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Use of Curaua Fibers as Reinforcement in Cement Composites

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Nowadays, the worry about the environment is a reality and the development of eco-friendly materials is a challenge. In this respect, increasingly attention should be given to lignocellulosic fibers, regarding both energy conservation and human health protection. The use of lignocellulosic fibers in concrete presents a striking challenge to the affordable housing construction industry, particularly in non-industrialized countries. Lignocellulosic fibers are cheap, are a readily available reinforcement and require only a low degree of industrialization for their processing. The main drawback to use cement composites reinforced with lignocellulosic fibers is that these fibers can mineralize inside an alkaline environment. This is due to the migration of calcium hydroxide to the fiber lumen, middle lamella and cell walls. In order to minimize this problem, 50% of Portland cement was replaced by metakaolin with the objective to produce a matrix totally free of calcium hydroxide. The replacement of Portland cement by metakaolin reduces CO_2 emissions, and increases the durability of the material.
In this work, cement composites reinforced with 6% v/v of curaua fibers were manufactured with five layers of long and aligned curaua fibers, with and without pressure, and were tested. The composites were cured during 28 days, and were submitted to four pointing bending tests in order to characterize their mechanical behavior. The results show that the pressure did not improve the strength of the composites.

1. Introduction

Increasingly attention should be given to lignocellulosic fibers in respect to energy consumption and conservation. Efforts have been made to replace the usual mineral reinforcements, like asbestos fibers, by organic reinforcements such as sisal, sugar cane bagasse, coconut, or other cellulosic fibers [Toledo et al., 2000; Toledo et al., 2003; Aggarwal, 1995, Toledo et al., 1999; Couts, 2005].
The advantages of lignocellulosic fibers include low density, high tensile strength, low cost and the fact that they come from renewable resources. The main disadvantage of using these fibers is that they can be mineralized inside the alkaline environment of cementitious matrices. This occurs owing to migration of calcium hydroxide to the fiber lumen, middle lamella and cell walls [Toledo et al. 2008]. In order to minimize this

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problem, 50% w/w of Portland cement was replaced by metakaolin with the objective of producing a cement matrix free of calcium hydroxide. Also the replacement of Portland cement by metakaolin reduces CO_2 emissions, and increases the durability of the material.
In this work, cement composites were reinforced with 6% v/v of curaua fibers, using five layers of long and aligned curaua fibers. These fibers have been used as reinforcement for polymer matrix composites [d' Almeida et al. 2007, Leão et al., 1998], and are nowadays being used by the automotive industry [Leão et al., 1998]. The effect of the molding pressure was also evaluated and besides a composite manufactured without pressure, composites were also manufactured under a pressure of 3 MPa.

2. Material and Methods

2.1 Material

In the present work, curaua (*Ananas erectfolius*) fibers were used. These fibers are extracted from the leaves of the *Ananas erectifolius* plants, which is a natural occurring *bromeliacea* from Amazon region, Brazil. Fibers as long as 1,5 m can be obtained (Figure 1).

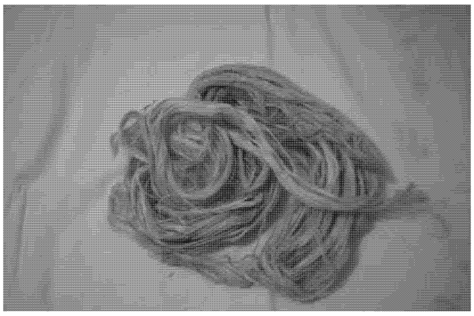


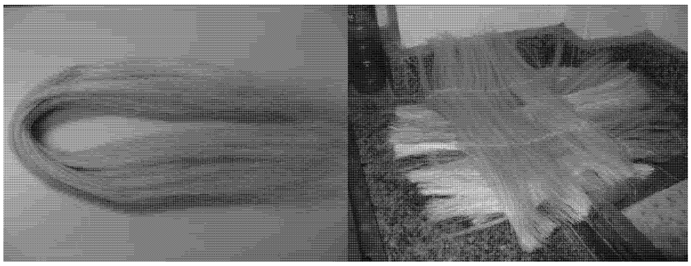
Figure 1 – Curaua fiber.

The Portland cement (PC) used in this study is a commercial type II, code CPII F-32 as defined by the Brazilian standard [NBR 11578], having a compressive strength of 32 MPa after 28 days. The commercial Metakaolin (MK) is manufactured by Metacaulim do Brasil Indústria e Comércio Ltda. The cement composition also comprises river sand with maximum diameter of 1.18 mm and density of 2.67 g/cm^3 and naphthalene superplasticizer Fosroc Reax Complast SP 430, with a content of 44% of solids.

2.2 Methods

2.2.1 Cement composites

The curaua fibers were cleaned in hot water, brushed and then cut into 39 mm length (Figure 2a) and needle worked in order to obtain a tissue like material (Figure 2b).



(a) (b)

Figure 2 – a) Curaua fiber after brushing, and b) The curaua tissue.

The mortar matrix had a mix ratio of 1:1:0.4 (cementitious material:sand:water, by weight). The matrix was fabricated using a bench-mounted mechanical mixer with 20 liters of capacity).The cementitious materials and sand were dry mixed during 30 seconds, and the superplasticizer diluted in water, was slowly poured in the running mixer. A final mixing step was done during 3 minutes in order to homogenize the mixture. For the production of the composite, the mortar mix was placed in a steel mould, one layer at a time, followed by one layer of the unidirectional aligned fibers (Figure 3).

Figure 3 – Manufacture of the composite.

The mold was, then closed and left at rest for 24 hours. After that the composite was removed from the mold and fog cured for 28 days in a cure chamber with 100 RH and 23 ^{o}C. More details about the casting procedures can be found elsewhere (Melo Filho, 2007). During this manufacturing process, the composites were submitted to molding pressures of 0 and 3 MPa.

2.2.2 Mechanical tests

The mechanical properties of the composites after 28 days of setting were determined in a Shimadzu UH-F apparatus with 1000 kN of capacity. Four point bending tests were performed at a crosshead rate of 0.5 mm/min. Three specimens 400 mm long, 100 mm large and 12 mm thick were tested, using a bending span of 300 mm. The deflections at mid-span were measured using an electrical transducer (LVDT) and the loads and corresponding cross-head displacements were continuously recorded using a 32-bit data acquisition system taking four readings per second (Figure 4).

From the load deflection curves, three parameters were calculated to evaluate the reinforcing effect of fiber:

1. The flexural strength of composite (σ_b) – determined from maximum post-peak load.
2. The first-cracking strength (σ_{RC}).
3. The Toughness (T)- calculated as the area under the load versus displacement curve.

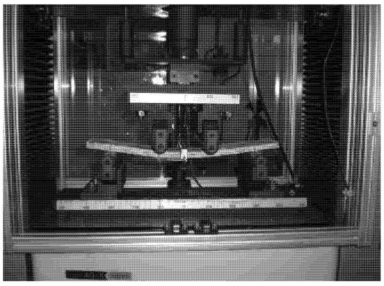


Figure 4 – bending test configuration

3. Results and discussion

3.1 Mechanical tests

The effect of the molding pressure on the four-point bending results is presented in Table 1. Figure 5 presents typical examples of the flexural stress-displacement curves obtained for the cement composites with 0 MPa and 3MPa of pressure.

One can see that the first-cracking strength of composite (σ_{RC}) is in accordance to that observed by Toledo et al. [Toledo Filho et al, 2008]. Besides, the flexural strength (σ_b) of 27.52 ± 2.65 MPa is higher than those obtained by Toledo Filho. In fact, Toledo Filho found a value of σ_b = 19.32 ± 2.07 MPa for a composite manufactured with Portland cement and reinforced by 10% of long and aligned sisal fibers and a value of 17.82 ± 0.66 MPa for a composite manufactured with free calcium hydroxide matrix.

Regarding to the bending toughness parameter, the value obtained in this work (29.13 ± 1.75 kJ/m^2) is higher than those observed by Toledo Filho et al. (22.54 ± 4.39 kJ/m^2) for the composite with the Portland matrix and 21.70 ± 3.36 kJ/m^2 for the composite manufactured with the free calcium hydroxide matrix.

The molding pressure reduced the value of σ_{RC} and the toughness from 27.52 ± 2.65 MPa and 29.13 ± 1.75 kJ/m^2 to 23.70 ± 3.73 MPa and 26.21 ± 1.00 kJ/m^2, respectively. However, a ductile behavior was observed for both composites.

Table 1 Four Point Bending Results

Composites	σ_{RC} (MPa)	σ_b (MPa)	Toughness (kJ/m^2)
0MPa	5.60 ± 1.17	27.52 ± 2.65	29.13 ± 1.75
3MPa	5.13 ± 0.53	23.70 ± 3.73	26.21 ± 1.00

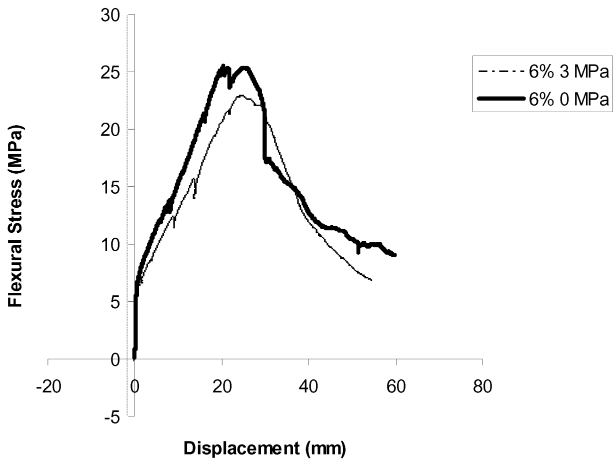


Figure 5 - Effect of applied pressure under bending strength.

4. Conclusions

Based on the results found in the present work it can be concluded that the composite reinforced with 6% curauá fibers and submitted to 3MPa pressure presented a reduction in flexural strength. In fact, for this composite the results obtained show that it is not necessary to apply any pressure.

The use of a matrix with a low content of cement and vegetable curaua fibres is a promising technique for developing sustainable materials to be used by the construction industry.

Acknowledgement

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