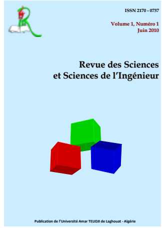
Revue des Sciences et Sciences de l'Ingénieur

ISSN 2170-0737

Journal homepage : http://www.RSSI.lagh-univ.dz



Mechanical and thermal properties of a cellular concrete formulated from dune sand, cement, lime and waste brick fillers

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Abstract

This paper present the results of an experimental study that investigate the properties of cellular concrete made with sand dune, fine of brick, lime and powder of aluminum as expansive agent. The aim of this work is both to enhance the sand dune in the production of lightweight concrete with local resources, but also enhance the performance of the sandcrete by incorporating fines mineral as fines from waste of brick. Different parameters were studied, in which the quantity of substitution of fines in the sand dune, the proportions substitutions of lime in the cement, the dosage of expansive agent. The researches examine the apparent density, the introduced porosity, the compressive strength and the thermal conductivity. The result shows that it is possible to producing lightweight concrete suited to the hot, arid environment of our region (South of Algeria). The matrix of the developed material who reach the optimum of compressive strength containing 15% of fine of brick as replacement of sand dune. The greatest introduced porosity and lowest density are reached from composition without lime and with 0.5 % Al. Materials obtained has an acceptable heat insulation and sufficient compressive strength.

Key words — Apparent density, Brick wastes, Cellular concrete, Compressive strength, Sand dune, Thermal conductivity.

1. Introduction

The current trend in research of new building materials, is the development of local materials for the manufacture of performants and durables concrete with the least cost. Indeed, Southern Algeria is known for its sand dunes, which occupy 60% of the surface of Algeria. In view of enhancement of local resources, the idea of promoting the use of sand dunes in the manufacture of mortars and concretes is interesting. Indeed, many studies in various scientific topics that are focused on sand dune concrete **[1-4]**. This sand has characteristics that allow us to foresee an exploitation in the construction field in the form of cellular concrete **[5]**. Cellular concrete is generally composed of fine sand (powder silica sands), cement, lime, water and an expansive agent (like Al or Zn). This one react with the lime liberated during the cement hydration and create macro- porosity (introduced porosity) generated by the expansion of the slurry due to the chemical process. The lighter weight and the heat insulation are two qualities suited to the region of Sahara. Some experimental and theoretical studies in the field of aerated concrete have shown some salient observation: (i) mechanical and thermal properties are influenced by method of curing, porosity and pore size **[6]**. (ii) Increase in the cement dosage increase the introduced porosity whereas an increase of the sand or lime dosages decreases the introduced porosity **[7]**. (iii) Insulation is more or less inversely proportional to density of concrete, **[8]**. (iv) The expansion of concrete during gas formation results in the development of ellipsoidal oriented pore. Finer filler materials help in uniform distribution of air-voids **[7]**. (v) Greater the proportion of aggregate, higher will be the density, replacement of sand with fly ash help in reducing the density with an increased strength **[9]**. The following experimental work aimed to proves that the valorization of the sand dune of the Sahara of Algeria is completely relevant in production of cellular concrete, and that the substitution of fines of brick wastes in the sand dune increases the properties of this type of concrete. The principal of the study consist in the first phase to change the water cement ratio (W/C) from 0.35 to 0.65 in all the mixtures in order to investigate the effect of brick substituted in the sand dune on the properties of the sand concrete. The mixtures have proportion of 35% of binder and 65% of sand dune **[10]**. The percentage of fines substitutions of wastes of brick in the sand dune was varied from 5% to 25% in order to keep the optimum mixture who gives the high compressive strength (noted SCB). In the second phase the work consist to add in the binder of the optimized sand concrete (SCB) different percentages of lime (as follow by weight of cement: 10 %, 15%, 20%, 25%, 30%, 40%, 50 %) with an expansive agent (aluminum powder) to create an air void in order to develop a cellular concrete (noted CCB) made with local sand dune and waste of brick. In this case the water / cement ratio was adjusted to 75% for giving an easy casting in the moulds.

2. Description of materials

2.1 Dune sand

Dune sand used in the mixtures was taken from Laghouat (south of Algéria) exactly from the North Oasis, near to our University, with maximum size of 0.5mm. Table 1 presents physicals and chemicals properties of this dune sand. The grading curve was presented in fig.1

Table 1: physicals and chemicals properties of dune sand

	Dune sand
Physical properties	
Apparent density (Kg/m^3)	1423.6
Absolute density (Kg/m^3)	2675
Equivalent modulus of Sand	0.067
ES (%)	97
Blue of methylene Vb	1.22
Fineness modulus	0.92
Chemical properties	
SiO_2 (%)	95.87
SO_3 (%)	2.29
$CaCO_3$ (%)	2.5

2.2 fines of brick

The wastes of brick were taken from the construction sites and companies; they were crushed to Ø< 100 µm. Physicals and chemicals properties of the fines of brick were presented in table 2. The grading curve was presented in (fig.1)

Table 2: physicals properties and chemicals composition of brick fines

Physical properties:	
Apparent density (Kg/m^3)	770
Absolute density (Kg/m^3)	2535.5
Blaine surface area (cm^2/g)	2847
Chemical composition:	
NaCl (%)	0.07
Cl^-	0.04
SO_3^{2-} (%)	2.4
$CaCO_3$ (%)	12

2.3 Cement

The cement used for optimization of the mortars with fines substitutions was Portland cement CEM II 42.5 from ACC (Algerian Cement Company) of M'sila. Chemicals and physicals properties were given in table 3.

Table 3: Physical properties and chemical composition of cement and lime.

	Cement	Lime
Physical properties		
Apparent density (Kg/m^3)	1030.03	378.05
Absolute density (Kg/m^3)	3100	2430
Blaine surface area (cm^2/g)	3700	-
Chemical properties		
SiO_2 (%)	-	0.46
Insoluble residue (%)	0.70-1.5	-
SO_3 (%)	1.80-2.30	1.13
CaO (%)	-	68.56
MgO (%)	1.60-1.80	0.65
Fe_2O_3 (%)	-	0.35
Al_2O_3 (%)	-	0.22
K_2O (%)	-	0.05
Na_2O (%)	-	0.03

2.4 Lime

The lime substituted to the cement for product the cellular concrete sample was an artificial Lime called "crushed lime of SODEPAC of Saida". Chemicals and physicals properties were given in table 3.

2.5 Expansive agent

The expansive agent was SIGMA-ALDRICH aluminum powder with 99% aluminum and fineness of 75 µm.

3. Moulds and casting

First of all, the solid components were dryly mixed for 2 min. then the total of amount of water was added and mixed for 2 min (In the case of manufacturing cellular concrete, the expansive agent was added at the end with mixing for 1 more minute). All mixtures were cast in 4x4x16 cm^3 moulds for approximately 24 h, after which time they were removing from the mould and stored in 20°C water during 28 days. The expanded samples were sawing of the excess material just before demoulded.

4. Result and discussion

4.1 Optimized Sand-Brick Concrete

The results of compressive strength were used as the indicator of the activity of brick admixture in the dune sand. (Fig. 2) shows that the mineral fine admixture posses a positive influence in mechanical performance of mortar made with sand dune **[11-13]**. The optimum of strength was reached for mortar with 15% of fines of brick. It indicate also that approximately all the compositions have their optimum for W/C = 50% after this percentage all the strength decrease. For the reference mortar chosen (SCB with 15% of fine of brick) the strength decrease from 73.59 MPa to 38.68 MPa.

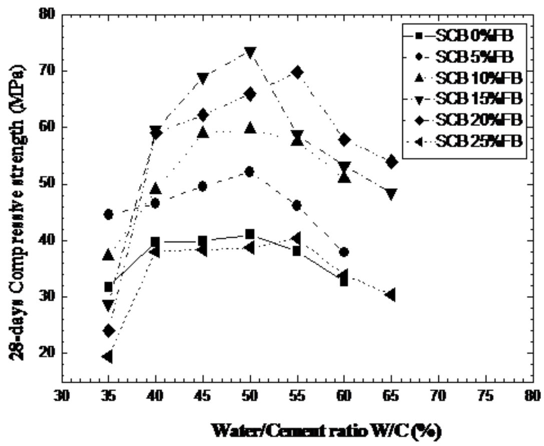

Fig. 2 Effect of fine of brick on compressive strength

4.2 Cellular Concrete of sand-Brick

For developing the cellular concrete in this research we have added to the reference optimized mortar (SCB) different percentage of lime (10%, 15%, 20%, 25%, 30%, 40%, 50%) with two percentage of the Aluminum powder (0.2% and 0.5%) in order to show the effect of the lime in the reaction with the aluminum with parameters of: apparent density, introduced porosity, compressive strength and thermal conductivity.

4.2.1 Influence of lime on the apparent density

The results showed in (fig. 3) indicate an increase in the apparent density until 25% of dosage of lime after this percentage the density decrease it is the same conclusion for the two ratios of Aluminum. The lowest density (1209.11 Kg/m^3) is reached from the concrete with binder made only of cement (0% lime). It means that the expansive agent acted only with the (Ca (OH) $_2$) formed during the hydration reaction of cement (In contact with water, tricalcium silicate (Ca_3SiO_5) and dicalcium silicate (Ca_2SiO_4)

dissolve as ions that interact and form calcium silicate hydrates (CSH) and portlandite ($Ca(OH)_2$)). This result is consistent with the literature **[7].**

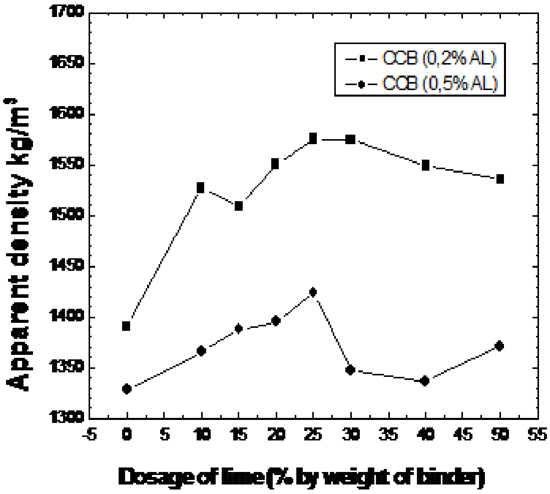

Fig. 3 Effect of lime on the apparent density of CCB

4.2.2 Influence of lime on the introduced porosity

The introduced porosity was determined from the measurement of the dry apparent densities of the reference mortar and of the expanded samples by the expression:

$P_i = (\rho_r - \rho_e) / \rho_r$

Where P_i : is the introduced porosity

ρ_r : the dry apparent density of the reference mortar

ρ_e : the dry apparent density of the expanded sample

The results of introduced porosity versus the dosage of lime complete the above conclusion. Fig. 4 indicate that the porosity decrease with the increase of percentage of lime till 25% of lime after this dosage the porosity increase. This decrease of porosity means that the reaction capacity of lime with the expansive agent is less important than that of cement **[7]**.

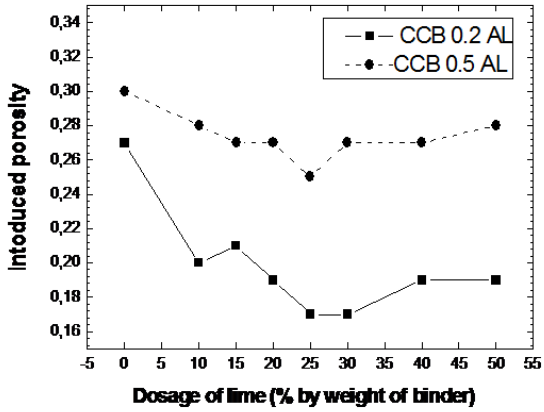

Fig. 4: Effect of lime on the introduced porosity of CCB

4.2.3 Influence of lime on the compressive strength

Figure. 5 shows the influence of dosage of lime on the compressive strength. The increasing dosage of lime increase the compressive strength till 25%, after this optimum the compressive strength diminishes with increase of dosage of lime. The highest strength which are obtained from composition with 25% of lime are 7.44 MPa with 0.5 % of Aluminum and 10.62 MPa with 0.2% of Aluminum.

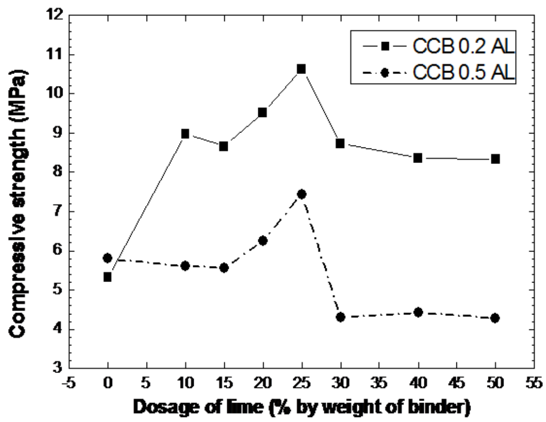

Fig. 5: Effect of lime on the compressive strength of CCB

4.2.4 Influence of lime on the thermal conductivity

The thermal conductivity depends on density and on insulation characteristics of the ingredients of the material **[14, 15, 16].**the amount and fineness of pores influence also the thermal insulation **[6, 16]**. Figure.6 and 7 shows thermogrammes obtained using hot wire method. In figure.8, the thermal conductivity versus the dosage of lime shows that the thermal conductivity increases with the increase of lime till 25% of lime and decrease after this dosage; this result proves that this lime has not a role in the processes of alleviation. The lowest value of thermal conductivity (0.505 W/m°C) is given by composition CCB without inclusion of lime, and which has the greatest introduced porosity (Pi=0.3).

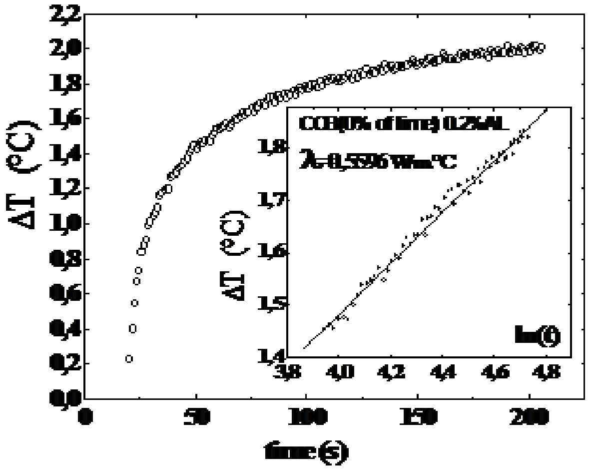

Fig. 6: Thermal conductivity of CCB (0% of lime, 0,2% AL)

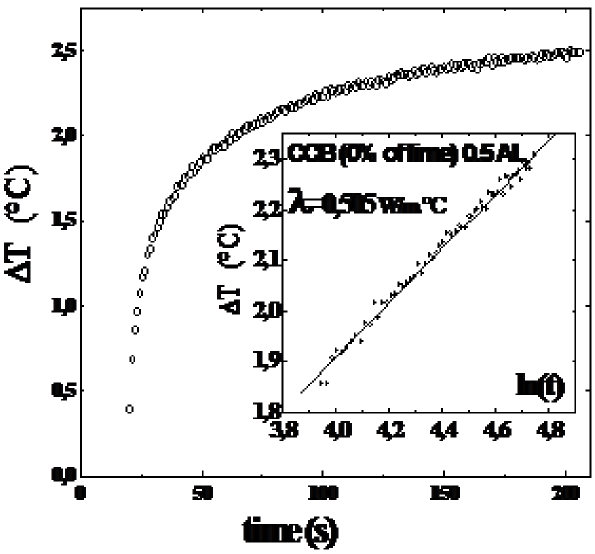

Fig. 7: Thermal conductivity of CCB (0% of lime, 0,5 % AL)

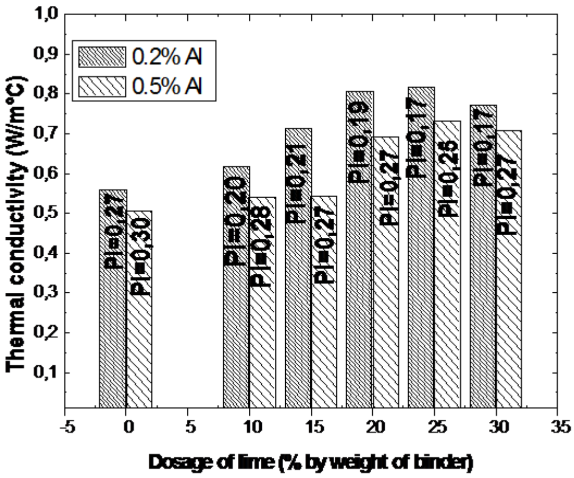

Fig.8: Thermal conductivity versus the dosage of lime

4.2.5 Influence of expansive agent contain

In this study all the results (fig. 3-4-5) shows that the dosage of aluminum possesses a great influence on the properties of the material developed. Compared with dosage of 0.2% of aluminum, the dosage of 0.5% gives the lowest apparent density which is due to the greatest development of the porosity (30%); consequently, the increase of porosity leads to a decrease in the compressive strength.

5. Conclusion

The results of this experimental work to develop a novel material as cellular concrete using especially local ingredients like sand of dune which is plentiful in the Sahara of Algeria and wastes of brick, shows that it is possible to investigate in this type of concrete to producing lightweight concrete suited to the hot, arid environment of our region.

The developed material in this research is a non-autoclaved concrete, and we have reach a very acceptable value of characteristic (1209.11 Kg/m^{3}for apparent densities, 3.67 MPa for the compressive strength and 0.505 W/m°C for thermal conductivity) entering in the margin Classification of lightweight concrete **[17]**.

Substitution of fine of brick in the sand of dune could play an important role in the increase of the mechanical performance of sand concrete.

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