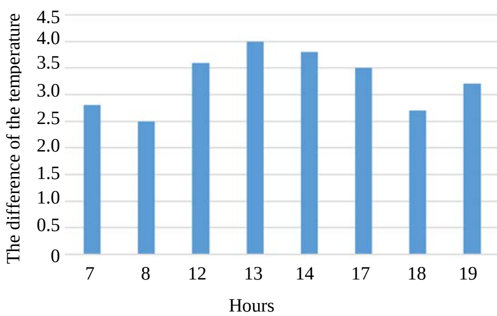

Fig. 11: The temperature difference between the inside and the outside of the prototype P2

temperature difference marked its maximum value (3°C), this is due to the storage of the heat by the concrete slab.

Prototype P2: Figure 8 summarizes the graph of variation of the interior temperature, exterior and moisture. From the results of Fig. 10, we have recorded a slight increase of difference between the external temperature and the inner (3-4)°C by Report P1 and C to this due to the thermal characteristics of the materials used (Table 10). The moisture increases as a function of the decrease of the temperature. Figure 11 summarizes the graph of the difference in temperature inside and outside of the prototype P2.

According to Fig. 11, we see that the indoor temperature is higher than that of the outside. The thermal gap varies between 2.5 and 4°C, we note that the elements of the prototype played their role concerning the penetration of the heat of the slab which has decreased the consumption of energy.

Table 11: The difference of the indoor and outdoor temperature of the prototype P3

Hours	T ext °C	T int °C P3	ΔP3
07 PM	4.80	8.40	3.6
08 PM	6.30	10.0	3.7
12 PM	23.7	28.3	4.6
01 PM	24.1	28.8	4.7
02 PM	22.8	28.2	5.4
05 PM	16.6	22.8	6.2
06 PM	15.4	19.3	3.9
07 PM	14.1	18.7	4.6

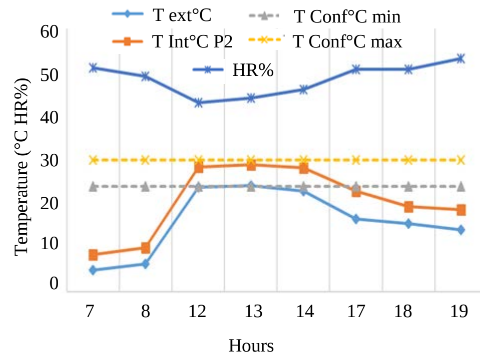

Fig. 12: The influence of temperature on the prototype P3

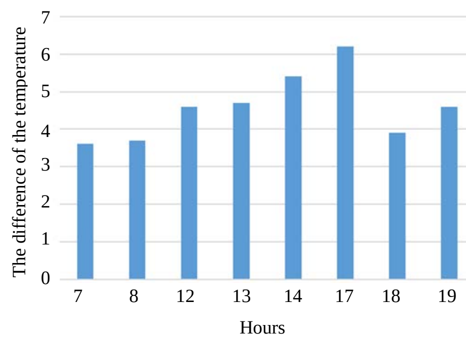

Fig. 13: The temperature difference between the inside and the outside of the prototype P3

Prototype P3: Figure 12 Summarizes the graph of variation of the interior temperature, exterior and moisture.

According to Fig. 12, during the period of the day, we have noticed that the difference of indoor and outdoor temperature of (3.6-6.2)°C This is due to the thermal characteristics of these and the type of the slab (clay). Between the hours 12 PM-02 PM, we have noticed that the inside of the prototype P3 is in comfort. The moisture increases as a function of the decrease of the temperature (Table 11).

Figure 13 summarizes the graph of the difference in temperature inside and outside of the prototype P3. According to Fig. 13, we note that the temperature in the interior is more important to that of the outside (the gap is

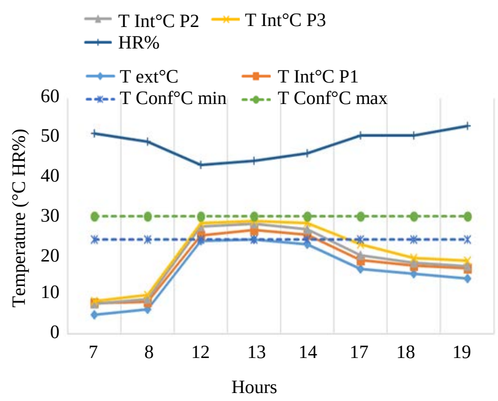

Fig. 14: The influence of the temperature on the prototypes P1-P3

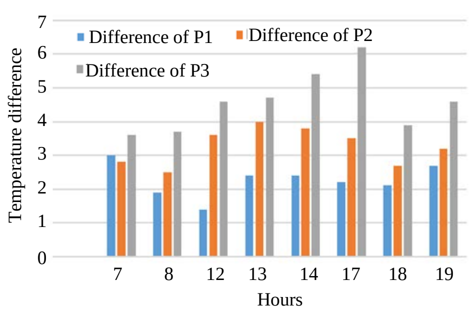

Fig. 15: Difference in the temperature of the prototypes of (P1-P3)

positive). This is due to the presence of the fibers of the palm trees and the characteristics of the materials used.

Figure 14 summarizes the variations of the indoor and outdoor temperature on the prototypes (P1, P2, P3). From the curves in Fig. 14, we observe that the model P3 gives the best results and its due to the presence of fibers which affects the thermal characteristics of the bricks of this model, the results obtained in the model P1 are due to the concrete slab. For this fact, we insist on the not adaptation of the concrete in the Saharan zone.

The degree of moisture to the outside is 43-53% during the entire period of the practice, these results are in the fork of the thermal comfort in relation to the moisture (30-60%).

Deviation of the temperature of the prototypes: To better see the influence of the prototypes on the decrease of the indoor temperature, we present on Table 12 and Fig. 15. The differences in temperature between the outside and the inside.

Figure 15 summarizes the graph of the difference in the temperature of the prototypes. According to Fig 15, we record the following points:

Table 12: Difference in the temperature of the prototypes in relation to the outside temperature

Hours	ΔP1	ΔP2	ΔP3
07 PM	3.0	2.8	3.6
08 PM	1.9	2.5	3.7
12 PM	1.4	3.6	4.6
01 PM	2.4	4.0	4.7
02 PM	2.4	3.8	5.4
05 PM	2.2	3.5	6.2
06 PM	2.1	2.7	3.9
07 PM	2.7	3.2	4.6

Prototype P1: Of 07 AM-07 PM The temperature difference is positive with a maximum value of 2.7°C. From 12 PM-02 PM the model P1 is in comfort.

Prototype P2: Of 07 AM-07 PM The temperature difference is positive with a maximum value of 4°C. From 12 PM-02 PM the model P2 is in comfort.

Prototype P3: Of 7 AM-7 PM the temperature difference is positive with a maximum value of 6.2°C. From 12-2 PM the model P3 is in comfort.

Therefore, we can say that there is a significant difference in temperature between the outside and the inside.

CONCLUSION

After the experimental study on the thermal characteristics of the various compositions, we can draw the following conclusions: adding the fibers of the date palm in the bricks reduced thermal conductivity, specific heat, density and increases the thermal resistance. The increase of sand dunes has a positive impact on the increase of the thermal conductivity, specific heat.

The absence of fibers of the palm fronds and the increase of sand dunes to a positive impact on the increase of mechanical properties. In conclusion, concerning the brick C4 and C8 of point of view them thermal characteristics thermal best but of point of view, the mechanical compositions without fibers are the best.

Adding the fibers of date palm in the bricks diminished the thermal conductivity, specific heat, the mass density and increases the thermal resistance. On the economic plan the use of these materials contribute to reduce the quantity of imported materials and reduces energy consumption.

From the point of view of thermal comfort, we have noticed that the addition of fibers gives good results. In conclusion, we recommend using the materials studied in the construction of houses.

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