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EFFECT OF THE ADDITION OF CACTUS MUCILAGE AND FIBERS TO SAMPLES OF POURED EARTH

E.J. Suarez-Dominguez[*], Y.G. Aranda-Jimenez, C. Zuñiga-Leal, A. De Leon-Ramirez
[*] FADU. Universidad Autónoma de Tamaulipas. Centro Universitario Sur. Tampico, Tamaulipas. México.
Edgardo.suarez@uat.edu.mx

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ABSTRACT

Nowadays, poured earth is proposed as a construction alternative in Mexico due to the obtainment of regional materials, additional to being economic to certain geographical areas. There are different types of earthen construction, like adobe, poured earth and rammed earth. At present, the mitigation of emissions due to the production of compounds used in construction is sought, so the use of existing materials around the building could support this. The objective of this research is to present the results of poured earth mixtures with cactus mucilage (in Mexico known as mucilage of nopal) in combination with potassium hydroxide and ixtle fibers in different percentages to obtain their resistance. Cylinders of different mixtures were made and, separately but with a lower water content, tests were carried out with compressed earth block replacing the earth with a mixture of clay soil and other lime. It was found in the different tests carried out that by adding cactus mucilage, the resistance has been increased from 25% to 300%, depending on the quantities used.
Differences of increase in mechanical resistance to compression of 125.46% were found due to the amount of cactus mucilage with dosed organic matter.

KEYWORDS: natural fiber in poured earth, ixtle mixtures, organic increase of resistance.

INTRODUCTION

Modern construction processes and requirements demand that the selection and stabilization of earth for compaction purposes should be quantified (Brurroughs, V.S. 2001). Vertical elements, such as compacted earth walls, have low carbon emissions and are efficient alternatives as load-bearing walls in comparison with the energy content of cement and energy in transportation of materials and that of the actual energy input during compaction of rammed earth under actual field conditions (Reddy, B. V. et al 2010).

Some countries have greater applications of earth-based techniques; the construction of buildings with earth in New Zealand has been used since the 19th century. Despite the initial rise of earth buildings, it was not the preferred building material, giving way to the construction methods for popular housing (Kiroff, L. et al. 2010).

Compressed earth constructions are attracting renewed interest throughout the world thanks to international trusts and "green" characteristics in the context of sustainable development. Several studies have been carried out to investigate this material and evaluate its durability along with its mechanical, thermal and earthquake capacities. (Bui, Q.B., et al., 2011) However, the need for reinforcements that are often not compatible with the blend has been noted.

The suitability of stabilized clay soils for the production of compressed earth blocks for the construction of low cost housing has been investigated (Waziri, B. S., et al., 2013).

In order to pour a liquid earth material, such as concrete, the technologies used by the concrete and ceramic industries can be transferred to the construction field with earth. Two different methods must be used simultaneously: The first refers to grain packaging theories and the second refers to the dispersion of the colloidal fraction of earth materials (Ronsoux, L. et al., 2013).

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The strength and durability of the earth can be improved by the addition of different stabilizing materials such as cement, lime, cement with lime and cement with resins, evaluated both in the laboratory and in real climatological conditions (Guettala, A., et. Al. 2006). The behavior of stabilized earth blocks against sulfate attack has been investigated. They were studied against continuous immersion cycles in water and a solution of sulphate dosed at 3 %, and oven dried (Chaibeddra, S., 2014). This is an important factor to denote because sulfates are commonly a problem in traditional concrete structures.

The mucilage is a viscous liquid that is extracted from the cactus (Opuntia rastrera spp) that has been used vernacularly construction. It is mainly composed of polysaccharides highly soluble in water and can function as a cementant (Ladd et al., 1996). On the other hand the ixtle is the fiber extracted from the agave torrey lechuguilla, from the family of the agavaceae, which are used to elaborate a myriad of products from handmade like belts, bags, fabrics, to brushes, carving fibers, where some of them have some tension resistance (Ortega-Lerma, M. et al., 2016).

In previous works the compressive strength of a type of poured earth made from mixtures of clay, silt and stabilized sand with cement and lime (Aranda-Jimenez, Y.G. et al., 2013) has been analyzed. Compressed earth blocks (BTC) are constructive elements with a high potential to be used in housing constructions in Mexico, mainly because of their similarity with traditional blocks, becoming convenient to improve their characteristics from a stabilizer. In fact, it was found that when adding cactus mucilage there is a significant increase in the resistance to wet and dry compression explained by Aranda-Jiménez, YG (et al 2010).

From the above, in the present work the effects of cactus mucilage in combination with a fiber obtained from a plant and other inorganic components were studied, the modifications in the mechanical resistance were evaluated along with the possible reasons for this.

MATERIALS AND METHODS

Samples with different proportions of materials (champayan, lime, cement, cactus mucilage and potasium hydroxide) were made to measure their resistance to compression using a universal press brand Controls.

These components were used together because they have been shown separately to improve the properties of structural elements used in earthen architecture. The soil called Champayan is present in banks of the region of Tampico, Madero and Altamira in Tamaulipas, Mexico.

For its elaboration, the soil corresponding to Champayan was sieved by mesh # 4, and it was poured in a tray next to the other materials (lime, cement, cactus mucilage, fiber) with their respective previously calculated measures, adding water or a mixture of water and mucilage or potassium hydroxide. The material was thoroughly mixed and then poured into the sample molds according to the percentages marked by groups below.

A cactus mucilage (from Opuntia rastrera.) extract was prepared by taking the cactus cladodes cut into pieces of approximately 5x5 cm, allowing them to macerate in water in a ratio of 1: 9 for 48h, after which it is completely triturated. The obtained mixture is totally mechanically triturated for 5 minutes preserved with sodium benzoate and citric acid. In all cases, 8 specimens were evaluated.

All groups of samples were made from soil called Champayan. The first group (Blank) of samples was prepared by adding 25% of lime in Champayan, with 18% water. The second group (A) was produced in this same proportion but replacing one-fifth of water with mucilage extract.

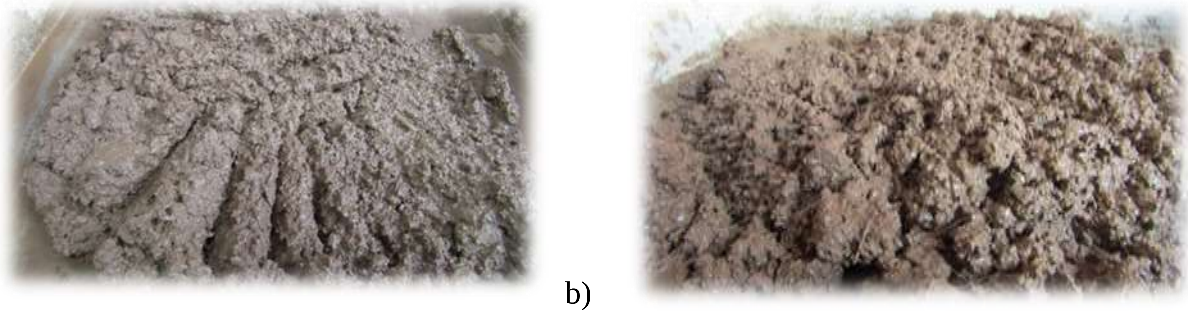
The third (B) group was made by adding 6% cement to the first group. The fourth group (C) was obtained by adding 6% cement to the second group.

From the results obtained it was decided to use, at best, a dosage of 100ppm of additional fiber of the mixture and to note its changes in relation to mechanical properties (D).

As a target sample, a mixture of Champayan soil mixed with water was used.

RESULTS AND DISCUSSION

Figure 1 shows images of the earth mix with mucilage and mucilage and fiber. According to Mexican norm NOM-021-SEMARNAT-AS-09, samples without any extra component had a composition of clay (7.7%), silt (16.9%) and sand (75.4%) and low salt content (less than 100ppm).

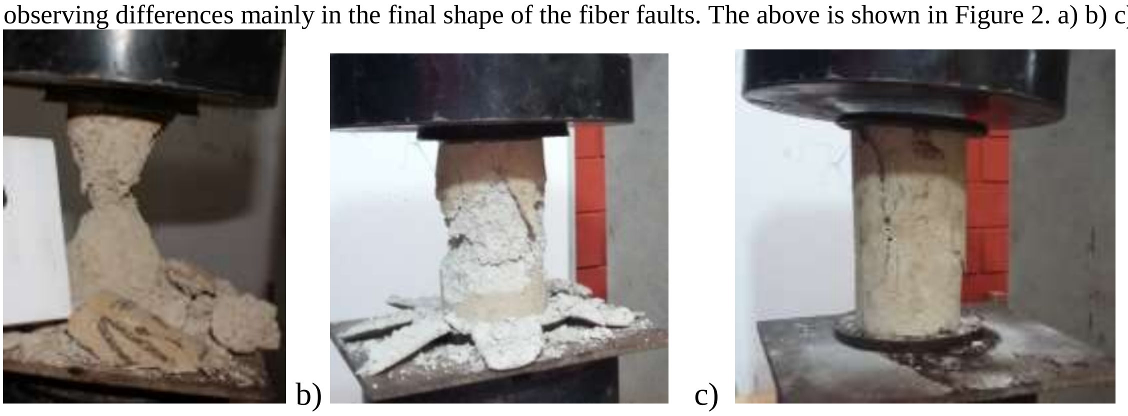


a) b)

Figure 1.- a)Mix of 25% Cal in Champayan, with 80% water and 20% Cactus Mucilage and b) same mix with ixtle fiber.

For the cases in which only lime, cementless or metered mucilage was used, a maximum compressive strength of 6.1 ± 0.8 kg / cm2 was obtained while the mixture of Champayan with water alone had a maximum compressive strength of 3.7 ± 0.8kg / cm2. It is important to note that the same compression strength was obtained for the samples of Champayan with and without lime.

It is important to point out that after the end of the tests, the final physical characteristics of the solid were very different. For samples made with only water, total disintegration of the element was found, whereas those containing lime obtained a higher consistency; Those containing mucilage presented the most uniform cracks without detachment of solids. As will be discussed later, it was decided to add ixtle fiber to all groups separately by observing differences mainly in the final shape of the fiber faults. The above is shown in Figure 2. a) b) c)



a) b) c)

Figure 2.- Samples at the end of test a) of mixtures of Champayan only with water (blank), b) samples with lime and cement and c) mixtures of Champayan with lime, mucilage and fiber.

Table 1.- Results of the analyzed samples. Resistance to flexion presented variations of 5kg.m while the compressive strength was less than 1kg / cm2.

Sample	Flexural strength (kg.m)	Mechanical compressive strength ($kg.cm^{-2}$)
Blank	50.1	3.7
A	58.2	4.0
B	69.4	4.5
C	85.0	6.1
D	225.0	24.5

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Table 1 shows the results in compressive and flexural analysis of this work. For the tests of resistance to flexion, plates of 15 cm x 15 cm x 60 cm were elaborated in triplicate for the four groups of mixture. In turn, the same test was repeated with blends with ixtle fibber. They were left for 28 days before being subjected to the flexural tests. It was found that the mixture with fibber in the best case was the one containing lime, cement bearing a load of 225 ± 5 kg while the mixture without the fibber dosage was 85 ± 5 kg and the one that did not contain fibber or mucilage was Of 50 ± 5 kg (blank). In general it was found that blends with fibber obtained more than 100% increase in flexural strength. For this case, a simple concrete mixture was prepared, based on sand, gravel and cement, with the same dosages of the components, having a result of 54 ± 5 kg, being observed similar to that of the mixture proposed with earth in this work.

When the mixtures were evaluated for their mechanical resistance to compression, it was found that those with fibber presented 7.21 ± 0.99 kg / cm2 while the samples without fibber was 5.92 ± 0.98 kg, which implies that there was no significant difference except for the sample without mucilage, whose resistance was 3.1 ± 0.4 kg / cm2

The deformation of the elements was modified with the dosing of the components. The best effects of components were as follows: the production of poured earth with soil (called Champayan) only with water is the one with the lowest values of mechanical resistance to compression, when adding the other components increases the mechanical resistance to bending. The lime and cement dosage are visualized as those that increase the mechanical resistance to compression. When dosing fibbers of ixtle a greater support of effort in transversal orientation is visualized and they improve the transfer of efforts through the elements studied.
The results presented in the previous paragraphs refer to mixtures where Champayan soil was used, whose characteristics appear at the beginning of this section.

In order to know the effect of the rock in the mixture a sieving with the mesh # 4 was realized. To this mixture was made the combination with lime, sand and solution of nopal mucilage in the same proportions as those exposed for the mixture A6. In this case, it was possible to observe that the value of the mechanical resistance to compression is 11.46 ± 0.8 kg / cm2. This may be due to the presence of rocks inhibiting the interaction of solids, as in the case of clay soils, where cohesion is greater and can be increased with the dosage of stabilizers.

Assuming a possible effect of the content of hydroxyl radicals in the mixture, the content of the hydroxide was increased by dosing certain proportions of potassium hydroxide (KOH). The results of mechanical resistance to compression were on average 20% below the similar samples without potassium hydroxide, probably due to the interaction with the clay and an ion exchange that modifies the stability of the sheets that form in this, however when cactus mucilage is dosed, similar values of compressive strength are found with respect to those that do not contain KOH but a mixture is formed which is more stable, in fact when the final blocks are obtained it is found that they have a greater compactness.
The results and discussion may be combined into a common section or obtainable separately. They may also be broken into subsets with short, revealing captions.

CONCLUSION

When mixing lime and cement, but adding extract of cactus mucilage a difference of 51.9% in its mechanical resistance to compression can be observed, however the latter mixture to which a small proportion of natural fiber is added only increases this resistance up to 6.7%, but within a margin of uncertainty that does not allow to observe if this difference is significant, what if it is for the sample without mucilage and only dosed with lime and cement where it increases up to 75%.

In addition, for the case of the cylinder tests corresponding to Champayan mixtures with lime cement and fibers, it was observed that the failures presented were uniform.

In all cases where potasium hydroxide was used in the mixtures a decrease in mechanical strength to compression was obtained up to 20%, probably due to the interaction with the clay and an ion exchange that modifies the stability of the sheets which are formed in this. However when dosed, cactus mucilage similar values of resistance to compression are found, in relation to those that do not contain NaOH but a mixture more stable is formed; in fact when the final blocks are obtained it is found that they have a greater compactness.

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