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Mechanical Properties of a Cement Mortar Reinforced with Arundo donax L. Reeds

[Clara E. Ferrández-García, Teresa García-Ortuño, Javier Andreu-Rodríguez, Manuel Ferrández-Villena and Maria T. Ferrández-García]

***Abstract*— The lack of technical information on the use of local building materials has driven the consumers to use industrializad construction materials. There is a lot of research on manufacturing concrete reinforced with agro-residues such as: coconut shell; sisal; sugar cane bagasse; bamboo; jute; wood; hemp; and bananama). But the fibre most used to reinforce cement has been the bamboo species. The giant reed (*Arundo donax* L.) is a plant with a hollow stem that resembles a bamboo. The purpose of this study was to use giant reeds to reinforce cement mortars in order to provide some technical data on the traditional building uses of this plant, and to manufacture a new product based on the ancient mediterranean building techniques.**

***Keywords*— Giant reed, cement mortar, compressive strength, flexural strength.**

I. Introduction

There is much interest in finding non-pollutant building materials and manufacture processes that require less energy for sustainable building. In the last decades, researchers and the building industry have been using materials with vegetable fibres. Moreover, a particular research trend has been directed towards the recovery of the tradicional building techniques using ancient natural materials like adobe, straw, hemp, and bamboo. A natural material is the one that consumes less energy since it is obtained until it is disponed of at the end of life, assuming that the environmental cost of its transport is low [1] .

The lack of technical information on the use of local building materials has driven the consumers to use industrializad construction materials. There is a lot of research on manufacturing concrete reinforced with agro-residues such as: coconut shell; sisal; sugar cane bagasse; bamboo; jute; wood; hemp; and banana) [2]. But the fibre most used to reinforce cement has been the bamboo species [3 - 10].

Giant reed (*Arundo donax* L.) is a plant that has been traditionally used in the countries surrounding the Mediterranean sea as a building material. In Spain it was used as a building element in housing until the 1960´s. It is considered a durable material since it can be observed intact in floor and ceiling slabs in buildings from the 18th century.

Clara E. Ferrández-García
Teresa García-Ortuño
Javier Andreu-Rodríguez
Manuel Ferrández-Villena
Maria T. Ferrández-García.
Escuela Politecnica Superior de Orihuela. University Miguel Hernández de Elche Spain ,

The giant reed is the biggest grass of the mediterranean countries (reaching 9 m of heigth). It can be considered as a green building material due to its characteristics: it is an annual plant; it can reduce energy consumption; it can mantain natural resources; it can reduce the contamination and thus keep a healthy environment. According to Spatz [11] it posseses good mechanical properties. During the maturation of the stems the cellulose gets lignified, improving the stem stiffness and the strength under compression. Besides, the stems have silicon cells and poliphenols that reduce the presence of decay. Some researches have investigated the feasibility of using A. donax to elaborate insulating boards [1], eco-friendly starch-bonded panels [12], for biomass production, etc.

The objective of this study was to provide information on the feasibility of using giant reeds as a low-cost reinforcing material for cement mortars.

II. Materials and Methods

A. *Materials*

The material used as a reinforcement was the giant reeds with an average diameter of 25 mm. The material to form the matrix was Portland cement CEM II/A-P-32.5, and sand particles measuring less than 0.25mm with a humidity content below 10%, and water.

One year old culms were obtained from a factory and were kept outside for air drying for another year until they reached an 8% of relative humidity.

B. *Methods*

The ratio of the cement mortar was cement: sand : water 1: 4: 0.6. (based on the weight of each component).

In order to evaluate the mechanical properties achieved by reinforcing the mortar there were performed strength tests under compression and under flexion. The Spanish standards for testing concrete and mortars were used.

Seventeen samples measuring 10x10x10 cm were formed in a cubic mold for the compression test as it can be seen in Fig. 1. First the mortar was added to the mold, then it was vibrated, and finally three reeds of 10 cm length were placed inside of twelve of the samples. The other five were left without reeds for comparison purposes.

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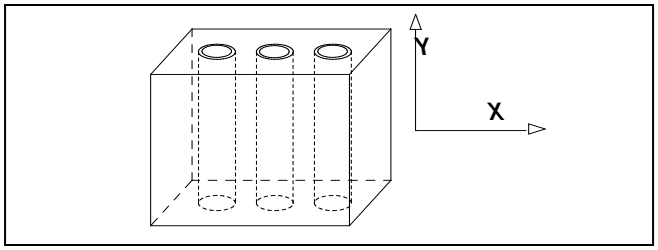

Figure 1. Sample prototype

Twenty-six beams measuring 400x100x70 mm were made (see Fig. 2.) in a mold following the same procedure as before. This time eighteen beams contained three pieces of reeds and eight were left only with mortar for comparison purposes.

The beams were tested after seven and twenty-eight day-period of curing according to the Spanish Standards of Cement.

Figure 2. Specimens for compression (above) and flexural (below) tests.

III. Results and Discussion

A. *Compression Strength*

The tests were carried out by applying an axial force in the direction of the X and Y axis of the samples. The maximum tension value obtained in the stress-strain curves was taken as the compression strength. The average values obtained after testing can be seen in Table 1.

The results of the compression test showed that the addition of the reeds reduced the density of the mortar almost a 9% , and the compression strength decreased a 15% in the Y direction and a 45% in the X direction. The modulus of elasticity did not show statistical significant differences.

TABLE I. AVERAGE VALUES OF PROPERTIES MEASURED AFTER 28 DAYS OF CURING

Materials	Density [kg/m^3]	Compression strength [N/mm^2]	Modulus of elasticity [N/mm^2]
Cement mortar-Arundo direction Y	2065 (23)[a]	25.79 (1.08)[a]	9469 (45)
Cement mortar-Arundo direction X	2046 (43)[a]	14.79 (1.18)[b]	8892 (850)
Cement mortar	2255 (2)[b]	30.33 (2.07)[c]	9833 (998)

Values in parenthesis are standard deviation.

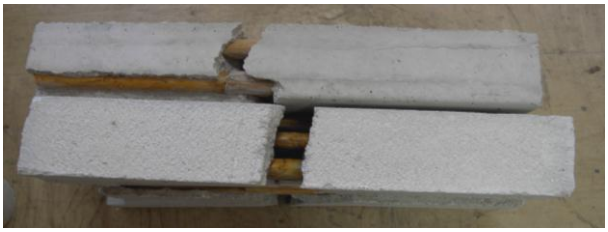

Figure 3. Displacement of the reeds produced due to a bad adhesion

B. *Flexural Strength*

A continuous load was applied and the tests finished when the adhesion between the reeds and the mortar failed, provoking a displacement of the reeds as can be seen in Fig. 3. this is due to the waxy tissue that the reeds have in their outer layer of dermis.

Fig. 4 and 5 show the stress-strain curves obtained during the flexural tests after 7 and 28 days of curing, respectively. The maximum value of strength achieved was taken as the flexural strength.

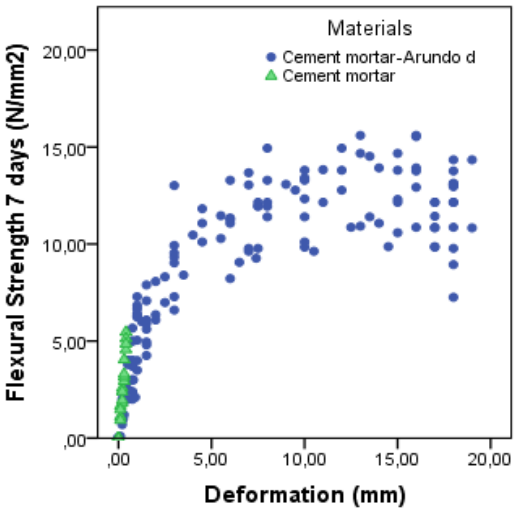

Figure 4. Stress-Strain curves obtained in the flexion tests after 7 days of curing

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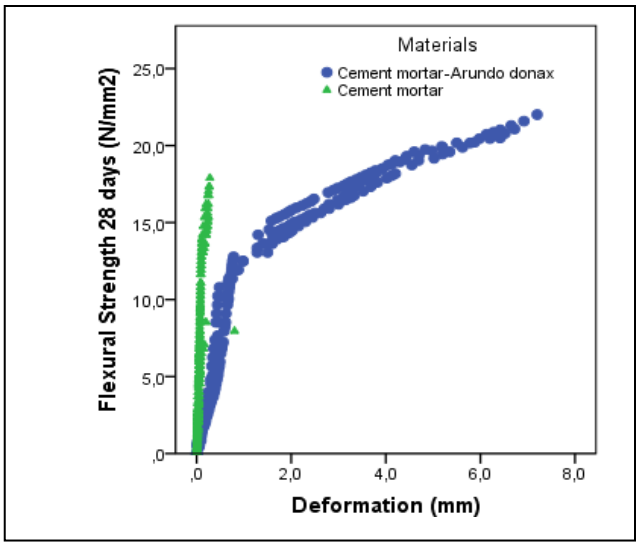

Figure 5. Stress-Strain curves after 28 days of curing

Table II shows the average values of the flexion parameters: modulus of elasticity (MOE), modulus of rupture (MOR), and density.

It can be observed that the density decreased with the use of the reeds in a 15.84 %. After 7 days of curing, the addition of the reeds increased the bending strength (MOR value) in a 157.28%, and the MOE value decreased an 87%. After 28 days of curing, the MOR value for the reinforced mortar is 21.21 N/mm^2, and the value of the cement mortat without reinforcing is only a 28.78 % inferior (16.47 N/mm^2). The MOE value decreased when using reeds in a 67.7% in comparison with the mortar without reeds, becoming an elastic material.

Materials	Density [kg/m^3]	MOR 7 days [N/mm^2]	MOE 7 days [N/mm^2]	MOR 28 days [N/mm^2]	MOE 28 days [N/mm^2]
Cement mortar-*Arundo donax* L.	1897 (78)	12.89 (1.83)	5,449 (559)	21.21 (0.74)	6,254 (449)
Cement mortar	2253 (29)	5.01 (0.38)	41,812 (1192)	16.47 (1.03)	18,779 (502)

TABLE II. AVERAGE RESULTS OF THE FLEXION TEST AFTER 7 AND 28 DAYS

Values in parenthesis are standard deviation

IV. Conclusions

Arundo donax can be considered as a low-cost material to reinforce cement mortars to elaborate beams for slabs, achieving strengths of 21.21 N/mm^2. It has been observed that this kind of beam does not collapse, even when the mortar cracks the reeds continue working, keeping the slab in its place.

The adhesion between the reeds and the mortar should be improved. In order to do this it could be useful to remove the outer layer of the reeds that contains wax.

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About Authors:

The authors are members of the group of investigation named “Building materials from vegetable residues”. They are all doctors and teachers at the Higher Polytechnic School of Orihuela, University Miguel Hernández of Elche, in Spain. They have been working with Giant reeds and other lignocellulosic materials like palm trees, Mulberry pruning wastes, and cereal stalks since 2003.

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