INFLUENCE OF THE ADDITION OF LIME ON A MATRIX EARTH REINFORCED WITH COCONUT FIBER

GUIDO ERNESTO FERRİN FERRİN\(^1\) and JOSÉ LUIS GALARZA VIERA\(^2\)

\(^1\)Universidad Técnica Particular de Loja, Loja, Ecuador
\(^2\)Departamento de Arquitectura y Urbanismo, Universidad Técnica Particular de Loja, Loja, Ecuador

The present research is based on improving the stability, resistance to moisture degradation and fire resistance of molded soil blocks for use in housing construction. The main objective was to include fibers obtained from the shell of the coconut fruit and slaked lime. The methodology includes a prior characterization of the materials using the Eades and Grim method (ASTM D6276), density test, Atterberg limits and granulometric study; and then combine the fiber and lime into a local soil matrix. It is then subjected to water absorption and erosion tests, and is also subjected to direct fire. The results reveal that the additions of 0.5% fiber and 7% lime showed changes in the weight of the blocks, at the same time improvements in the resistance to water absorption and also good fire resistance. Finally, the results are compared with the scientific literature consulted, in order to correlate them with each other.

**Keywords:** Fibrous, Reinforcement, Stability, Water resistance.

1 INTRODUCTION

Raw clay is a sustainable building material; However, it has low resistance to water erosion. A matrix is proposed that contains soils extracted from a sector that is dedicated to the production of blocks with cooked and raw clay, with a reinforcement made of coconut fiber extracted as waste from a beverage and food production process; The main objective is to use residual materials from the site, adding calcium hydroxide as a cementitious stabilizer and natural fiber inside a clay specimen. It begins with the study of the physical properties of the materials, then the effects of the addition of slaked lime within compounds with a clay matrix are analyzed, then it is reinforced with coconut fiber after cleaning treatment, based on the study of Maubec et al. (2017). Finally, the degree of disintegration caused by water and the resistance to fire are measured through tests of water absorption, erosion, density alteration and exposure to a created fire (Danso and Manu 2020).

2 METHODS AND INSTRUMENTS

The methodology used is experimentation based on the scientific method, begins with the physical characterization of the materials in their natural state through *Eades and Grim* method (ASTM 2019), and then the elements are characterized through density tests changes, water absorption by capillarity and immersion, erosion and fire resistance. Finally, an application of the comparative method for analysis of results and later the conclusions and suggestions.
The instruments used to measure weight are Camry EK5055 Scale, XY3000-2C Electronic Scale. The Quincy Lab oven for drying, a manufactured liquefied gas torch, among other measuring instruments such as electronic calipers (see Figure 1).

![Figure 1. (a) Electronic scale model XY3000-2C, (b) Quincy Lab oven (c) Sieves.](image)

### 3 MATERIALS

#### 3.1 Soils

The soil was obtained from the sector called Las Guaijas here operate adobe and CEB’s factories canton of Santa Ana-Manabi-Ecuador (X: 570.553; Y: 9.866.716), the sample was obtained at a depth of 3 m below ground level. The sample was completely dried in an oven at a constant temperature of 180°C for 24 hours, then stored at room temperature. The tests and measurement of the Atterberg limits were applied (see Figure 2).

![Figure 2. Soil recovered from Las Guaijas quarry.](image)

#### 3.2 Coconut Fibers

The coconut fiber used is from Portoviejo canton, Rio Chico place (X: 562.924; Y: 9.891.114). The fruit peel is the waste of the fruit once it is marketed, then the interior liquid of the fruit is extracted, for this reason the color of the fruit peel and therefore of the fiber’s changes to brown. The coconut fibers were obtained from the middle fibrous layer of the coconut and separated from the upper hard shell manually by sinking the fruit into a spike to split it (husking) (Soundara and Senthil Kumar 2015), then they were mechanically separated following a manual process and cut into lengths of less than 50 mm (Danso and Manu 2020), after which they were subjected to a
moisture content test according to López et al. (2013) and the apparent density of vegetable fibers according to Moreno et al. (2007). (see Figure 3).

![Figure 3. Coconut fiber recovered from Río Chico quarry.](image)

3.3 Calcium Hydroxy (Lime)

Calcium hydroxide (slaked lime) and the specific products derived from it are obtained through an industrialized process of calcium oxide hydration ($\text{CaO} + \text{H}_2\text{O} \rightarrow \text{Ca(OH)}_2 + \text{heat}$). The product was obtained from a local store.

4 PROCEDURES


4.1 Lime Addition

A sample of dry or humid soil is taken, weight = 2 kg and stored in a hermetically closed plastic container. Then sieve the sample in a mesh # 40 (425 µm) trying to break up the lumps manually so that the greatest amount of material passes through.

A series of samples of 20 g each were set aside and placed in equal bottles with screw caps. Another series of lime samples with equivalents of 3, 5 and 7% of the weight of the soil sample was set aside. Then, the percentages of soil set aside are added to each bottle; 100 ml of drinking water was added; shaking vigorously for 1 minute in 15 to 20-minute series for 1 hour. Finally, the pH of the obtained solution was measured with the help of a pH paper.

4.2 Density Test

The dry density of the samples was determined following the procedure described by BS EN 771-1. The specimens were dried in an oven at 160°C until constant mass was obtained, then they were weighed and their dimensions were recorded to calculate the volumes. The density of each specimen was determined with Eq. (1).
where $\rho$ is the density in kg/m$^3$, $m$ is the mass in kg and $V$ is the volume in m$^3$.

### 4.3 Water Absorption Test

The water absorption was determined by the capillary method\(^1\) guided by the BS EN 772-11 standard. An electronic scale and a metal container with water were used. The weight of each oven-dried specimen was measured. The face of the specimen was immersed to a depth of 5 mm in water, for ten minutes, and finally the weight of the sample absorbed was recorded (Eq. (2)).

$$C_{w,s} = \frac{mt-mo}{\rho_AVt}$$

where $C_{w,s}$ is the coefficient of water absorption by capillary (kg/(m$^2$ x min)), $mt$ is the wet mass of the specimen after $t$ (kg), $mo$ is the initial dry mass of the specimen (kg), $A$ is the area of specimen in contact with water (m$^2$) and $t$ is the time (min) (Danso and Manu 2020).

### 4.4 Erosion Test

The erosion test used the Geelong method following the New Zealand standard NZS4298 (2020). A glass container with 100 ml of water, which drops through a 16 mm hose and a cylindrical probe with a final diameter of 3.15 mm towards a support plate located on the floor at an angle of 30°. It is placed on the plate at a height of 400 mm for 60 minutes (Danso and Manu 2020). Finally, the percentage difference in mass between the sample when it is dry and when it is wet is measured.

### 4.5 Fire Resistance Test

The fire resistance test used cubic specimens with an edge of 50 mm. The specimen was placed on a metal grill and below, a candle as a constant source of fire and heat, the distance between the sample and the flame is 1.5 cm. The test has a maximum of 60 minutes, unless the failure occurs earlier. The moment when punctures, cracks or collapse of the specimen occur should be observed (Official Chilean Standard 1997).

### 5 RESULTS

Below is a series of specimens, containing soil + lime, and also soil + lime + coconut fiber (CF) in groups of three test tubes, which were subjected to tests for water absorption, water erosion and fire resistance.

#### 5.1 Water Absorption

The water absorption behavior by immersion and capillarity tests shows that the addition of coconut fiber (CF) + soil and lime are greater than >1.5 and increase in percentages of 1 with an eccentric indicator of 3.64. The soil + lime specimens present higher percentages > 1.5, this being; the lower and eccentric indicator. The results differ from Danso and Manu (2020), which have a tendency of decreasing absorption as the greater amount of cementitious is added (Figure 4).

\(^1\) Determines the speed at which water is absorbed by a material.
5.2 Erosion Test

The erosion test shows low resistance indicators, in the case of soil + lime from 6.18 to 9.78 and in the case of soil + lime + CF it increases from 8.05 to 10.36, generating a trend that implies greater erosion in the specimens that do not contain fiber. In the case of Danso and Manu (2020), no erosion is observed. The results are shown in Figure 5.

5.3 Fire Resistance

The fire resistance test for soil + lime gives figures between 37 and 43 minutes, and soil + lime + CF indicates 54 to 59 minutes; which classifies the two groups of specimens as F30 as shown in Figure 6.

6 CONCLUSIONS

- In the fiber + lime additions, greater water absorption was evident, a similar resistance to erosion with and without fiber, and fire resistance was optimal.
- In comparison with Danso and Manu (2020) where cement was added to the analyzed matrix, the present results differ from those previously mentioned since in these tests it was observed that the specimens only had small notches on their surface, that is who did not suffer significant damage when subjected to this test.
- In the absorption of water by capillarity, the soil with lime recorded improvement, while the test tube containing soil, lime and fiber showed low values. In the immersion test, a change in slope is observed in the graph, which is deduced to be due to an error in the laboratory.
- In the erosion test, those specimens that contain fiber show greater resistance, possibly caused by the decrease in soil and lime in relation to the total volume, as well as the presence of fiber.
- Regarding fire resistance, it was observed that the addition of fiber did not imply an increase in combustibility in the test piece, resisting between 54 and 59 minutes. However, the control specimens had lower resistance. This could be studied in the future in terms of fiber protection using calcareous stabilizers.

References

López, L., Sarmiento, A., Fajardo, J., Valarezo, L., and Zuluaga Gallego, R., Determinación del Porcentaje de Humedad, Solubles e InSolubles en Agua de la Fibra de Carludovica Palmata (paja toquilla), Ingenios, 9, 2013.