Oct 28th, 8:00 AM - Oct 29th, 6:00 PM

Assessment of the geometric potential of the rubber tree fruit endocarp as a reinforcing element in cement-based matrices

Fernanda AL Resende
University of Lavras, fernanda.resende1@estudante.ufla.br

Saulo Rocha Ferreira
University of Lavras, saulo.ferreira@ufla.br

Rodolfo Giacomim Mendes de Andrade
Department of Buildings – Federal Institute of Espírito Santo (IFES), Zip code: 29040-780, Vitória, Espírito Santo, Brazil., rodolfo.andrade@ifes.edu.br

Assessment of the geometric potential of the rubber tree fruit endocarp as a reinforcing element in cement-based matrices

Fernanda Carolina Resende[1], Rodolfo Giacomim Mendes de Andrade[2], Saulo Rocha Ferreira[3]

[1,3] Department of Forest Sciences – Federal University of Lavras (UFLA), Zip code: 37200-900, Lavras, Minas Gerais, Brazil.
[2] Department of Buildings – Federal Institute of Espírito Santo (IFES), Zip code: 29040-780, Vitória, Espírito Santo, Brazil.
fernanda.resende1@estudante.ufla.br, rodolfo.andrade@ifes.edu.br, saulo.ferreira@ufla.br

Abstract. The use of plant residues in cement matrices shows promise. The endocarp of the rubber tree fruit is a plant residue that may have the potential to be used in the production of cementitious composites. Therefore, the objective of this study is to evaluate the geometric potential of the rubber tree fruit endocarp as a reinforcing element in cement-based matrices. The waste was collected on the UFLA campus. The endocarps were subjected to treatments in hot water (80°C) and in an alkaline solution containing $Ca(OH)_2$. To evaluate the potential of the endocarp as a reinforcing element, the specimens containing treated and natural endocarp were subjected to flexion tests. The results obtained in the flexion test indicated that the endocarp did not act satisfactorily as a reinforcing element in the cement matrix. This result was justified due to the low endocarp/matrix adhesion, which made its action as a reinforcing element impossible.

Keywords: Plant waste, Reinforcing element, Composites, Sustainability

1 Introduction

The application of vegetable residues in cementitious composites became prominent from the 70 onwards, with the replacement of asbestos fibers by vegetable fibers, for the production of fiber cement tiles [1]. Since then, different ways of incorporating these materials into cement-based matrices have been investigated, highlighting their use as a reinforcing element, to reduce the fragility of the cement matrix [2].

However, before producing composites, it is necessary to take into consideration the issue regarding chemical compatibility between plant residues and the cement matrix, as some components present in the chemical composition of these residues can delay or even inhibit the hydration of the cement, compromising the mechanical resistance of the material. To remove these undesirable compounds, plant residues must be subjected to pre-treatment, such as washing in hot water and immersion in an alkaline solution [3].

The use of plant residues for the production of cementitious composites has been highlighted in recent years, as they are low-cost, renewable and biodegradable raw materials [4]. It is estimated that by the year 2030 the production of agro-industrial waste in Brazil will be approximately 967.005.044 (thousand tons). Coconut shells, sugar cane bagasse, wheat straw and corn cobs are some of the waste produced by this sector [5].

The agro-industrial sector covers different types of agricultural crops, among which rubber trees stand out. The rubber tree is a tree native to the amazon region, well known for its latex production [6]. Its fruit is composed of a trichoca-type capsule, apparently resistant, containing three seeds [7].

Studies indicate that rubber tree seeds can be reused for the production of biodiesel, food supplements, cereal bars and fish feed [8]. However, to date, no ways of reusing the endocarp of the rubber tree fruit have been found in the literature. Therefore, through this study seek to evaluate the geometric potential of the endocarp of the rubber tree fruit as a reinforcing element in cement-based matrices, to provide as environmentally appropriate destination for this waste and produce a material that can be used in the construction.

2 Materials and methods

2.1 Materials that were used for the production of the composites

The endocarp of the rubber tree fruit (Figure 1) was collected on the campus of the Federal University of Lavras (UFLA), located in the city of Lavras – Minas Gerais, Brazil, with latitude: 21°14’45’’ south and longitude 49°59’59” west. For the production of the composites, Portland compound cement (CPII F40) from the Holcim brand, quartzose river sand, with particles less than 600 µm (ABNT, sieve number 30) and water from the Lavras city supply network were also used.

Fig. 1. Endocarp of the rubber tree fruit
Source: From the authors (2023)

2.2 Endocarp treatments

To improve their chemical compatibility with the cement matrix, the endocarps were subjected to washing cycles in hot water and immersion in an alkaline solution containing calcium hydroxide ($Ca(OH)_2$).

In the first treatment, the endocarps were subjected to 3 washing cycles in hot water at 80/C for 1 hour, at a proportion of 100 grams of endocarps per liter of water. After this process, they were dried in an oven and stored for later use.

In the second treatment, the endocarps were immersed in an alkaline solution containing calcium hydroxide ($Ca(OH)_2$), for a period of 50 minutes, at a temperature of 22°C. They were then dried in an oven at 40°C for 24 hours and stored for later use.

2.3 Test specimen molding

63 specimens were molded with dimensions 160 mm long x 40 mm wide. For the production of the specimens, CPII F40 cement was used, adopting a ratio of 1:3 (cement:sand) and w/c (water/cement) of 0,70. An endocarp was added to the central region of each specimen. Natural endocarps were used, washed in hot water and treated in calcium hydroxide solution, with the concavities facing upwards (CC) and downwards (CB). Specimens were also produced without the addition of endocarp, for comparison purposes.

2.2 Mechanical 3-points bending test

To evaluate the geometric potential of the endocarp as a reinforcing element, a 3-point mechanical bending test was carried out. To carry out this test, a universal testing machine, from the Arotec brand, was used, equipped with a 20kN load cell, adopting a span of 140 mm and a displacement rate of 5mm/min. The specimens were evaluated after 7, 14 and 28 days. Three repetitions were performed for each treatment evaluated.

3 Results and discussions

3.1 3-points flexion

Figures 2, 3 and 4 show the typical load x displacement curves of the 3-point bending tests for the specimens produced with natural endocarp (ENCB and ENCC), washed in hot water (EAQCB and EAQCC) and treated with calcium hydroxide (ETHCB and ETHCC) with the concavities facing upwards (CC) and downwards (CB).

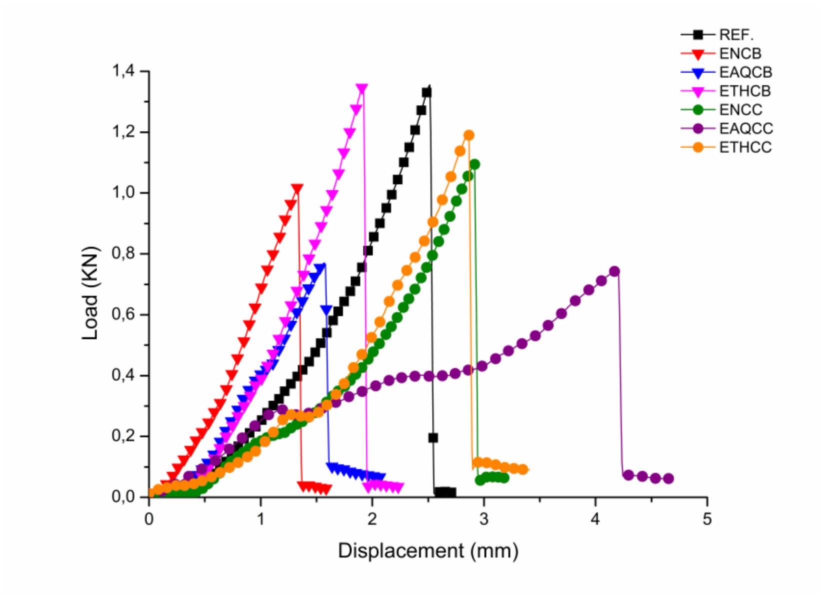

Fig. 2. Typical load x displacement curves after 7 days
Source: From the authors (2023)

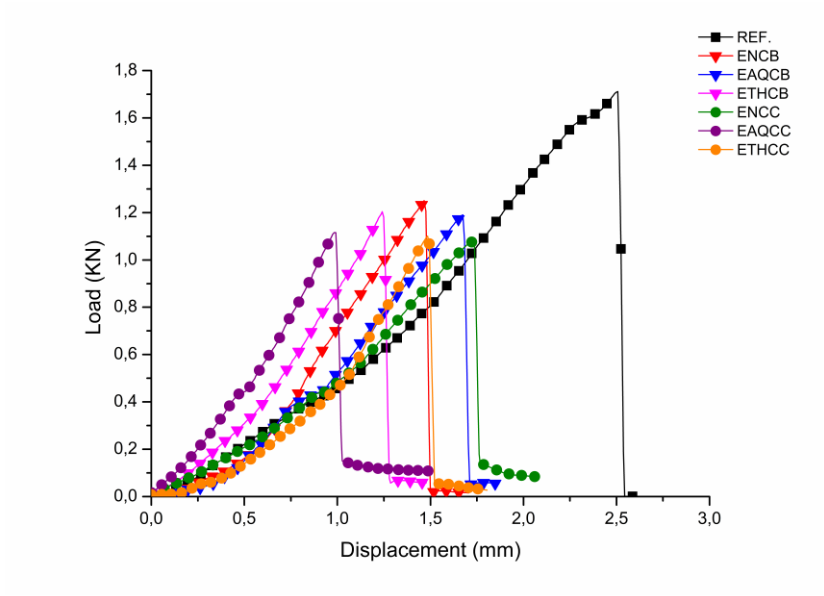

Fig. 3. Typical load x displacement curves after 14 days
Source: From the authors (2023)

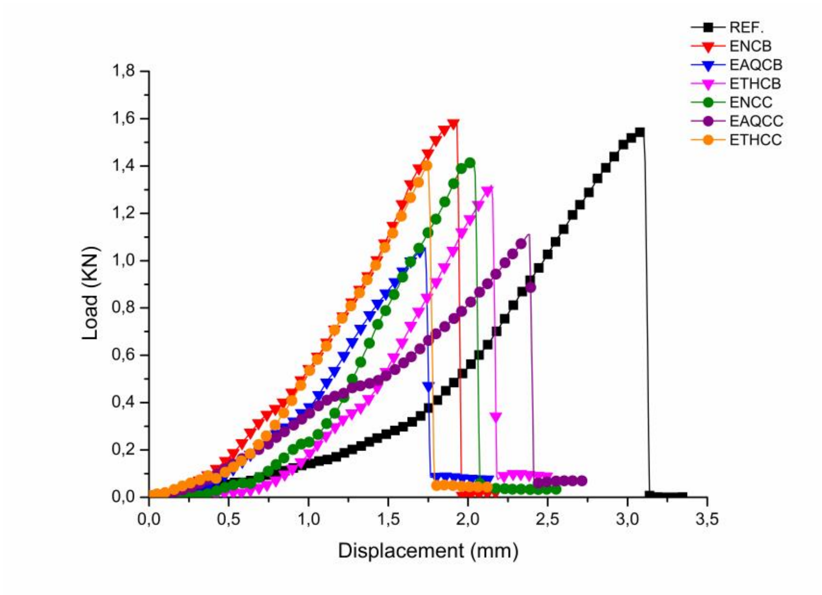

Fig. 4. Typical load x displacement curves after 28 days
Source: From the authors (2023)

According to the results presented, it was possible to observe that the proposed treatments did not work satisfactorily as a reinforcing element in the cement matrix. These results can be justified by the lack of adhesion between matrix/endocarp, which can be proven through Figure 5.

Fig. 5. Matrix/Endocarp interface
Source: From the authors (2023)

Analyzing Figure 5, it is observed that even after the specimen ruptured, in the flexion test, the endocarp remained intact, that is, it did not rupture along with the matrix, demonstrating that it was not well adhered to the matrix. This behavior can be justified by the surface of the endocarp, which presented low roughness and did not provide satisfactory anchorage to the cement matrix.

4 Conclusion and future work

According to the results obtained in this study, it is concluded that the lack of adhesion at the matrix/endocarp interface did not allow a clear assessment of its geometric potential as a reinforcing element in cement-based matrices. Therefore, in future work, intend to carry surface treatments on the endocarp, to increase its roughness and thus improve the adhesion of this material to the cement matrix. Among the treatments planned is the impregnation of the material with styrene-butadiene polymer (XSBR).

5 Acknowledgments

The authors would like to thank the financial support of the agencies FAPEMIG, CAPES and CNPQ.

References

1. Vo, LT.T., Navard, P.: Treatments of plant biomass for cementitious building materials – A review. Construction and Building Materials, Vol 121, (2016), 161 – 176.
2. Santos, G.Z.B.dos, Caldas, L.R., Filho, J. de A.M., Monteiro, N.B.R., Rafael, S.I.M., Silva, N.M. da: Circular alternatives in the construction industry – An environmental performance assessment of sisal fiber-reinforced composites. Journal of Building Engineering, Vol 165, (2022).
3. Alencar, M.A.S., Rambo, M.K.D., Botelho, G.L.G.T., Barros, P.M.M., Sergio, R.L., Borges, M.S., Bertuol, D.: Feasibility study of incorporation of bamboo plant fibers in cement
4. Souza, A.B., Ferreira, H.S., Vilela, A.P., Viana, Q.S., Mendes, J.F., Mendes, R.F.: Study on the feasibility of using agricultural waste in the production of concrete blocks. Journal of Building Engineering, Vol 42, (2021).
5. Brazilian Association of Biomass, Bioenergy, Bioelectricity, Pellets and Renewable Energy Industries – ABIB.: Biomass potential of agro-industrial waste in Brazil, (2022).
6. Sant'anna, I. de C., Cruz, C.D., Gouvêa, L.R.L., Junior, E.J.S., Freitas, R.S. de, Gonçalves, P. de S.: Genetic diversity analyses of rubber tree genotypes based on UPOV descriptors. Industrial Crops & Products, Vol 165, (2021).
7. Souza, G.A. de: Physiological and biochemical changes in rubber tree seeds [*Hevea brasiliensis* (WILL. EX ADR. DE JUSS) MUELL – ARG.]. Thesis (Doctorate in Plant Physiology) – Department of Plant Physiology. Federal University of Viçosa. Viçosa – MG, (2014), p. 152.
8. Unicentro: Research on rubber tree seeds will continue thanks to the university-company partnership, (2022).