ANALYSIS OF FIBER-CONCRETE INTERFACE IN CEMENT MATRIX COMPOSITES

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Abstract
In the present work, the properties of fiber-cement interface were evaluated in order to enable the use of continuous glassfiber-AR (alkali resistant), replacing steel bars often used in concrete structures by civil construction industry. Pull-out tests were applied in a continuous glassfiber-AR (alkali resistant) reinforcement element. The fiber was 250 mm length and it was inserted 50 mm in a cement matrix specimen whose dimensions are 100 x 100 x 100 mm. The bond strength values were compared to concrete specimen that was manufactured corrugated steel bars. Preliminary results identified an increase of 41% in the fiber-cement bond strength value by using glassfiber – AR when compared to steel bar and cement matrix composites.

1 Introduction
One of the applications of composites in civil construction regards the recovery of structures which suffer continuous action of aggressive agents, like acid rain for example, and/or when they are submitted to a load that is beyond the strength limit they have been designed for, which might be a consequence of the alterations on their initially proposed characteristics, [1]. However, studies on structures of cement matrix composites with continuous synthetic fiber have been barely related in the literature, [2].
In the present work, the properties of fiber-cement interface were evaluated by manufacturing concrete specimens of 100 x 100 x 100 mm with compression resistance (f_{ck}) of 29 N/mm² at 28 days, as illustrated in Figure 1.

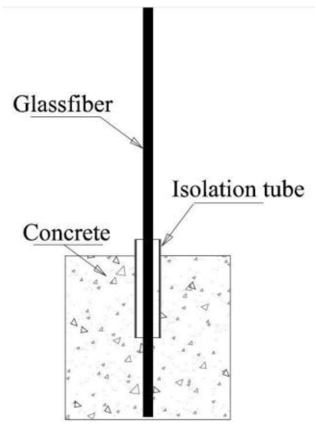


Figure 1. Fiber-cement composites specimens to pull-out tests.

Continuous glassfiber-AR (alkali resistant) rod, 250 mm length, was prepared and inserted 50 mm length in the concrete block. The several specimens were submitted to pull-out tests and the bond strength values were compared to the results obtained in concrete steel bars specimens which are daily used in civil construction, also obtained in pull-out tests.

2 MATERIALS AND TESTING METHODS

2.1 Concrete matrix

Conceptually, a composite material allows the engineer to quantify the percentages of each mixture component in order to create a new material for every application need considering the applied load and its effects. In other words, the calculus engineer can highlight some desirable characteristics and minimize other undesirable ones through a calculated combination of components, [3]. The concrete matrix itself is a three-phase composite, which consists of cement, thin and thick aggregates. Its physical characteristics are directly related to the percentages of each mixture component and the necessary water volume, chosen according to the last resistance and geometry of the calculated parts for this work. In the present study, the concrete presented compression characteristic resistance (fck) of 29 N/mm², obtained from the water-cement ratio of 0.53, by using cement proportions type CP – 32, medium washed sand and No.1 gravel of respectively 1: 2.24 : 2.34. Table 1 shows the amounts of each concrete component related to one 50 kg cement bag used to mold the specimens.

Description	**Amount**
Cement	50.0 Kg
Medium washed sand	112.0 Kg
Nº. 1 gravel	117.0 Kg
Water	26.5 Kg

Table 1. Concrete compound with fck = 29 N/mm².

2.2 Glassfiber

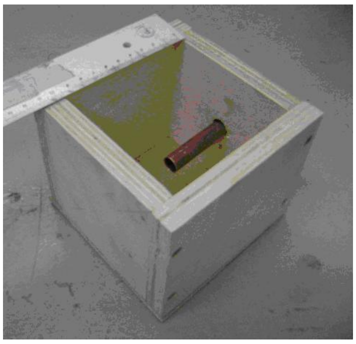
In order to better understand the method, rod is the name given to a fiber length that received a superficial treatment to increase fiber/cement bond and it will react to requiring strengths (internal forces, action effects) in a structural concrete part, [4]. Rods are a composite material of two components: the glassfibers, which do not suffer plastic deformation, and the matrix, which keeps the fibers parallely bonded. The rod was manufactured with 9 single fibers together, 250 mm length each. The physical characteristics of glassfiber and rod are shown in Table 2. The rod molding polymeric matrix was obtained through the materials mixture MY750, HY2918 and DY062.

Description	**Value**
Fiber density	2.55 $g.cm^{-3}$
Fiber transversal section	0.96 mm^2
Rod diameter	6.50 mm²
Rod friction area	451.50 mm²

Table 2. Glassfiber properties and rod use.

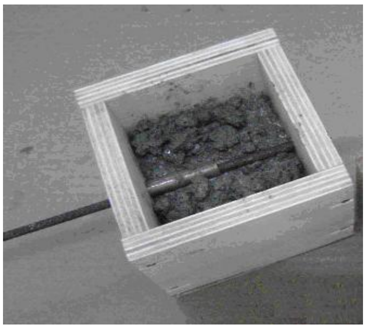
2.3 Specimens manufacturing

Two different kinds of arrangement for manufacturing specimens were prepared. In the single arrangement, a single concrete block was trespassed by a glassfiber rod and in the double arrangement two concrete blocks were fused and kept bonded by the glassfiber rod. The formworks were prepared to fuse concrete blocks measuring 100 x 100 x 100 mm; a plastic hose whose inside diameter was 10 mm was introduced through a hole on the formwork side to isolate the rod in 50 mm from concrete mass, Figure 2. Then, the formworks were filled with concrete in 25 mm layers and manually compacted, Figure 3. The samples were left outdoors for 3 hours, then they were placed underwater in alkali saturated water (Ph 12) and remained there for a 28-day cycle.


a)


b)

Figure 2. Formworks to fuse specimens, highlighting the plastic tube for isolation: a) single formwork; b) double formwork.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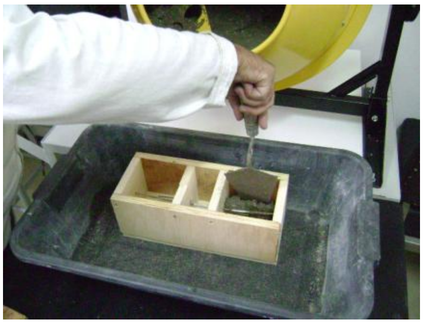
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Figure 3. Manual filling in 25 mm thick layers: a) single formwork with steel bar; b) double formwork with glassfiber.


a)


b)

Figure 4. Samples underwater curing: a) specimens in single formworks; b) specimens in double formworks.

2.4 Pull-out tests

To analyze the interface fiber/concrete matrix, where the reinforcement element consisted of a glassfiber composite rod, two different kinds of metal support were prepared. In order to test specimens with single block, a piece of high density cardboard called Tab was glued to the free tip of the glassfiber rod, which improves fixating the rod to the hydraulic press grip,

Figure 5. For the testing in the arrangement with single block, it was fixated to a metal support and the fiber tip already glued with Tab was gripped by the press, Figure 6. In the double arrangement, each concrete part was placed in a separate metal support to measure the fiber pull-out strength, Figure 7. In the case of pulling out a corrugated steel bar 6.4 mm diameter often used in civil construction, only the single concrete block testing method was used.

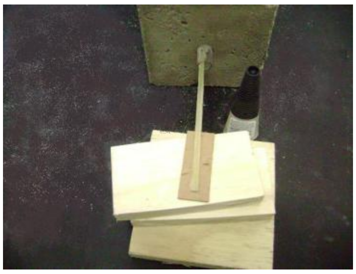


Figure 5. Tab preparation of fiber specimen.

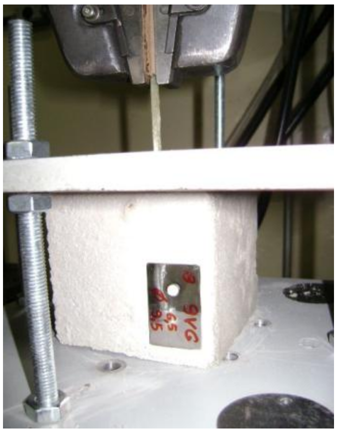
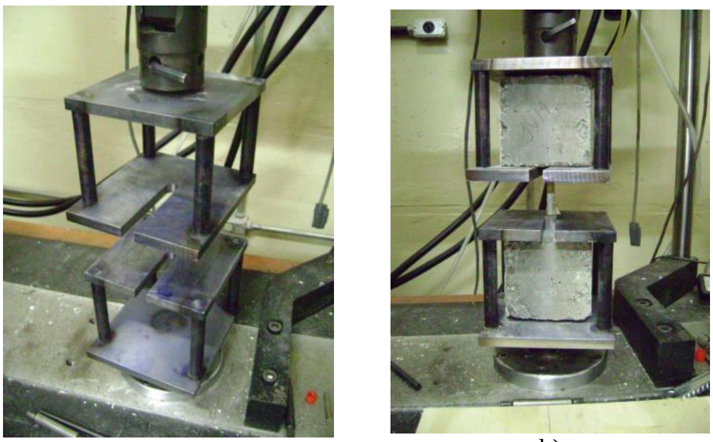


Figure 6. Pull-out test .



a) b)

Figure 7. Pull-out test by using the two-block technique: a) apparatus assembly; b) assembled set for testing.

3 Results and Discussions

Similar results were obtained for the average behavior of glassfiber rod in both testing methods. Concerning the two concrete blocks assembly, the loading up to the rupture point reached the average level of 11,100 N, whereas in the single block assembly, the rupture was at the average value of 10,230 N. The pull-out test of a corrugated steel bar, in the single concrete block testing method, resulted in the average value of 8,000 N. Two relevant aspects were observed regarding the glassfiber rods testing: in the double blocks testing, the rods ruptured out of the concrete block before there was a slide (friction loss) in the interface fiber/concrete; the same thing happened in the single block testing, but in that case, the fiber rupture was next to Tab, possibly due to low resistance to glassfiber shear.

4 Conclusions

Preliminary results showed that composite concrete specimens with glassfiber–AR had a bond strength average value of 24 N/mm², whereas in the concrete specimens manufactured with steel bars the bond strength average value was 17 N/mm², considering the reinforcement and steel bar diameters of respectively 6.5 and 6.4 mm. Based on these results, it is possible to identify a significant increase of 41% in fiber-cement bond strength value by using glassfiber–AR when compared to steel bars and cement matrix composites, ambos com concrete matrix of 29 N/mm² compression resistance at 28 days. However, it is necessary to improve the testing assembly system in order to avoid the rods rupture during loading process. Thus, it will be possible to measure the real friction strength value in the interface fiber/concrete matrix.

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