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Behavior of the heat capacity and ultrasonic characterization for poured earth

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Abstract: *Nowadays, there is a globalized concern on behalf of the scientist of the subject, to use low-impact, sustainable materials that contribute to energy saving. Earth-based construction has proven to be a viable alternative and studies are being further continued. This paper analyzes one of the most important properties inherent to this material as it is the calorific capacity associated with hygrothermia, specifically in one of its constructive systems as is the poured earth. The analyzed samples were made with Champayan, soil of the region, ixtle fiber, obtained from the Agave Lechuguilla Torrey; the measurements of thermal conductivity and ultrasonic wave traffic that were obtained showed that the stabilized samples with ixtle fiber have a minor calorific capacity but greater thermal conductivity, nonetheless, the fiber diminishes its compression resistance. On the other hand, from the samples without ixtle, a greater calorific capacity was obtained but with less thermal conductivity, as well as a greater compression resistance.*

Keywords *- ultrasonic measurement, sustainable architecture, material calorific capacity, poured earth*

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I. Introduction

The earth was used from the beginning of the construction of cities together with vernacular materials. Quagliarini, E., & Orazio, S. L. (2014) show a study in which earth structures can be designed to withstand the passage of time, mainly in block form where their durability is increased; in general, earthen architecture has been presented as an efficient eco-technology (Benghida, D. 2016), and it is possible to use clay soils that can normally present problems under normal conditions (Topličić-Ćurčić, G. et al., 2017). Nowadays, it is for this reason that in certain European and Mediterranean regions the conservation of existing earth elements is being carried out and the creation of new ones is sought (Pica, V. 2017) this is in some cases advisable depending on the economic conditions and the space available Montoliu-Hernández, J., & Rodríguez-Álvarez, J. 2017). A specific analysis is necessary to the area where it is desired to apply techniques related to this type of architecture. Some advantages of the use of earth have been demonstrated in several ways, such as tapial (Serrano, S. et al., 2017). It has its advantage mainly in hot climates where it implies a greater comfort (Beccali, M. 2017) and this property can be improved by the dosage of granulated materials (Correia da Silva, JJ 2015) in conjunction with certain chemicals of common use (Leitão , D. et al., 2017), although natural fibers have also been used (Raj, S. et al., 2017) showing increases in resistance when dosed in certain proportions. It is important to note that in addition to the thermal characteristics, the physical-chemical effects of the surrounding environment on the earth element as well as its effect should be evaluated (Shen, Y. X. et al., 2017).

In order to evaluate the earth architecture, a number of regulations exist in the world (Jiménez D., MC; Canas G., I. 2005), although in Mexico there is no regulation focused on earth materials, there is more than one referring to the blocks of (Mexico, NXM-C-508-ONNCCE-2015 (2015)), and other applied techniques are used to recognize the properties of the materials (Love, S. 2017).

Heat capacity is one of the most important variables to be considered in sustainable architecture strategies (Adrian et al., 2013). It basically refers to hygrothermal welfare conditions in the interior, but from the point of view of its equilibrium relation with the conditions of air temperature and relative humidity of a given place. (Hubbart et al., 2014) in their studies on the characteristic architecture of the world, point out that the main objective of the constructors is the search for the optimum conditions of thermal comfort with poured earth, and they conclude that the constructive typology is defined more by the climatic zones than by the territorial borders, and affirms that even if there are variations, as a result of local traditions or taste, the general form of the native building is born of its relation with the environment. Therefore, the thermal effects of its construction materials and its relation between heat capacity and the temperature distribution within the built-up area correspond to a set of thermophysical phenomena. To that end, (Ouldboukhitine et al., 2014) the properties of materials and their components, which affect the heat exchange between the interior and exterior, conditioned by the climatic modifications produced in the building envelope, and the thermal transformations that result from the interaction of the interior environment with the internal enclosures of poured earth.

Understanding that the thermal characteristics of materials are: in first instance the transmittance, to say (Ramaswami et al., 2012) is the heat flow that is conducted through the materials from the outside air to the interior or vice versa, per unit of temperature and per unit area. It does not correspond to materials exposed to solar radiation, which heats its surface, since the heat flow depends on the differences in air temperature on both sides of slab and wall and not the surface. The unit of K is W / m2,000 ° C.

The gain factor is the proportion of incident solar radiation transmitted through the materials when the air temperature is equal on both sides of the material. In this case the heat flux depends only on the incident solar radiation and not on the air temperature, (Hatuka & Saaroni 2013). The proportion of transmitted solar radiation influences the temperature of the material and the heating of air and other interior surfaces. The solar gain factor is closely related to the thermal behavior, either with opaque walls or transparent or translucent walls. Also, the delay (Coseo & Larsen 2014) is the difference between the peak temperature of the outer face of the material and the peak of temperature of the inner face when the materials are subject to periodic temperature fluctuations. The difference arising from the relationship between the interior and exterior temperature range is called thermal damping or decreasing factor, d. The difference in time between the outside or inside temperature peaks is called the thermal delay Ǿ. The thermal characteristics of the materials that determine the delay are conductivity and thermal capacity. Finally admittance is the characteristic of a surface receiving heat from the air or supplying heat to the air under cyclical temperature variations. The admittance is the heat flux in Watts per m2 of surface and by degree of difference of temperature between the air and the surface, W / m2.000 ° C; the same units as K, thermal transmittance, (Futcher et al., 2013).

The exploitation of solar radiation through solar systems of direct gain causes an inevitable increase in the interior temperature. To avoid excessive variations it is advisable to use large admittance surfaces capable of reducing excessive variations. During night time, this same property prevents the excessive fall of the interior temperature, favoring a thermal balance that keeps the interior conditions more comfortable. Likewise, the materials present, through these characteristics, certain values of efficiency that are presented below.

II. Materials And Method

In order to obtain the material, it was made a preparation of earth stabilized with nopal mucilage 10% weight solution in three ways: compressed in a molded with a compaction machine Controls with 60 PUSHING per minute, by separated a mixed and poured in a 15cmx30cm cylinder and other one in the same way but with fiber extracted from *Agave Lechuguilla Torrey*. Fiber was used at a dosage of 50ppm because in previous work it was found as an optimal dosage for earth samples according to M. Ortega-Plaza, et al. 2016.

The determination of the mechanical resistance to compression was performed using the universal machine Controls 2009 in compression mode as well tensile force for fibers. To determine the thermal conductivity of the material was used a KP2867 device with sensor TR-01 from the company Decagon Devices, Inc. At a temperature of 25 °C. The measurement was performed in triplicate for 60 minutes. The determination of ultrasonic wave transit time was performed with an ultrasonic pulse rate meter brand Controls model E48. The linear shrinkage determination was performed using mixes of soil as blank sample and in a separated way, the ixtle metered sample.

III. Results And Discussion

The results obtained from the tests developed are shown below. Figure 1 shows the cracks shown after the contraction and compression test for fiber specimens.

Figure 1.- *Crack visualization of specimens with ixtle for: a) tensile test and b) compression test*

When the test is performed on specimens without fiber, complete disengagement of the sample is observed and the fault is due to the diversion of the charges towards the x-axis of the central diameter of the sample.

	Earth	Compressed earth	Stabilized earth without ixtle	Stabilized earth with ixtle
Heat capacity (°$Cm^{-1}K^{-1}$)	28.920	8.227	3.543	1.935
Thermal conductivity ($Wm^{-1}K^{-1}$)	0.035	0.122	0.282	0.517
Compression resistance ($kgcm^{-1}$)	N/A	1.025	4.857	3.964
Load supported by traction in 30 cm cylinder (kg)	N/A	50.0	450.8	600.8

Table 1. *Values of variables measured of earth and experimental tests.*

Table 1 shows the results regarding the heat capacity and the thermal conductivity of an earth sample. They are placed from left to right from highest to lowest value in terms of the first property that is inversely related to thermal conductivity. In the first case the highest value of heat capacity is displayed and the lowest value for thermal conductivity, which means a short time for the passage of heat through the material. However, this is the case in which it has less utility due to its low utility in terms of the load they can withstand, since the elements are disintegrated or with cohesion values that do not allow to contain load. An increase in the heat capacity as it is compacted is visualized, which reduces the volume occupied by the same amount of mass but increases the mechanical resistance to compression

The poured earth study corresponds to the stabilized earth that presents a lower heat capacity and higher thermal conductivity but a higher value of compressive strength. When the ixtle fibers are dosed, the amount of heat that can be transmitted over time is greater than could be due to the space occupied in the fiber, however, the load value that can be supported by traction is increased.

It can be seen that the fibers have their best effect on the traction of the element which implies a minor crack formation.

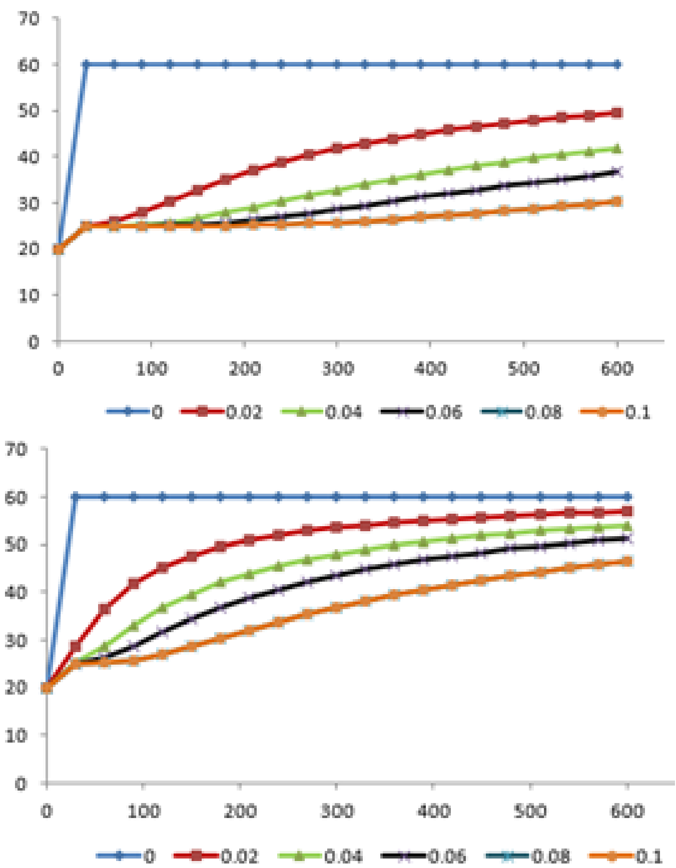

Figure 2.- *Behavior of temperature variation (y axis in ° C) with respect to time (x axis) for different thicknesses in meters for: poured earth (left) and poured earth with ixtle (right).*

Figure 2 shows the results of the behavior of the temperature in correlation to the time for different thicknesses in meters obtained with the model published by Suarez-Domínguez and collaborators in 2014. It can be noticed that there is a shorter time for the sample with ixtle than without it in terms of thermal transmission. Even when an outside wall temperature of 60 °C at 0.1m was assumed, no significant increases were found at the beginning of time. It is important to note that the poured earth walls are usually of thicknesses greater than 0.20 m whereby a much longer time will be expected so that the increase in temperature inside the wall is noticeable, so also the interior temperature can be substantially less. On the linear shrinkage tests, it was found that the earth sample without fiber presents a value of 11% and this is reduced to 9% when the fiber is dosed.

Finally, with determination of transit time in a 15cm sample it was found that samples without fiber takes 450µs while with them value increases 508µs with an error of 5% which means that fiber causes a separation in solid part. Ultrasonic time monitoring was not possible for fibers alone because of its geometry, in the other hand, compressed earth takes 398µs to an ultrasonic wave travel the same length which correlates with the waited less distance among particles.

IV. Conclusion

From the above it is clear that the samples stabilized with ixtle fiber have lower heat capacity but higher thermal conductivity, however the fiber decreases its resistance to compression. On the other hand of the samples without ixtle, it was obtained greater heat capacity but lower thermal conductivity, as well as greater resistance to compression. With respect to the linear shrinkage, it was found that the samples of land fed without fiber present a reduction to the same up to 9%. In a future it is necessary to know the adherence between fiber and solid and to describe the effect into the resistance properties.

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