STUDY ON MECHANICAL BEHAVIOR OF CEMENTITIOUS COMPOSITES PRODUCED WITH MINERAL ADDITIONS AND REINFORCED WITH JUTE FIBER MESH

Ficher Nadine M.(1), Eichholz Emanuele(1), Stefanello, Leonardo (1), Marangon, Ederli(1) Kosteski, Luis E. (1)

(1) Department of Civil Engineering, Federal University of Pampa. Alegrete, Brazil

https://doi.org/10.21452/bccm4.2018.02.12

Abstract

This work aims to study the behavior of cementitious composites reinforced with natural jute fibers mesh by means of mechanical tests. For this, samples were prepared with Brazilian Portland cement, and with replacement of 50% of the cement, on mass, by metakaolin, fly ash and rice husk silica. The study, 35x40x1,2cm size plates (LxCxE) were molded in which five layers of jute fiber mesh were embedded with a 5x5 mm opening. After 21 days of age the plates were cut with a diamond saw in 5x40x1,2cm (LxCxE) samples. For order to obtain the evaluation of the mechanical behavior of the composites bending tests were performed. The use of the fibers directly affected the decrease of the first crack stress when compared to composites without fibers. The reduction of this value, on average, to the reference matrix 69,36%, while the reduction for the substitutions of fly ash, metakaolin and silica of rice husk were, respectively, 57%, 38,32% and 15,89%. On the oder hand, the reduction of the first crack stresses, the addition of the jute fiber was able to overcome the fragile behavior of the cementitious matrix, presenting a strain-softening behavior.

1. INTRODUCTION

Civil construction has been seeking in recent times, along with the other branches of the construction industry, technological innovations that will provide improvements in its most varied areas. The science of materials, for example, is one of the fields that has undergone great evolution. Within this context of innovation in materials science, composites are elements that have gained an important focus, since they have a good resistance to compression, with this they have a wide applicability in the civil construction, like tiles, partitions and wall coverings, in the However they are brittle materials when subjected to traction and loads dynamicase that has small deformation at break. To overcome the brittle behavior and improve the properties of this material in terms of ductility, thus increasing its field of application, it is suggested the combination with another material that has properties capable of absorbing these deformations.

Many authors, such as [1][2[3], investigate the mechanical properties of very different plant fibers available in nature, such as coconut, bamboo, sisal, curauá and jute, mainly due to the fact that natural plant fibers have the advantages of being non-toxic , renewable, recyclable and biodegradable and have a relatively low cost (considered to be one of the greatest advantages over steel fibers, for example).

The use of pozzolanic materials - such as fly ash, metakaolin and rice husk silica - is a requirement when using vegetable fiber reinforcement in cementitious matrices, because they are responsible for consuming calcium hydroxide (CH) during the process of hydration of the Portland cement, the main cause of the degradation of the natural fibers[1][4].

[1] and [5], studied the ideal amount of layers of natural fibrous reinforcement, and the fibers used for the study were jute and sisal, respectively. The authors concluded that the higher the number of reinforcement layers, the greater the formation of fissures and the higher the values of ultimate stress, being 5 considered the ideal number by this study. Jute fiber reinforcement was associated with a partial substitution of Portland cement by 40% of metakaolin and 10% of volatile ash, other percentages of the same additions were studied, which was the one that provided the highest consumption of calcium hydroxide at 28 days . The sisal reinforcement was inserted into a matrix with partial replacement of Portland cement by 50% of calcined clays (metacaulinite and ground brick), which, through microscopy, were also efficient in calcium hydroxide consumption.

Thermogravimetric tests performed on composites reinforced with natural fibers that were submitted to a wetting and drying cycle, proved that the mass substitution of 30% of Portland cement by metakaolin is able to reduce the calcium hydroxide content to zero by controlling the pH of the solution and being effective for the mitigation of the degradation of the natural reinforcements, without damaging the mechanical behavior of the composite [1][6][7].

[4] studied the behavior of sisal fiber reinforced composites, produced with a matrix with 30% partial replacement of Portland cement by rice hull ash, this substitution content was able to mitigate alkaline deterioration and mineralization of sisal fiber, showing that rice hull ash has effects similar to fly ash and metacaulim found in the studies cited above.

2. EXPERIMENTAL PROGRAM

2.1 Materials and processing

In the production of the cementitious composites, was used jute fibers mesh, Brazilian Portland CP V-ARI cement, mineral additions (fly ash, metakaolin and rice husk silica), river sand with a maximum diameter of 1,18mm and superplasticizer in amounts adjusted according to each matrix to maintain the desired workability in the blends (between 250mm and 300mm). The concrete mixtures used for the different matrices were based on previous research [2].

Table 1 shows the proportions of cement (CT), fly ash (CV), metakaolin (MK) and rice husk silica (SL) ratios used in the fourth mixtures that were prepared, namely M1, M2, M3 and M4, respectively. For each matrix, laminates were molded without reinforcement and reinforced with 5 layers of jute fibers. The composites were molded into 35x40x1,2cm (LxCxE) dimensions that after 21 days of curing were cut by a diamond saw in the dimensions of 5x40x1,2cm.

Table 1: Composition of matrixes and composites

Composite	CT(%)	CV(%)	MK(%)	SL(%)	Layers
M1-0	100	0	0	0	0
M1-5	100	0	0	0	5

M2-0	50	50	0	0	0
M2-5	50	50	0	0	5
M3-0	50	0	50	0	0
M3-5	50	0	50	0	5
M4-0	50	0	0	50	0
M4-5	50	0	0	50	5

2.2 Mechanical test methods

After 180 days, the samples were submitted to a three-point flexural test to evaluate the mechanical behaviour of the composites. The tests were performed on the Shimadzu AGS-X mechanical test machine, Figure 1, which has a maximum capacity of 5 kN. The tests were run at a controlled speed of 0.2mm/min with capacity of 5kN.

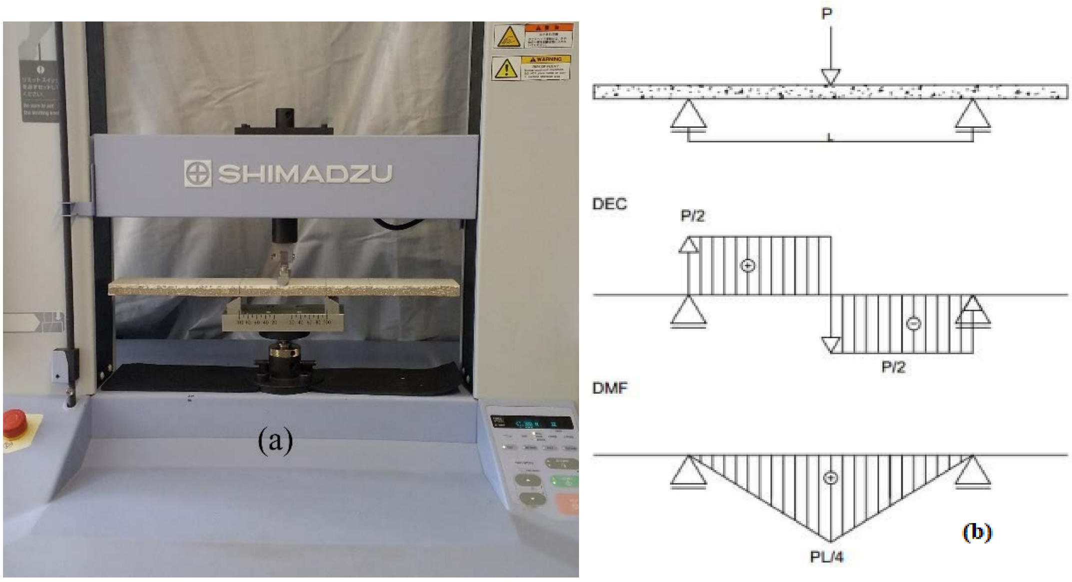

Figure 1: (a) Bending test in progress at Shimadzu (b) Configuration of the behavior of the sample under flexural tests.

3. RESULTS AND DISCUSSION

3.1 Compressive Stress

Compressive tests were performed on the matrices produced, the values of compressive strength, as well as standard deviation and coefficient of variation, are shown in Table 2.

Table 2: Compressive Strength of the matrices

Matrix	*fc(MPa)*
M1	72,68 (±14,8%)
M2	58,61 (±3,19%)

M3	58,44 (±11,96%)
M4	60,51 (±16,34%)

Analyzing the results it is possible to observe that the partial replacement of the Portland cement by mineral additions caused a decrease in the compressive strength of the cement matrix, being a reduction of 24% from M1 to M2, 24.36% for M3 and 20.11% compared with the matrix M4.

3.2 Bending behavior of the composites

In Figure 2 are the values of the average maximum stress reached for each composite produced. Through the analysis of the data, it is observed that the matrices M2-0, M3-0 and M4-0 had a maximum strain reduction around 35% in relation to the composite M1-0. In contrast, it is possible to observe that the composites M1-5 had a greater influence on the maximum peak resistances, suffering a reduction of 69,36% compared to the composite M1-0, while the composites M2-5, M3-5 and M4 -5 were reduced by 57%, 38.32% and 15.89%, respectively, compared to composite references (M2-0, M3-0 and M4-0).

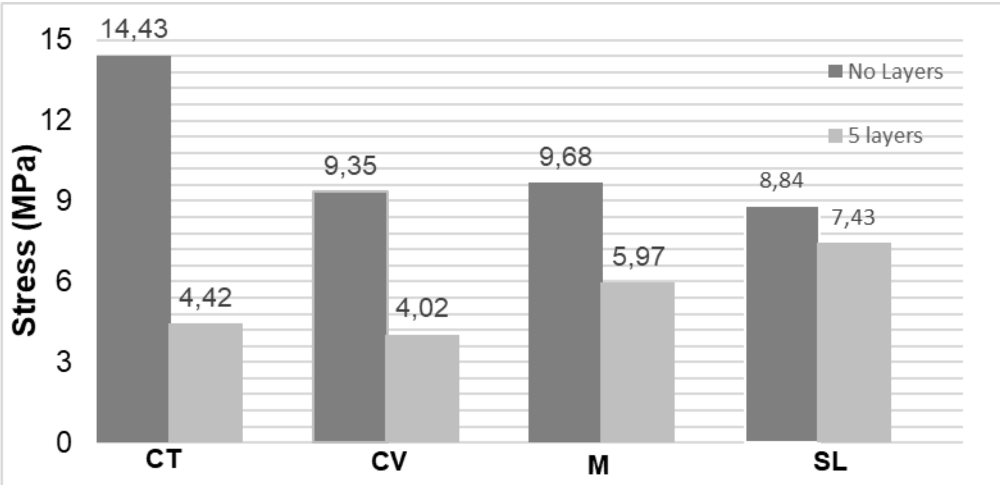

Figure 2: Maximum stresses of rupture of the composites

The typical Stress x Displacement curves of the composites M1-0, M2-0, M3-0 and M4-0 are shown in Figure 3, according to the expected behavior of these composites is fragile, breaking immediately when the sample reaches the maximum breaking strength.

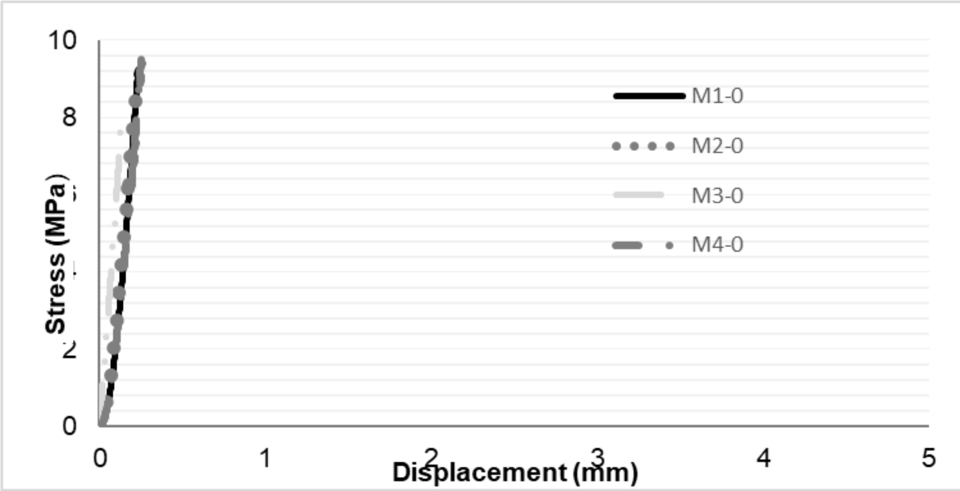

Figure 3: Typical curves of composite behavior without reinforcement

According to the typical Strain x Displacement curves of the composites M1-5, M2-5, M3-5 and M4-5 in Figure 4, the reinforced composites with 5 reinforcement layers when reaching their maximum peak tension suffer a large fall of resistance, but there is no abrupt rupture of the material, thus characterizing *strain softening* behavior. Thus, the mesh used as reinforcement was able to overcome the problem of composite fragility.

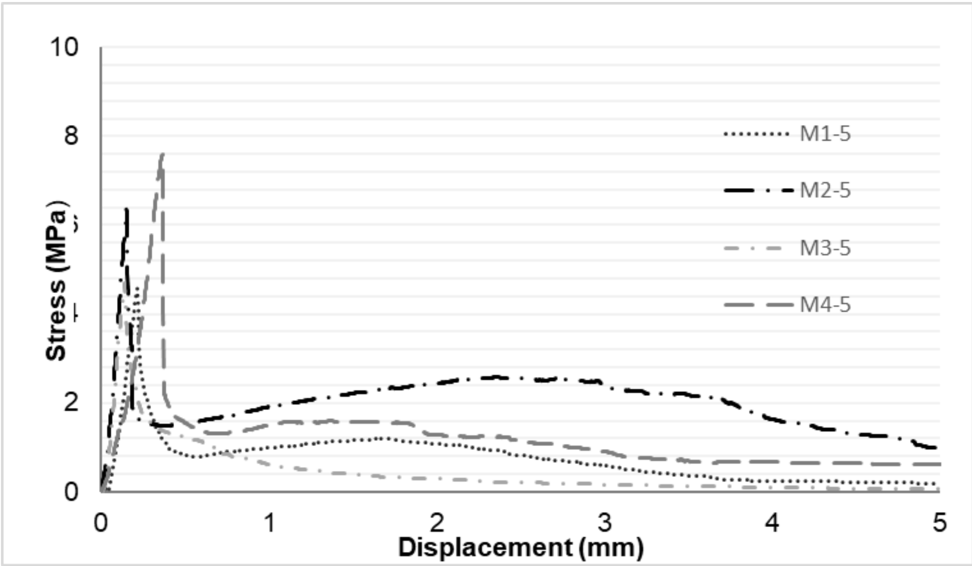

Figure 4: Typical composite behavior curves with 5 layers

4. CONCLUSIONS

- The partial substitution of Portland cement by mineral additions caused a reduction in the resistance of the cimenticeas matrices produced, in both the compressive strength and the maximum tensile strength. The compressive strength losses were 24% for the replacement of fly ash and metakaolin and 20% for rice husk silica, while for tensile the reduction was approximately 55% for the three mineral additions.
- The use of the jute fiber fabric as a reinforcement of the composites decreased the maximum tensile strength of the composites, reaching a reduction of more than 50% in the case of the composites produced with the matrix M1 and M2. The composite M4-5 also presented reduction in the load capacity in relation to the composite M4-0, but in a relatively low value, only 15.89%, in comparison with the other composites.

- It is believed that the reduction of the performance of the composites is associated with the fluidity and viscosity of the matrix used. Possibly, the rheological properties were not adequate to fill the mesh of the jute, impairing the transfer of stresses.

REFERENCES

[1] SILVA, F. A. Durabilidade e propriedades mecânicas de compósitos cimentícios reforçados por fibras de sisal. 2009. 243 p. Tese (Doutorado em Engenharia Civil) – Universidade Federal do Rio de Janeiro, Rio de Janeiro, 2009.Sterman, S. and Marsden, J.G., 'Silane coupling agents', *Ind. Engng. Chem.* **58 (**3) (1966) 33-77.

[2] MELO FILHO, J. A. Durabilidade química e térmica e comportamento mecânico de compósitos de alto desempenho reforçados com fibra de sisal. 2012. 184 f. Tese (Doutorado em Engenharia Civil) – Universidade Federal do Rio de Janeiro, Rio de Janeiro, 2012.

[3] FIDELIS, M. E. A. Desenvolvimento e caracterização mecânica de compósitos cimentícios têxteis reforçados com fibras de juta. 2014. 266 f. Tese (Doutorado em Engenharia Civil) – Universidade Federal do Rio de Janeiro, Rio de Janeiro, 2014.

[4] WEI J. MEYER C. Utilization of rice husk ash in green natural fiber-reinforced cement composites: Mitigating degradation of sisal fiber. Cement and Concrete Research, v. 81, p.94-111, 2016.

[5] MELO FILHO, J. A. Desenvolvimento e caracterização de laminados cimentíceos reforçados com fibras longas de sisal. 2005. 124 f. Dissertação (Mestrado em Engenharia Civil) – Universidade Federal do Rio de Janeiro, Rio de Janeiro, 2005.

[6] LIMA, P. R. L. TOLEDO FILHO, R. D. Uso de metacaulinita para incremento da durabilidade de compósitos à base de cimento reforçados com fibras de sisal. Ambiente Construído, v. 8, p.7-19, 2008.

[7] WEI J. MEYER C. Degradation mechanisms of natural fiber in the matrix of cement composites. Cement and Concrete Research, v. 73, p.1-16, 2015.