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RESEARCH ARTICLE

MECHANICAL AND THERMAL CHARACTERIZATION OF CLAY WITH A VIEW TO POPULARIZING ITS USE AS AN ECOLOGICAL MATERIAL IN CONSTRUCTION

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Abstract

This work is carried out with the aim of enhancing the soils of Djarmaye in order to popularize its use as an ecological material in construction. However, a study of thermo-physical parameters was made to see the influence of cow dung in the mixture. As a result, thermal characterization tests were carried out, using the hot wire method for the determination of thermal conductivity, supported by the hot plane option for the determination of thermal conductivity.supported with the hot plane option for the determination of thermal effusivity was used. The test tubes are made with an incorporation of 0%, 2% and 4% by mass of cow dung. The parameters studied are the thermal conductivity, the thermal effusivity, and the thermal capacity by volume of the specimens. The results showed that the thermal conductivity decreases with cow dung, which confirms its use as an additive to obtain a good thermal insulator.

Introduction:-

The use of the material "earth" in construction is a very old tradition. Given the availability and implementation, construction with the latter is widespread in several countries, particularly in Chad in rural areas. In all corners of the world, it is estimated that about one-third of humanity lives in earthen buildings [1]. In recent decades, the ecological earth material has been abandoned in favor of cementitious materials, but the latter release a lot of CO2 that contributes to global warming. To remedy this, it is necessary to reduce energy consumption in the building by integrating the concept of thermal comfort, thus reducing the need for conventional energy. Thus, the use of insulating building materials makes it possible to reduce theheat transfer through the walls of the building [2].

However, the artisanal production of adobe bricks stabilized with elements such as straw is very varied, but in addition to the use of straw, there are fibers for building in cob, earth-straw, cob as well as compressed blocks and rammed earth (Houben, 2006) [3]. As a result, not all researchers [4] have agreed upon the stabilization of Adobe by fibers.The use of a material in construction requires knowledge of its mechanical and thermal behaviour. To determine the thermal properties of materials, there are several methods such as the hot plane method [5, 6], hot wire [7], box [8], hot tape [9, 10], hot disk [11, 12] etc.

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The objective of this work is to formulate and manufacture 4*4*16 cm3 specimens in which we have incorporated the percentages of 0%, 2% and 4% of cow dung. The method used for the determination of thermal parameters is the hot plane.

Material and Methods:-

Identification Testing

The purpose of the tests carried out is to determine some parameters allowing the identification of the clay materials used. We are talking here about particle size; Atterberg limits and natural water content.

Particle size analysis

The particle size analysis was carried out on a 1500g sample by the wet sieving method in accordance with the NF P 94 – 056 (1996) standard.

The Purpose of the Test

The aim is to determine the particle size of the material under study and to classify it.

The principle of the test

The test consists of separating the agglomerated grains from a known mass of material by stirring under water, splitting this soil, once dried, by means of a series of sieves and successively weighing the cumulative rejection on each sieve. The cumulative rejection mass on each sieve is related to the total dry mass of the sample submitted for analysis.

Equipment.

Sieve Series (mm) - Oven - Precision Electronic Scale - Tray - Water Container - Brush.

Fig.1:- GA Travelcard Equipment.

Mode opératoire

The sample submitted for particle size analysis weighs 1500g. It is soaked in a container of water for a sufficient time for the aggregated elements to detach. The sample is then washed and oven-proofed for 24 hours at 105°C. After drying well, it is poured into a series of sieves well arranged according to the diameters of the meshes. Sieving is done starting with the sieve with the largest opening. We shake, there will be a passage depending on the diametersieves. The first sieve is removed and the rejection is weighed. The operation is repeated for the second sieve, and so on until the last sieve in the series. The sieve contained in the bottom of the sieve series is also weighed. The sum of the cumulative rejects measured on the different sieves and the sieve on the bottom must be equal to the weight of the sample introduced into the series of sieves.

Fig.2:- Determination of GA by wet sieve.

The Limits of Atterberg

Liquidity and plasticity limits are used to characterize the behavior of clay soils. They are the water content at which a soil changes from one consistency to another and make it possible to assess plasticity, which is a very important property.

The Purpose of Testing

The goal is to determine the liquidity limit (WL) and the plasticity limit (WP) in order to derive the plasticity index (Ip).

Principle of the test

The determination of the Atterberg limit is done in two phases: the liquidity limit at the cup and the plasticity limit of the roll.

Equipment

CASAGRANDE appliance with a cup; a marble plaque; a grooving tool; a container of water; a wide-ended spatula for kneading; a thin-tipped spatula for sampling (Cat's Tongue); an oven; defects; 0.40 mm square mesh sieve and precision electronic scale..

Fig.3:-Material Used to Determine Atterberg Boundaries.

Sample Preparation

Fig.4:- Sample preparation.

•Take a representative sample of the soil; Add water and wash with the 0.400 mm sieve until the fine particles are detached and the sieve rejection is rejected.
• Collect the sieve (m ≥200 g), let stand and decant for 24 hours.
• Siphon off the supernatant liquid; Place in the oven to release some of the water.
• Remove the sample from the oven and let cool for a few minutes.

Determination of the liquidity limit (WL) Standard NF P 94-050

The WL liquidity limit is the water content of a reworked soil characterizing the transition from a liquid state to a plastic state that corresponds to a closure within an interval of 15 to 35 shocks.

Principle of the test

The test is carried out by ascertaining the moisture content for which a groove made in a soil placed in a standard cup closes when the cup and its contents are subjected to repeated shocks.

Procedure:-

To obtain the values of the liquidity limit, it is necessary to: Take part of the sample by quartering, knead it on the marble with the spatula and add water. Put a portion in the cup of the Casagrande appliance and make a groove of about 2mm passing through the center of the cup then operate the crank of the appliance at a rate of 2 strokes per second. Count the number N of strokes that cause a closure of about 1cm of the lips. Take a mass of about 5g on either side of the lips of the sample from the closure in a petri dish, then weigh and put it in the oven. Weigh dry samples after 24 hours to determine moisture contents. For a good representativeness, the complete operation is repeated three times while varying the water content in order to cover a range of 15 to 35 shots.

Fig.5:- Determination of the Liquidity Limit.

Determination of the plasticity limit (WP) Standard NF P 94-051
The plasticity limit Wp is the water content of a reworked soil characterizing the transition from a plastic state to a solid state.

Principle of the test
The test is carried out by ascertaining the moisture content for which a roll of the sample, of standard dimensions made by hand, cracks.

Procedure:-

Spread a portion of the remaining sample from the liquidity limit test on the marble slab and allow to dry slightly. Make patties of 3 mm in diameter and 10 cm in length obtained after cracking during production. The cracked wafer is put in the oven after its wet weight has been determined. The dry weight is taken after 24 hours and then determine the plasticity limit which is nothing more than the water content of the cakes.

Fig.6:- Determination of the Plasticity Limit.

Natural water content (NF P 94 – 050 (1995).
The natural moisture content was determined by steaming according to the current standard.

Principle of the test
The natural water content is obtained by weighing after steaming.

Equipment
Precision Electronic Balance - Tares - Oven.

The modus operandi
A soil sample of minimum mass is placed in an oven and heated to 105°C for 24 hours to a constant mass. At the end of the drying process, the sample is taken out of the oven and weighed. Moisture content is determined as the ratio of the weight of the water in the sample to the weight of the dry sample.

$$w = m_w/m_d \times 100$$

In order to meet the set objectives, the manufactured samples are first air-dried for 3 days, then put in the oven for 24 hours. After removal from the oven, they are subjected to the thermal characterization test. The determination of thermal parameters such as thermal conductivity, effusivity was done by the FP2C device (Neotim), the other parameters are determined by calculation. However, for the different measurements, the probe is sandwiched between two test tubes. The contact between them must be perfect to avoid measurement errors. Thus the probe is connected to the 100W power acquisition device via a computer.

Fig.7:- FP2C Device (Neotim)

Résultats et Discussion:-

Thermal and Mechanical Testing

Manufacture of briquettes for mechanical and thermal testing

Briquettes with dimensions of 4 x 4 x 16 cm and dimensions of 4 x 5 x 8 cm are made from clay + cow dung + water using different formulations. The 4 x 4 x 16 cm briquettes are for mechanical testing and the 4 x 5 x 8 cm briquettes for thermal testing. The same formulations are used for all briquettes used for mechanical and thermal characterization.

To make these briquettes we used an experimental device consisting of a manual press with double inlet, a mould and its accessories to shape the samples, a tank to make the mixing, a precision electronic scale, a graduated cylinder to measure the mixing water. A 2 mm sieve was used for the clay and a 5 mm sieve for the cow dung after being steamed for 24 hours. To make these briquettes, the amount of clay, cow dung and water needed for each formulation is measured using a precision electronic scale. By means of a tank, the clay-cow dung mixture is homogenized while gradually adding water. Once the mixture is prepared, it is placed in a plastic bag for proper impregnationthe moulds are filled and the excess material is removed with a squeegee to have regular shapes before closing the press lid. The same pressure is applied (compaction stress of 4.5 MPa) and the demoulding is done with great care to avoid any deformation of the briquettes After demoulding, the briquettes are dried at room temperature in the laboratory for 3 days for the 4 x 4 x 8 cm briquettes and 7 daysFor briquettes size 4 x 4 x 16 cm to avoid quick drying. Once dried, the briquettes are stabilised by steaming for 24 hours. A total of 12 briquettes measuring 4 x 4 x 16 cm for mechanical testing and 12 briquettes measuring 4 x 5 x 8 cm for thermal testing were produced.

Material Formulations:-

For ease of reading, the formulations are named by abbreviations based on the content of clay (A), and cow dung (BV. Once the briquettes are dried, conductivity and effusivityare measured by the hot wire method. The heat capacity and thermal diffusivity are calculated from the experimentally measured quantities. The briquettes are then tested for compression and tensile to determinetheir mechanical strength.

Formulation of the samples tested

The specimens studied have dimensions of 4 cm × 4 cm × 16 cm. Cow dung used with a percentage of up to 4%.

Number	**Arg (%)**	**BV (%)**	**Volume (cm3)**	**weight sec(g)**	**ρ(kg/m3)**
1	100	0	160	235	1468.75
2			160	236	1475
3			160	236	1475
4			160	234.7	1466.875
1	98	2	160	231	1443.75
2			160	231	1443.75
3			160	230.2	1438.75
4			160	229.5	1434.375
1	96	4	160	225	1406.25
2			160	224.5	1403.125
3			160	226	1412.5
4			160	225	1406.25

Mechanical behaviour of two floors

Table 1presents the results of mechanical tests on hardened earth mortars without stabilizer.

Table 1:- Hardened Mortar Test Result.

Percentage		Rf (Mpa)	RC (Mpa)
ground (%)	Cow dung (%)		
100	0	0,79	1,98
98	2	0,98	2,25
96	4	1,15	2,49

This result shows that flexural and compressive strengths vary with increasing cow dung. When the percentage of cow dung increases from 0 to 4%, the flexural strength also decreases from 0.79MPa to 1.15MPa. Similarly, compressive strength increases from 1.98 MPa to 2.25 MPa when the percentage of cow dung increases from 0% to

4%. This variation in flexural strength is explained by the behaviour of cow dung due to the fact that it is a lightweight material and by the mode of failure. During drying, the specimens did not shrink.

Thermal Conductivity

Thermal conductivity is the amount of heat transferred in a unit of time through a material of one unit area and one unit of thickness, when the two opposite faces differ by one unit of temperature. Thermal conduction is the corresponding heat transfer mode. It is expressed in W.m-1.K-1. For a given body, its value can be influenced by temperature and the presence of impurities.

Table 2:- Tested formulations.

ECH	BV	λ(W/m/K)
1	0	0.585
2	2	0.52
3	4	0.46

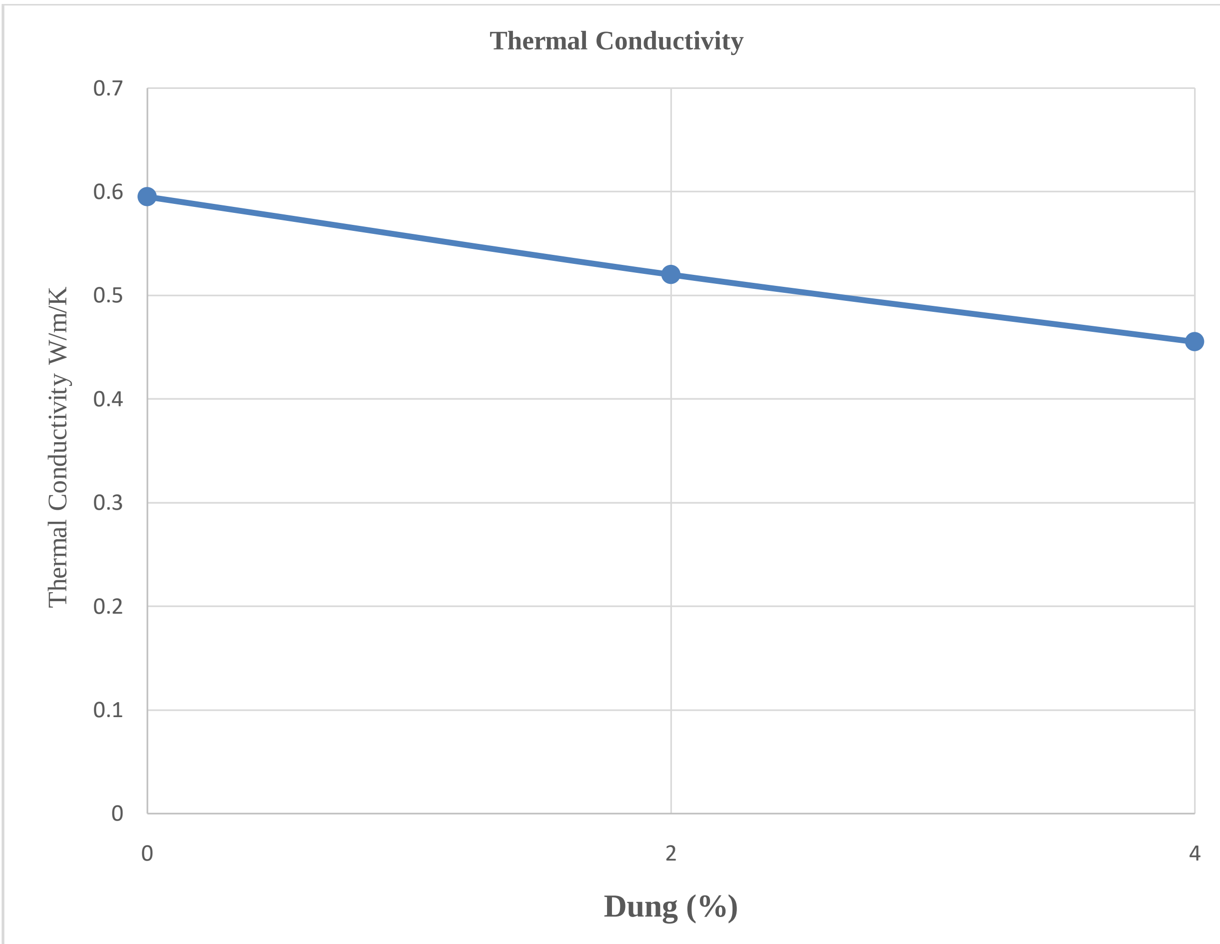

Fig.7:- Thermal conductivity.

Heat capacity

The heat capacity (or heat capacity) of a body is a quantity used to quantify the ability of a body to absorb or release energy through heat exchange during a transformation during which its temperature varies. It is expressed in J.kg-1.K-1. It corresponds to the energy that must be brought to a body of unit mass to increase its temperature by one Kelvin. It is an extensive quantity: the larger the quantity of matter, the greater the capacity thermal is great. 128 The heat capacity is sometimes shown as a density capacity, which is expressed in J.m-3.K-1, in which case the density ρ of the material comes into play.

Table 3:-Tested Formulations.

ECH	BV	λ(W/m/K)
1	0	1166
2	2	1200
3	4	1434

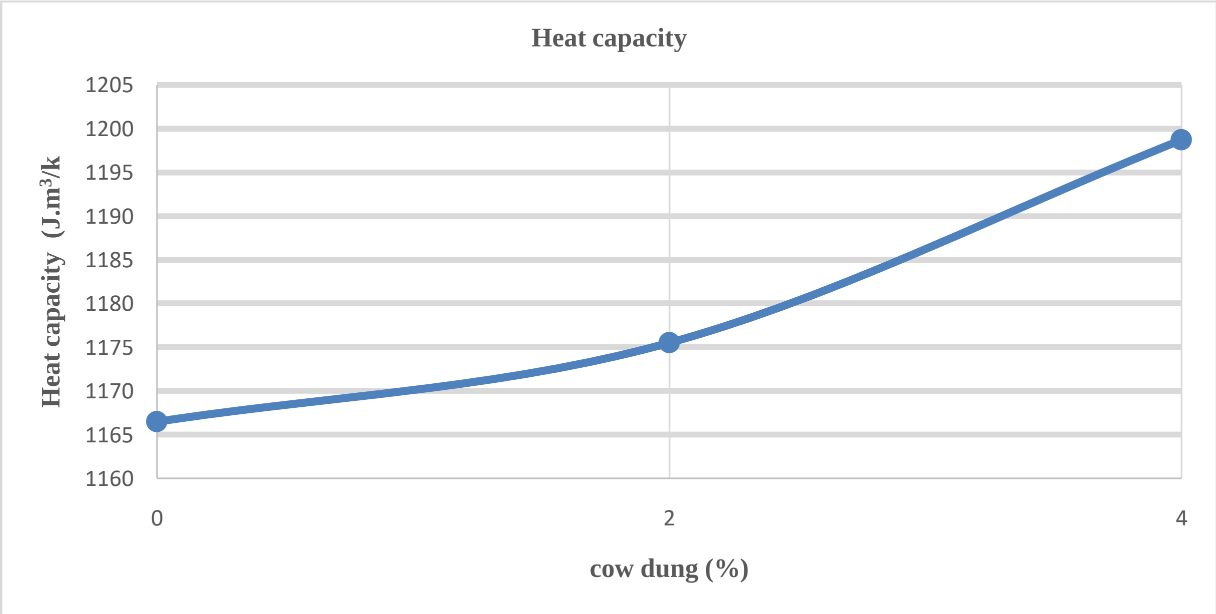

Fig.8:- Heat capacity.

Thermal Efficiency
Unlike thermal diffusivity, which describes the speed at which calories move through the mass of a material, effusivity describes how quickly a material absorbs calories. The higher the effusiveness, the more energy the material absorbs without noticeably heating up. It is expressed in J.K-1.m-2.s.

Table 4:- Tested formulations.

ECH	BV	ß
1	0	1010.5
2	2	938
3	4	876

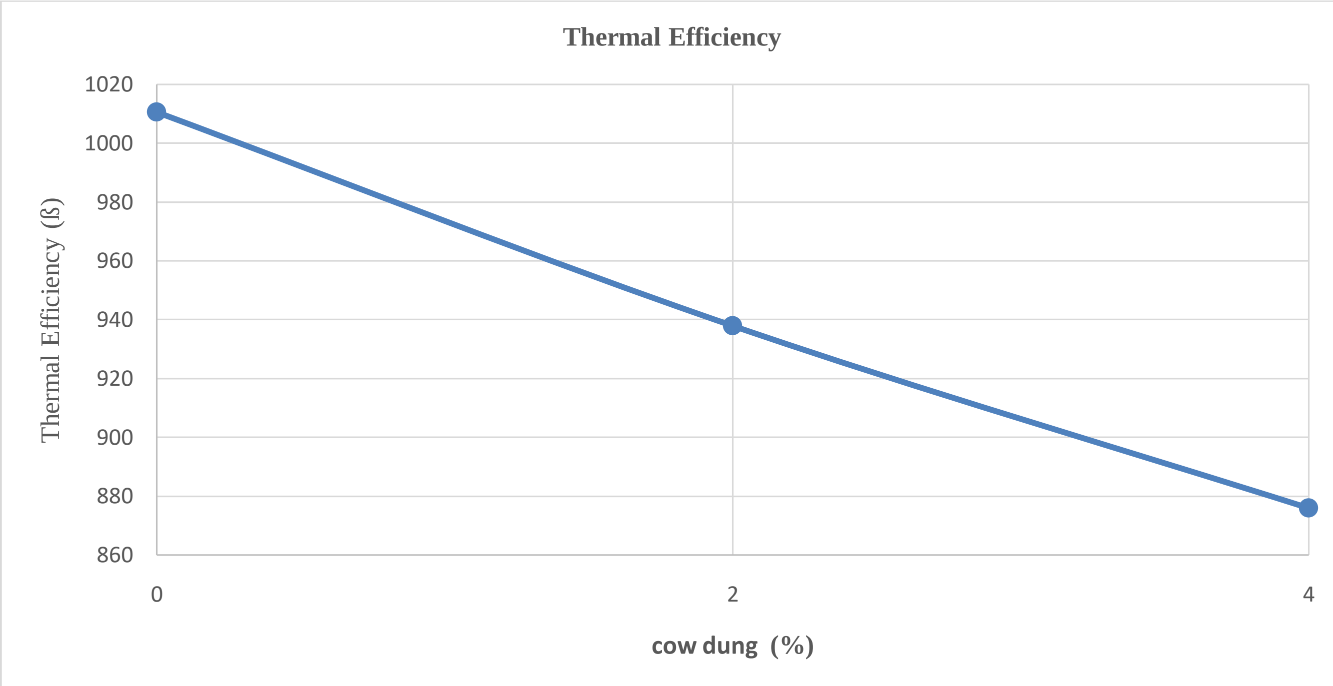

Fig.9:- Thermal efficiency.

Conclusion:-

The experimental campaign allowed us to specify the physical characteristics of the clay (particle size, density and Atterberg limit). These parameters allowed us to classify our clay soil, which is of the "Clay with little plastic" type.

Measurements of the mechanical characteristics of the samples studied show that the resistance increases with cow dung. The addition of clay and the compaction stress further improve this performance. Thermal conductivity increases with density, resulting in lower thermal conductivity. It helps to improve the thermal insulation of the home.

References:-

[1] Duc Chinh Ngo, Développement d'un nouveau éco-béton à base de sol et fibres végétales : étude du comportement mécanique et de durabilité, thèse, Université de Bordeaux ,2017.
[2] P. Meukam, y. Jannot, a. Noumowe, t. C. Kofane, Thermo physical characteristics of economical building materials, Construction and Building Materials, 18 (2004) 437 - 443
[3] Traité de construction en terre Broché » Hubert Guillaud (Auteur), Hugo
Houben (Auteur), CRATerre. 24 janvier 2006.
[4]Etude du comportement physico-mecanique du bloc deterre comprimée avec fibres »… taallahbachir. 14/12/2014
[5] Y. Jannot, théorie et pratique de la métrologie thermique, laboratoire d'energétique et de mécanique théorique et appliquées (lemta), (2011)
[6] S. Raji, y. Jannot, p. Lagière and j. R. Puiggali, thermophysical characterization of a laminated solid wood pine wall, elsevier : construction and building materials, 23 (2009) 3189 - 3195
[7] Y. Jannot, z. Acem et a. Kanmogne, transient hot plate method with two temperature measurements for thermal characterization of metals, institute of physics publishing, meas. Sci. Technol, 17 (2006) 69 - 74
[8] L. Boukhattem, r. Mir, m. Kourchi, a. Bendou, caractérisation thermo physique du mortier à base du ciment et de sable, laboratoire d'ingénierie des procédés de l'energie et de l'environnement (lip2e), ensad'agadir, maroc, (2007)
[9] A. Benazzouk, o. Douzane, k. Mezreb, b. Laidoudi and m. Queneudec, thermal conductivity of cement composites containing rubber waste particles: experimental study and modeling, elsevier : construction and building materials, 22 (2006) 573 - 579
[10] A. Saleh, measurements of thermal properties of insulation materials by using transient plane source technique, elsevier : applied thermal engineering, 26 (2006) 2184 - 2191

[11] A. S. Bahrani, y. Jannot and a. Degiovanni, extension and optimization of a three-layer method for the estimation of thermal conductivity of super-insulating materials, elsevier: journal of applied physics, 116 (2014) 1 - 9.
[12] Y. Jannot, z. Acem et a. Kanmogne, transient hot plate method with two temperature measurements for thermal characterization of metals, institute of physics publishing, meas. Sci. Technol, 17 (2006) 69 – 74.