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Mechanical Analysis of an Ixtle Based Cable for Its Use in Architecture

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Abstract:*Thegrowing conscience for sustainability has driven humanity to attempt to go back to basic and natural materials, such as the use of earth, and the incorporation of biopolymers and fibers, producing, among other things, a diverse kind of structural elements applied to architecture. Natural fibers can be a good alternative given its abundance and the great number of possibilities in regard to its use.The lechuguilla agave Torrey is a plant, belonging to the Agavaceaefamily, that can be found in several zones of Mexico, and from it, the fiber known as ixtle, generally used in the elaboration of crafted structures, can be obtained.The present paper has studied the stress resistance of the ixtle fibers, of this specie and its qualitative effect when dosed in an earth mixture to be used as mortar for wall coating. The study consisted in stress testing the fibers separately and entwined for its possible use. In the case of the mortar, different samples of clay soils were taken, stabilized and dosed with and without the fiber, observing the effect when used to cover a block surface and determining the material's resistance to compression. It has been found that it is possible to add fibers in mixtures and obtain a greater adherence in the block's surface, besides, it can be added to clay samples for revoke obtaining resistances of 18kg/cm2. Finally it was obtained that by weaving the fibers, the stress resistance can be enhanced by over 600%.*

Keywords: *Ixtle, mechanical analysis, natural fibers.*

I. Introduction

The genre Agave has about 275 species, from which several products are obtained, such as fibers, tequila, etc. Fibers can be classified in natural and man made, among which there are the synthetic and the recycled; among natural fibers are the ones extracted from plants, animals and minerals (Kadole, P. Hulle, A. 2014).Archeological evidence has been found of the lechuguilla fiber being used since hundred of years ago by the mesoamericans, north of Mexico, in the state of Coahuila (Maiti, R. 1995). The lechuguilla fiber is an important source of income for country people of the ixtle regions in Mexico, before it started being substituted by plastic fibers. Belonging to the Agavaceae family, (Narcia V. 2006) this plant is of calcareous soils, so that the calcium is the main nutrient from which it feeds. Approximately from the sixth year on, the buds are removed to extract the fiber, this in regard to the size the fiber reaches.

The lechuguilla is an excellent resource in dry areas, for which its fiber properties should be further investigated so that the loss of the artisanal techniques of extraction, defibrillated and the products elaborated with it is avoided.

The plant is perennial, reaching heights of 50 cms and its leaves are arranged as a rossette and grow up to 4 cm wide, with strong thorns along its perimeter, classified by Torrey in 1859, to whom they owe their name (Narcia, V. 2006) Earth architecture often includes fibers as to increase the flexion resistance (Aymerich, F. et al. 2016) observing a decrease in fractures. Some products used are the chitosán or biopolymers that also increase their compression resistance (Aguilar, R. et al. 2016). An extense variety in the use of fibers can be visualized in the study performed by Laborel-Preneron, A. (et. al. 2016). Not only the fibers can be added but also the plants in different proportions. Diverse are the properties that have been found to modify in the presence of humidity besides its resistance as it was previously mentioned. To determine the optimum quantity of fiber that has to be added it is necessary to perform a series of experiments that depend on the type of constructed element, for example, in the case of adobe blocks, they must be dosed in quantities less than 40% (Calatan, G. et al. 2016). The advantage of adding fibers is that it becomes ecoefficient (Lima, J., &Faria, P. 2016). The dosage of fibers not only has worked for earth architecture but can also be used to produce structures with traditional materials, such as concrete (Afroughsabet, V. et al. 2016), or in an exterior form with bamboo, which we call bamboocrete (Weber, M. O. et al. 2016) presenting a variety of techniques in the use of ecological or natural materials in these type of structures.

Earth architecture stands out because of its thermal delay (Benghida, D. 2016) although polymers can also be used along with some inorganic products in almost every type of soil (Lu, W. et al. 2015; Anjorin, M. et al. 2016). The microcomponents can be used to minimize the amount of energy used (Sardá, R. C., &Pioz, J. 2016). There can also exist a versatility of use even among prefabricated structures for the use of a slab or wall (albuja, V., &Pani, N. 2015). The ixtle is a natural material that can be used in earth architecture, as presented by (Rincon-Ramírez, M. et al. 2016).The fibers can be evaluated by diverse techniques that go from the non-technical tests to the simple observation to the technical tests that include chemical and physical tests. Having the knowledge of the properties of the fibers contributes in knowing how they can be used.The present paper presents the results of studies of the tension resistance of ixtle fibers entwined among each other and without intertwining them, besides the tests performed to mixtures of stabilized clay earth with lime to which ixtle fiber was dosed to consider its use in architectonic structural elements and the interior design of housing.

II. Experimental Part

For the experiments the earth used had as characteristics:

The soil with which the work was made contains 31% clay, 62% fine and 7% coarse aggregate.Material characteristics:The 93% goes through mesh number 4, the 85% goes through mesh num. 40, the 62% goes through mesh num. 200. The liquid limit goes from 27 to 34 while the plastic index is 14.03- The linear contraction is 5.8.On the other hand, the volumetric dry weight and loose was of 1195 and the maximum volumetric dry weight obtained was of 1744.

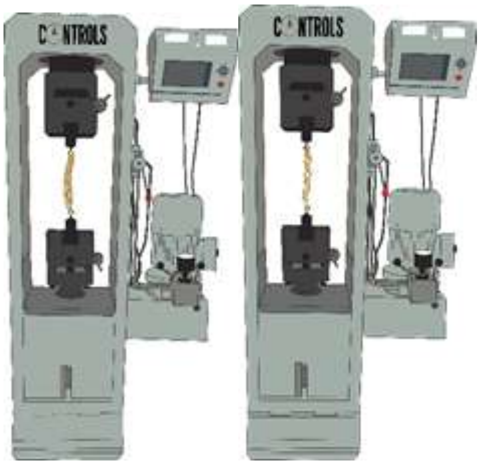

Figure 1. Loose fibers resistance test (left) and entwined (right)

The tests was made with fibers in groups of ten until completing the hundred fibers placed vertically, sustained on both ends.The earth used was stabilized only with aloe in proportions under 2% in weight.The qualitative effects of specimens to which 0.5% in fiber weight was added, were determined. The fiber had different lengths that corresponded to 0.1, 0.5, 1 and 5 times the side length of the plaque. Furthermore, the mechanical resistance to compression was determined 28 days for each of the mixtures according to official mexican norm NMX-C-486-0NNCCE-2014.

III. Results And Discussion

The results obtained are shown in Table 1

Table 1.- Test results of generated palm specimens. The variation of results is of 2%

	Strain (kg)		
Fiber number	**Entwined**	**Linear**	**Increase (%)**
10	380	50	660
20	400	110	264
30	510	240	113
40	530	330	61
50	550	390	41
80	610	490	24
100	810	580	40

The results obtained, regarding tension resistance, are presented on Table 1. They show that as the fiber number is increased, even though they're not entwined, the difference in the resistance values decreases. When having an entwined system of 10 fibers, that offer a diameter of approximately 4 mm. The previous statement has several implications. For example, fibers can be used inside elements that have to endure tension. In this case, biodegradable tests for 6 months were made without finding any changes in the results of tension resistance. Neither did a fungus formation or bacterial growth was found. Afterwards, mixture preparations of earth with ixtle fibers in differents lengths were made. The effects of adding fibers in a 14 day period after being prepared and dried in room temperature were visualized.It was found that when fibers longer than 7 cm are cut they can no longer adhere, but if they're cut in a diameter of 3 cm or less than this, a better adherence of the fiber is achieved, besides having less cracking as compared in Figure 1a 1b and 1 c.

Figure 1. Photographs of the test and results obtained in the mixture made with fiber cut to a length of 7 cm

About compression it was found that mixes without fibers present a compression mechanical resistance of 12kg/cm2, when it is added mucilage it increases to 14kg/cm2 and when it has fiber it goes to 18kg/cm2.

IV. Conclusion

It can be concluded that the intertwined of the fibers increases tension resistance of the fibers in over 600%. On the other hand, it has been found that, with earth mixtures, by adding shorter fibers, the number of cracks presented decreased considerably, in relation to the samples without fiber.Qualitatively, a different interaction was observed depending on the length of the fibers, possibly because of the entwinement between them. Has a degrading resistance without presenting any physical alteration after 6 months, even when being exposed to conditions of degradation, but it is necessary to do further research in quantitative determinations regarding its mechanical resistance.

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