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Contribution to the study of the thermo mechanical properties of compressed earth brick (CEB) produced by waste red bricks

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ABSTRACT:

The Saharan region of the Algerian country has been characterized by hot, dry summers and cold, dry winters. Commonly used building materials in these regions are concretes or mortars which have poor thermal and mechanical properties. In order to produce a product of bio-material clay bricks, with good mechanical and thermal properties, this study is launched. This report is the result of an experimental work involving two major fields of applied building mechanical and thermal sciences. The study is part of a global objective which focuses on the development of local natural resources in order to produce bioclimatic constructions. The study focused on BT earth bricks chosen as reference material to which we associate red brick and gravel waste. The percentage of red brick and gravel waste varies from 0% to 30% and from 0% to 6% by mass respectively of cement. the sand dune of Ain El Beida in Ouargla in Algeria was used. The clay was extracted from Beldet Amer in Touggourt Ouargla Algeria. The results showed that the increase in the mass fraction of cement was beneficial for the improvement of the thermal mechanical properties.

KEYWORDS:

Cement ,sand dunes, *gravel, red brick waste, resistance, clay, thermal mechanical*

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1. Introduction

The Saharan region of the Algerian country has been characterized by hot, dry summers and cold, dry winters. Commonly used building materials in these regions are concretes or mortars which have poor thermal and mechanical properties [1, 2]. In order to produce a product of bio-material clay bricks, with good mechanical and thermal properties, this study is launched. This report is the result of an experimental work involving two major fields of applied building mechanical and thermal sciences. The study is part of a global objective which focuses on the development of local natural resources in order to produce bioclimatic constructions. where compressed earth bricks are used for the construction of the building envelope, as evidenced by traditional housing in many parts of our planet, given its economic interest and ease of operation[3,4]. Through the world heritage of earthen construction, there are several techniques for using earth for construction: adobe, adobe, cob, straw earth, cob, compressed earth ... etc. Compared to the history of earthen construction, the compressed earth block technique (BTC) is a recent technique, which is a modern evolution of the molded earth block, more commonly referred to as adobe block. Compared to adobe, BTC is very regular in shape and size, denser, and exhibits better compressive and water resistance. In our study we realized new materials incorporating four components in order to improve the thermal insulation quality of bricks. Using building materials such as (clay, sand, gravel, brick waste). We carried out different compositions of the BTCs, after carrying out a series of thermal and mechanical tests on test specimens (brick) with a view to improving the thermo-mechanical properties [5].

2. .Materials and Methods

2.1. Clay:

The clay used in this study was from Baldet Oumar enlargement Touggourt Algeria. Whit followed mechanical and physical proprieties[6,7] see figure 1 and 2.

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figure 1 Baldet Oumar clay enlargement

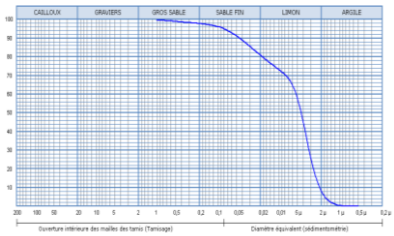

figure 2 Sieve sharker (mm)à Grinding curve of clay

Atterberg index (Norme NF P 94-051) index:

-liquid limit: WL =68.75 % - Plastic limiite WP = 26.54%

- Plasic index IP= WL –WP = 42.21% then the used clay is very platic .

Table1. Chemical compositions of the clay

Chemical characteristics	Components	Percentages (%)
Insoluble NF P 15 - 461	Insoluble	63,91
Sulfate BS 1377 (1	SO3	0,72
	Ca SO4 / 2H2O	3,88
Carbonate NF P 15 - 461	CaCO3	18
MOHR method	Cl-	0,363
	NaCl	0,595

The table1 shows that the elements of this clay are insoluble in percentage of approximately 64 %, the levels in sulfates [8].

2.2. Dune sand:

The used dune sand was from Sidi-Khouiled town in Ouargla Algeria. These analyzes of physical properties are conducted in the laboratory of Civil Engineering of KASDI Merbah University of Ouargla. For all the tests three samples was used. The results obtained are giving in the Table 2.

Table 2. Physical Characteristics of sand dunes

Test	The dry bulk density	The apparent density	Equivalent of Sand	Fineness modulus	porosity
Result	2553.28 kg/m3	1481.50 kg/m3	ESP = 93.8	1,23	0.16

The Table 2 shows the chemical components of dune sand. This analysis carried out in the Ouargla L.T.P.S laboratory[8,9].

Chemical Compositions of Sand

Meeting the following standards: Insolubles NF P15 - 461, Sulfates BS1377, Carbonates NF P15 - 461. The main results of the chemical analyzes carried out are grouped together in the following table 3

Composants	Percentages (%)
$Fe\ 2O_3$ - $AL_2\ O_3$	0,25
$Ca\ SO_4$, $2H_2O$	2,78
SO_4	0.51
$Ca\ CO_3$	1.30

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Insoluble	93.23
Na cl	trace
Perte au Feu	1,16

Table 3 Chemical compositions of sand

Particle size analysis

This test is carried out in accordance with standard NF P18 560 [71] The representative sample must have a mass between 200D and 600D, where D is the largest dimension of the aggregates the results obtained are present on the figure 3

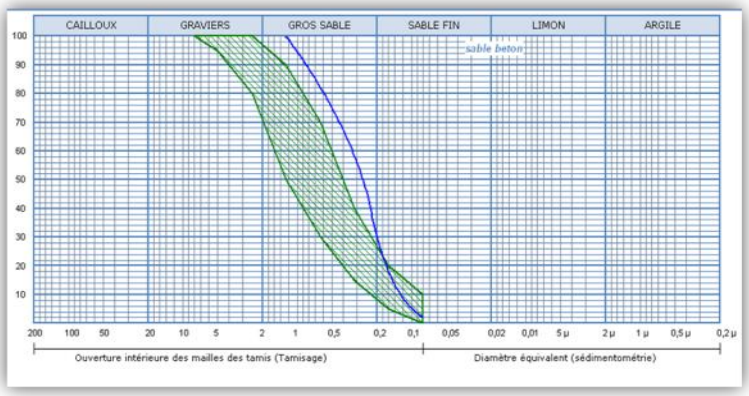

figure 3 Sieve sharker (mm) Granding curve of sand

2.3. Waste bricks

there is little information available on the fate of clay brick waste which constitutes the bulk of demolition waste and rubble. Technically, brick waste is practically recycled as a component of a masonry-like material [10].

Ownership of brick waste

• crushed bricks, coming from bricks and tiles have inherent resistance of 100 to 300 kg / cm3

• The absorption of crushed bricks is estimated between 5 and 15% relative to the weight of the material in its dry state.

• The use of coarse crushed brick aggregates can produce high strength structural concrete with a weight saving of up to 15% for about 20% reduction in strength compared to normal concrete.

• Concrete containing fired clay has a much higher fire resistance than concrete made from natural gravel.

• A concrete containing aggregate of crushed brick is more permeable than normal concrete. If the bricks contain soluble salts, there may be corrosion and efflorescence in the concrete.

• Brick waste is also used as aggregate in the construction of road foundations, as backfill material, for landscaping [10] see figure 4.

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Figure 4 red brick waste

Brick Waste Recycling Standards:

DIN 4155: hollow body and concrete T-blocks made from broken brick.
DIN 4158: hollow slabs for lightweight concrete floors for ribbed reinforced concrete floors.
DIN 4161: concrete blocks of brick.
DIN 4162: Concrete wall tiles from debris brick.
DIN 4163: concrete from brick debris: condition of manufacture and use.

2.4 Mixing Water

The water used was from the laboratory of civil engineering of the University of Kasdi Merbah. The chemical analysis of the water has been carried out at the level of laboratory of wastewater treatment in the University of Kasdi Merbah Ouargla. as a result in the table 6

Table 6.Chemical composition of water (mg/l) [11,12].

Ca^{++}	Mg^{++}	K^{+}	Na^{+}	Cl^{-}	NO_3^{-}	SO_4^{-}	HCO_3^{-}	pH	Salt
242	125	31	536	755	14.5	755	124	7.75	2799

Table 6This water can be used for normal concrete [6].

2.5 Gravels:

Gravels have origins similar to those of sands, they come from the disintegration of rocks. The maximum dimension of the aggregates is conditioned, on the one hand, by the minimum distance to be achieved, and on the other hand [13]., by the minimum distance between the different reinforcements of the structure. Fraction 3/8 is considered to be crushed sand

Particle size analysis :

We have prepared a quantity of gravel class 3/8 of ouargla, below we present the granular curves of the two classes see figure 5

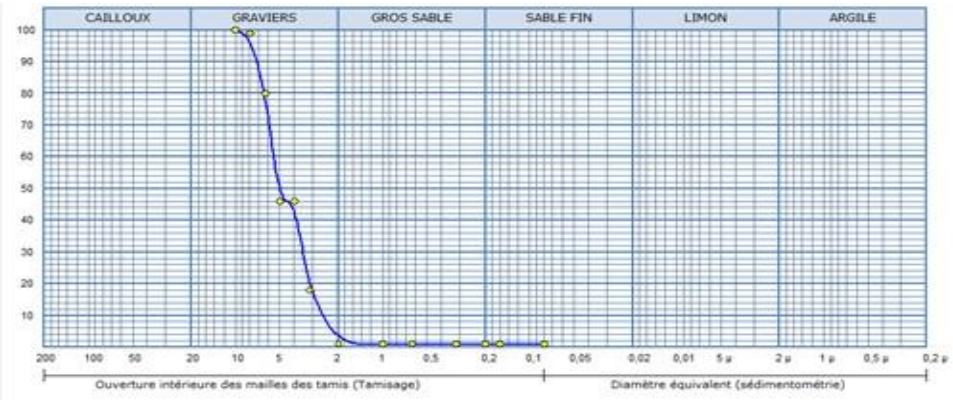

Figure 5 Sieve sharker (mm) Granding curve of gravel

3. Composition Nine types of bricks were prepared:

COMPLETION OF EARTH BRICKS

Thermodynamics can predict the total amount of energy that a system must exchange with

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the outside to go from one state of equilibrium to another. Thermal (or thermo kinetics) proposes to describe quantitatively (in space and time). The evolution of the characteristic quantities of the system, in particular the temperature, between the initial state of equilibrium and the final state of equilibrium. The experimental study of this paper consists in determining the thermal and mechanical characteristics of the local earth-based BTC of dimensions (29.5x 14 x 9) cm, see figure 6 by the use of the clay of Beldet Amor, the sand of the dunes of Sidi Khouiled , Ouargla grivlette [6,7,13,14 ,15], brick waste, cement in the goal of compactness between the elements, to obtain the best composition that gives good thermal and mechanical results. In this aim, we carried out various tests on the bricks, namely:

1- Thermal tests:
- Thermal conductivity;
- Specific heat;

2- Mechanical tests:
- Resistance to bending by traction;
- Resistance to compression;

These tests are carried out at the Civil Engineering laboratory of the universality of Ouargla, under the following conditions: Temperature (30 ± 5 ° C), and relative humidity RH = 35 ± 3%.

Description of the mold

To make the test pieces necessary for the test program, a mold was designed according to the CRATerre group (see figure 6). It is made of hardened steel, and it is composed of 5 elements forming, after assembly, a volume of 29.5x14x9 cm3. The mold is fitted with a piston to ensure the transmission of the compaction stress from the press to the mixture [8,9].

PREPARATION FOR SAMPLES USED IN THE STUDY FOR THE PREPARATION OF BRICKS, WE ARE THE FOLLOWING

For the preparation of the bricks, we followed the following steps:

1 Weigh the clay;
2 Weigh the dune sand;
3 Weigh the aggregates (waste / gravel) depending on the percentage of aggregates in each mixture;
4 Soaked in clay until saturation for 24 hours;
5 Add the mixing water;
6 Mix the ingredients with the mixer (see figure 7);
7 Filling the molds;
8 Dry in the open air;.

Figure 6: The mold used for the manufacture of BTC

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Figure 7: Manual and electric mixing

The bricks BTC :

We classified the bricks used in this study by two categories see figure 8

1st category bricks A:

the witness They are bricks which only contain basic materials Presented in Table 7.

2nd category bricks C:.

Are bricks that contain different percentages of gravel, shown in table 7.

The bricks are presented in the table 7

Numéro de composants	cly %	sand dunes %	Gravel %	waste red bricks %	Cement %
A1	40	30	30	0	0 the witness
A2	40	30	20	10	0 the witness
A3	40	30	10	20	0 the witness
A4	40	30	0	30	0 the witness
C1	39	30	30	0	1
C2	39	30	20	10	1
C3	39	30	10	20	1
C4	39	30	0	30	1
C5	37	30	30	0	3
C6	37	30	20	10	3
C7	37	30	10	20	3
C8	37	30	0	30	3
C9	34	30	30	0	6
C10	34	30	20	10	6
C11	34	30	10	20	6
C12	34	30	0	30	6

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Table 7: Bricks used ingredients.

Figure 8 BTC bricks

EXPERIMENTAL STUDY OF THERMAL AND MECHANICAL PROPERTIES OF EARTH BRICKS

Description of thermal conductivity measuring device:

CT-METER was developed with the aim of making it possible to evaluate with precision, the thermal characteristics of a certain number of homogeneous and isotropic materials. The operating principle consists, thanks to the association of a heating element and a temperature sensor (both associated in the same probe), in measuring the temperature rise undergone by the sensor, during a heating period chosen by the user according to the material to be tested and the type of probe. In figure 9 is presented the CT-meter which is made up of two elements namely : control unit, responsible for generating the heating power and interpreting the temperature rise curve induced in the material to be tested; and the probe responsible for transmitting the heating power and collecting the induced temperature (NF in 993-15) [10,11,12,16].

Figure 9: CT-meter.

Four-point flexure test- NFP18- 407

The experiment is carried out on the BTC building blocks which are used in the walls using a machine (type CONTROLS) as shown in the figure 10, where the device is equipped with movable support (horizontal movement) below. The upper part has got a vertical motion where it is driven by hydraulic pressure (the experiment used is inspired by NFP18-407). The machine is provided with a solid piece of metal placed on top of the tested sample. The load is applied to the sample continuously at a speed of 0.5 kN / min until the sample collapses [11,12,13,14].
The value of the force leading to collapse is given directly from the machine. The tensile stress calculation relationship is given using the equation 1 :

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$\delta t=3.F/2\alpha^2$ (1)

where:

F: Force applied to the sample.
α: The height of the tested sample

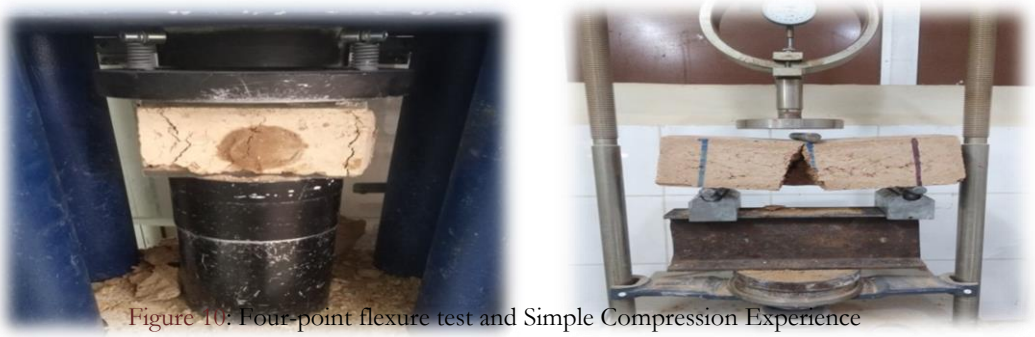

Figure 10: Four-point flexure test and Simple Compression Experience

Simple Compression Experience - Inspired by NFP18-406:

This experiment is carried out using the CONTROLS compression machine on raw and fired bricks,. The machine is equipped with two fixed lower plates and the upper mobile hydraulic pressure system where the sample is placed in their centers as shown in figure 10. Both plates are square where a = 100 mm. The load is applied to the sample continuously at a rate of 5 kN / min until the sample is exhausted. Reading of the value of the force leading to collapse collapses directly from the machine. [15,16,17,18].

The relationship used in compression stress calculation is given in equation 2 :

$$\delta p=(F/S)$$

Where:
P: value of the force leading to the collapse of the sample.
S: Plate area supplied to the machine. Where S = 10000 mm.
This experiment is performed on the pure gypsum completed block using a machine of type (CONTROLS).

5. Results and discussion

5.1. Results of thermal bricks BTC as function of cement fraction

Thermal experiments

The results thermal properties measurement results In what follows, we detail the results for each thermal property. The variation in thermal conductivity is added to that of the function of the percentage of cement and of the percentage of gravel at the first stage then make the thinning a second time Before measuring the thermal conductivity λ and the specific heat cp of our brick, it is necessary to use the machine CT -METER for that of figure 9 shows the thermal conductivity the specific heat for the bricks BTC see figure 11 and figure 12

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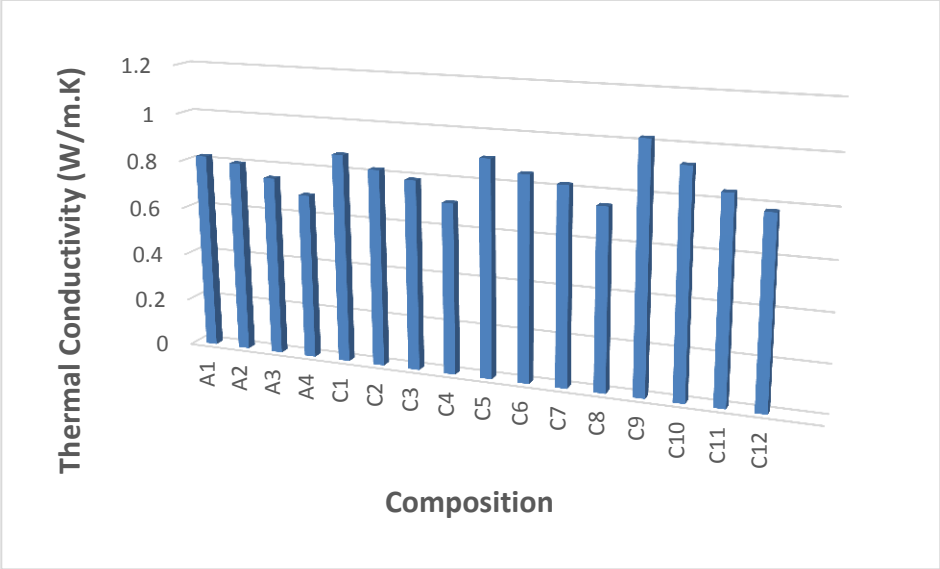

Figure 11: The thermal conductivity λ (w/m.k) in function of Cement percentage

From figure (11) we see: -A decrease in conductivity based on the percentage increase in waste in the mixture. This is attributed to the voids left by the waste -The bricks (A4) and (C8) give the lowest thermal conductivities, this is due to the presence of waste with 30% which created voids. -The brick (C8) which contains the large percentage of gravel gives the highest value of conductivity due to the absence of waste. -The compositions that have the highest percentage of waste are the mixtures that give us the best thermal conductivity

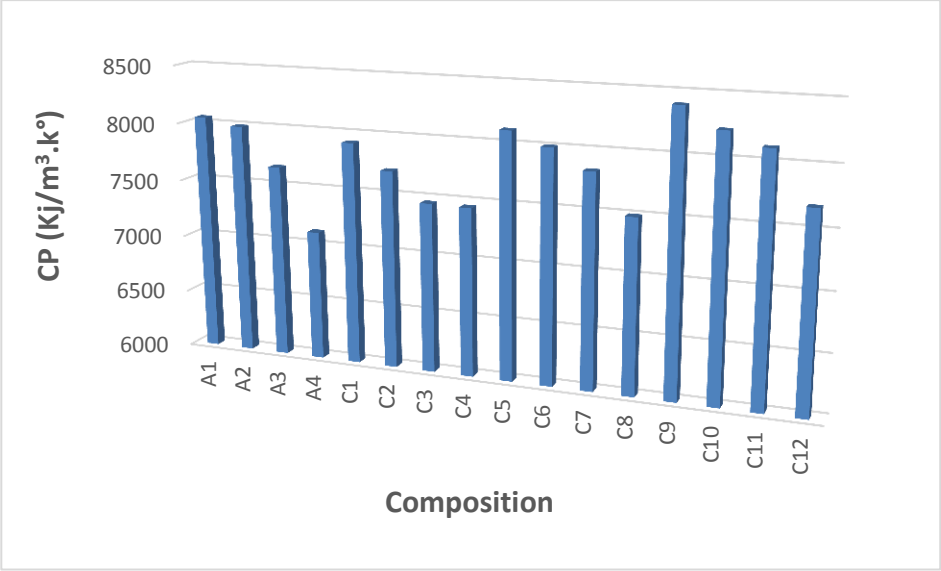

Figure 12: Specific heat in function of Cement percentage

From figure 12 we see that: - The specific heat decreases as the percentage of waste increases. This is logical because theoretically Cp varies in the same direction as λ -The specific heat of bricks (C9) and (C10) are the highest and this is due to the absence of waste 0% in (C9) and 10% in (C10)

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Mechanical experiments

Result of measurement of the mechanical properties

a .Flexural Resistance:

Figure 13 represents the variation of flexural strength as a function of the percentage of cement

b. Compression Resistance:

The purpose of this test is to determine the compressive strength or the crushing strength of a part of the brick after the bending test

The results of the compression experiment for mud bricks are shown.the Resistances in (MPa) at 28 days

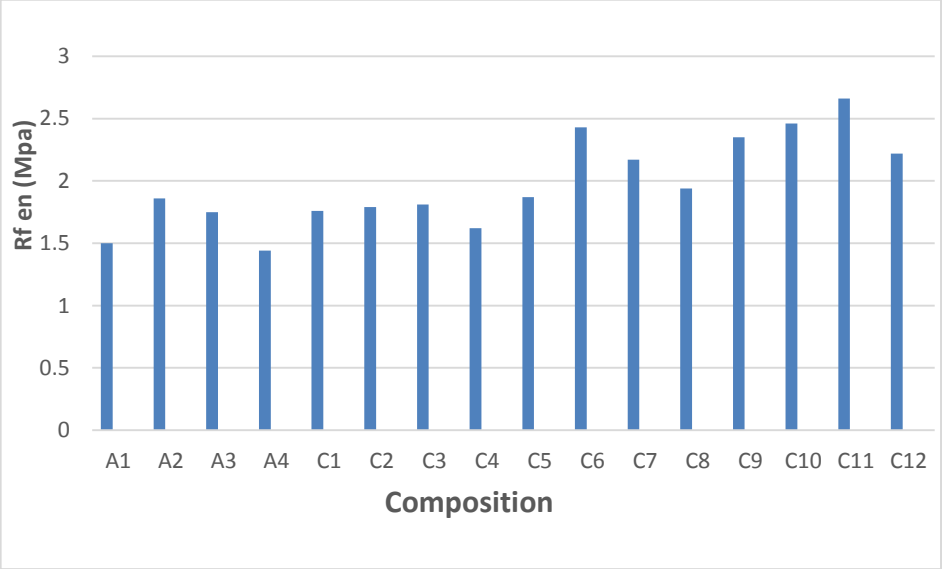

Figure 13 Flexural Resistance in function of Cement percentage

An increase in flexural strength as the percentages of waste in each percentage of cement increase. -The brick (C11) which contains 20% waste and 10% gravel and 6% cement gives the best bending result -the flexural strength of bricks which contains 6% cement is the highest

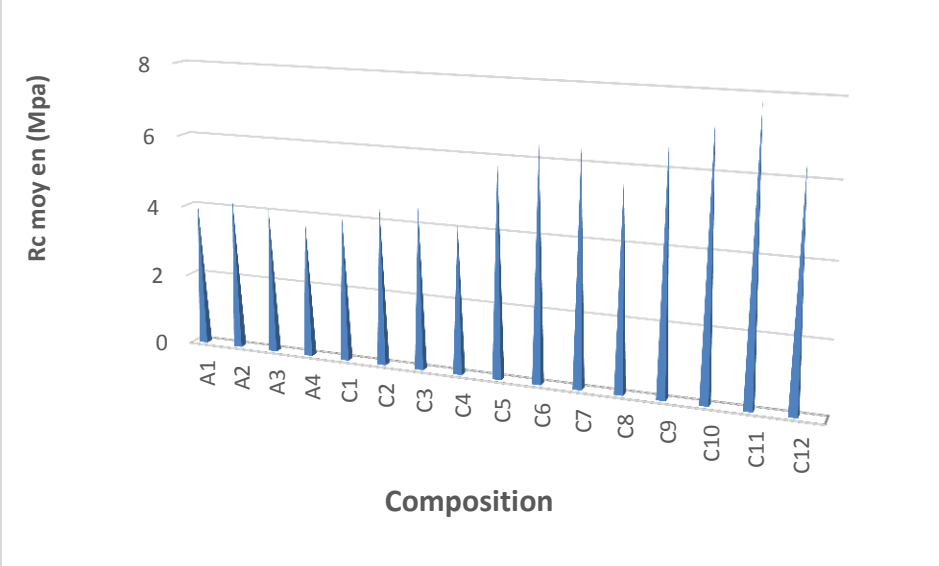

Figure 14 Compression Resistance in function of Cement percentage

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From figure 14

A convergence of the compressive strength to bricks which have (0% and 1%) cement with a value of 3.8 MPa up to 4.48 MPa - An increase in compressive strength from (C5) up to 6.8 MPa (C 11) up to 7.8 MPa

5. CONCLUSION :

From the experimental study on the thermal and mechanical characteristics of the different compositions, and the results obtained in this chapter, we can draw the following conclusions:

- The addition of recycled brick waste in BTC decreases thermal conductivity, specific heat, density and increases thermal resistance.
- The addition of gravel has a positive impact on increasing thermal conductivity, specific heat, thermal effusivity, etc. this is due to the thermal properties of the gravel.
- The bricks which contain 6% of the cements give the best performances in front of the bending and compressive force.
- In view of the results obtained, we notice that the thermal insulation of bricks produces where the percentage of brick waste is 30% better, therefore the presence of waste improves the insulation.

If we compare our results with those of the bibliography we notice that our bricks have excellent thermo mechanical properties.

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