Production of Structural Type Mortars

Reinforced with Coconut Fibre

(Coconuts nuciferas)

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Abstract

In this research, the effect of flaxseed oil and paraffin oil as hydrophobic substances used for the protection of coconut fibres against the alkaline medium of cement in structural type mortars was studied. Mortars reinforced with coconut fibre were mechanically characterized by compression and bending tests, which were carried out 7, 21 and 28 days after processing, varying the length (1, 2 and 5 cm) and the percentage by weight of the fibre (0.5 % and 1 % by weight). The results showed that after 28 days, the paraffin-coated coconut fiber reinforced mortars, 1 cm long and 0.5% by weight, obtained the best results with an increase in their compressive and flexural strength by 84.27% and 43.32% respectively, compared to the unreinforced mortar.

Keywords: Mortar, coconut fiber, compressive strength, flexural strength

1. Introduction

Natural fibers can be used in composite materials to reduce weight, improve toughness and flexibility, which improves the ductility of relatively brittle cement matrices, increase tear strength and is also very safe during handling, processing
and use [1]. However, the most important factor affecting the large-scale use of natural fibres is their durability. The strongly alkaline conditions of the Portland cement matrix (pH > 12) are mainly caused by the presence of calcium hydroxide (portlandite) and the interactions that can occur between the constituents of the natural fiber and portlandite result in its degradation. One way to counteract degradation and improve the durability of plant-based fiber-reinforced cement mortars is to modify the surface of the fibers using hydrophobic substances that allow them to be coated, protecting them from the alkaline environment to which they would be exposed and reducing the amount of water the fiber can absorb, which will provide stability in the cement matrix [2]. The average chemical composition of coconut wool is: Lignin 42.5%, Cellulose 32.2%, Pentanose 14.7%, Saponifiable fats 5.1%, Unsaponifiable fats 0.7%, Ash 3.5%, Proteins 1.2% [3]. In this work, structural type mortars reinforced with coconut fibre were developed in order to determine the influence of the protective substance, the length and percentage by weight of the fibre on the mechanical properties of the reinforced mortar.

2. Experimental methodology

2.1 Preparation of the fibres

The coconut fibres after extraction were immersed in water for 24 hours. After this time, the fibers were removed to the sun for 3 days, in order to eliminate all possible moisture content. The fibres were cut into lengths of 1, 2 and 5 cm and then dipped in flaxseed and paraffin oil for 24 hours and allowed to dry at room temperature for 24 hours.

2.2. Mortar dosage

The mortar mixes were designed following the methodology proposed by Sánchez de Guzmán [4]. For this, 14.81 kg of Portland cement type I, 10.96 kg of water, 56.88 kg of fine aggregate were used and mixed in a Water-Cement (A/C) ratio of 0.74 for the production of 150 test tubes. Table 1 summarizes the codes used in this work for sample identification. The response variables in this study are compressive strength and flexural strength, which can be affected to a large extent by the length, weight percentage, and protective substance of the fiber.

2.3. Mechanical tests

In order to evaluate the strength of the coconut fibre reinforced mortars, the specimens were subjected to compression and bending tests using a Yueke brand universal testing machine with a head speed of 10 mm/min. Compressive strength tests were carried out under the guidelines of the NTC 673[5] standard, for this purpose, reusable PVC moulds [6] with cylindrical geometry and dimensions of 5.08 cm x 10.16 cm [7] were developed. The bending strength tests were carried
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out in accordance with INV.E-324-07[8], for which rectangular geometry specimens (beams) with dimensions of 4 x 4 x 16 cm were developed. Specimens were manufactured in duplicate and tested at 7, 21 and 28 days.

Table 1. Codes for sample identification

<table>
<thead>
<tr>
<th>Sample coding</th>
<th>Percentage by weight of fibre</th>
<th>Fiber length (cm)</th>
<th>Protective substance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 cm - 0.5%</td>
<td>0.5</td>
<td>1</td>
<td>Paraffin wax</td>
</tr>
<tr>
<td>2 cm - 0.5%</td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>5 cm - 0.5%</td>
<td></td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>1 cm - 1%</td>
<td>1</td>
<td>1</td>
<td>Linseed Oil</td>
</tr>
<tr>
<td>2 cm - 1%</td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>5 cm - 1%</td>
<td></td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Reference sample</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. Analysis and discussion of results

3.1. Compressive strength

There are many factors that would affect the physical and mechanical properties of cement compounds reinforced with natural fibers. These factors can be grouped according to [9]: (1) the type and characteristics of the reinforcing fibers, (2) the nature of the cement matrix and design of the mixture, and (3) the form of the mixture, melting and curing of the compounds. Among these parameters, the compatibility between the fibre and the cement matrix leading to a homogeneous distribution of the reinforcement fibres remains one of the dominant factors influencing the mechanical properties of these compounds. The fiber-matrix compatibility is determined by the chemical composition of the fiber and its surface properties and according to the conditions at the interface, the content of the reinforcement establishes the degree of affectation on the mechanical properties of the compound [10, 11].

Figure 1 summarizes the results of the compression test of fibre-reinforced mortars sealed with paraffin and linseed oil. Figure 1(a) shows higher compressive strength values for paraffin-coated coconut fiber reinforced mortars 28 days after cure than for flax oil coated coconut fiber reinforced mortars. This behavior shows that paraffin more adequately protected the fiber from the chemical and physicochemical point of view, modifying the fiber/mortar interface
producing a lower water absorption capacity. The best compression results were obtained in mortars reinforced with 0.5 % by weight of 1 cm long, paraffin-coated coconut fibres (13.08 MPa). Osorio et al.[12] reinforced concrete with 5% Ca(OH)$_2$ treated bagasse fibers for 24 hours obtaining increases in compressive strength with a 0.5% fiber addition.

As for the length of the fiber, this can affect the way the reinforcement is aligned and arranged. Short fibers are difficult to align, which explains why they are usually included at random. The maximum fibre load and the maximum strength of the reinforced mortar are reached when the fibres are aligned parallel to a unitary axial load. In this case, the greatest resistance was obtained with the short fibers, since they present an isotropic behavior before the mechanical efforts. Fujiyama and his colleagues [13] studied the mechanical behaviour of sisal fibre-reinforced mortars of different lengths, finding that these fibres did not improve compressive strength; however, long-length fibres had a more detrimental effect compared to shorter ones. This can be attributed to a decrease in mortar density, associated with an increase in porosity. Aziz et al[9] stated that a high amount of fiber makes mixing difficult and tends to clump together, generating inadequate adhesion between the fibers and the matrix, which decreases their strength and reduces the workability of fresh concrete, which can result in increased porosity[14, 15]. In addition, the increase in fiber percentage reduces specific gravity and increases water absorption and moisture movement [16].

Figure 1b shows that, for all the cases studied, the compressive strength of flaxseed oil-coated coconut fibre reinforced mortars is lower than that obtained with the control mortar (7.1 MPa). This behavior can be attributed to the low surface protection obtained in the fiber by flaxseed oil, which allowed its further degradation due to the alkaline elements contained in the cement, this could affect the adhesion of the fibers to the cementitious matrix, generating spacings in the fiber/
matrix interface. These spaces decrease the compactness of the cement and thus the compressive strength of the fiber-reinforced mortar [12]. Another possible cause of the low compressive strength of linseed oil-coated fiber-reinforced specimens compared to non-reinforced specimens [17] was the phenomenon of bleeding, which occurs in concrete and mortars with a high water/cement ratio.

3.2 Bending strength

Figure 2 summarizes the results of the bending test of paraffin- and linseed oil-waterproofed fiber-reinforced mortars. A higher bending strength is noted for mortars with paraffin-impregnated fibers (see Figure 2a) compared to those with flaxseed oil (see Figure 2b). This is due to the fact that the paraffin-treated fibers showed good chemical resistance and lower water absorption capacity, while in the fibers treated with flaxseed oil, the fibers showed a great degradation in the presence of the alkaline elements contained in the cement, which caused the adhesion between the fiber and the matrix to decrease, making the fiber fragile and therefore decreasing its resistance to bending, as reported by Juarez et al [17]. In Figure 2a it can be seen that the mortars that had the best results 28 days after curing were those that were reinforced with coconut fiber coated with paraffin with a length of 1 cm and 0.5% by weight with a value of 4.12 MPa, higher than the value of the control mortar (3.09 MPa).

![Figure 2. Results of the test on bending strength of fibre-reinforced mortars impregnated with (a) paraffin and (b) linseed oil.](image)

The length of the fibre drastically influences the bending strength, long and continuous fibres can be aligned in a specific direction, however, unidirectional orientations cause poor properties if the load is perpendicular to these fibres[18]. It is for this reason that mortars reinforced with 1 cm and 0.5% by weight fibers, having short fibers, are aligned randomly and show an isotropic behavior to mechanical stresses and thus an improvement in the resistance to bending. Juárez et al [18] found that reinforcing concrete with 0.5% lechuguilla fibers by volume
increased flexural strength and that flexural strength decreased as the percentage of fiber volume increased. Quintero [20] reported that the addition of coconut fiber positively affected the flexural strength; the higher flexural strength value was presented by concrete with a volume percentage of 0.5% and length of 5 cm. The improvement in flexural strength is due to the fact that fibre reinforcements improve the tenacity of the matrix in several ways, as cracks that may appear in the matrix are transmitted to the fibres, absorbing energy and blocking the spread of cracks. A poor bond between the fiber and the matrix can cause the fiber to begin to separate from the matrix increasing the possibility of fractures [19], in which case the crack is forced to propagate around the fiber in order to continue the fracture process. Both processes consume energy and therefore increase fracture toughness. Finally, when the crack in the matrix begins, the unfractured fibers can still form a bridge over the crack, providing compressive stress that prevents the crack from opening [16].

4. Conclusions

Natural fibers such as coconut fiber are a good alternative as reinforcement for the production of structural type mortar, according to the results obtained showed an increase in the compressive and flexural strength of 84.27% and 43.32% respectively, compared with unreinforced mortar.

Paraffin treatment improves the chemical resistance of the fibre, reducing the water absorption capacity and providing good protection against the alkaline medium of the cement. The fibers added in small percentages (0.5% by weight) improve the compressive and flexural strength, since they do not hinder the mixing.

The short fibers (1cm) are aligned at random, presenting an isotropic behavior to mechanical stresses, improving the compressive and flexural strength compared to the control mortar.

References


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