Performance Evaluation of Açaí Fiber as Reinforcement in Coating Mortars

J. F. Natalli, I. S. A. Pereira, E. R. G. Júnior, S. A. A. Malafaia, I. D. Batista, M. V. Barbosa, M. T. Marvila, F. M. Margem, T. E. S. Lima, S. N. Monteiro, and A. R. G. Azevedo

Abstract The Amazon region faces a major obstacle caused by the high production of several natural fibers, such as açaí (*Euterpe oleracea*). There is still no specific and consolidated destination for agro-industrial waste generated in the different stages of processing Amazonian fibers, causing environmental changes in the region. Furthermore, it is known that the use of these fibers can promote an increase in ductile behavior and tensile strength in cementitious composites. With the objective of contributing to the creation of new strategies that guarantee the improvement of mortar properties and, at the same time, collaborate for an efficient disposal of the waste in question, this work aimed to evaluate properties of mortars in the fresh state with the addition of acai fibers. Three types of mortar were developed: (1) reference (without the use of fibers); (2) with the addition of fibers without surface treatment; and (3) with the addition of material with surface treatment based on tannic acid with a concentration of 5% by volume. The fibers were added in the proportions of 0.5,

J. F. Natalli · I. S. A. Pereira · E. R. G. Júnior · S. A. A. Malafaia · I. D. Batista · M. V. Barbosa · T. E. S. Lima
LAMAV—Advanced Materials Laboratory, UENF—State University of the Northern Rio de Janeiro, Av. Alberto Lamego, 2000, Campos Dos Goytacazes, Rio De Janeiro 28013-602, Brazil
e-mail: 20211100131@pq.uenf.br

M. T. Marvila
UFV—Federal University of Viçosa, CRP—Rio Paranaíba campus; Rodovia BR 230 KM 7, Rio Paranaíba, Minas Gerais 38810-000, Brazil
e-mail: markssuel.marvila@ufv.br

S. N. Monteiro
Department of Materials Science, IME—Military Institute of Engineering, Square General Tibúrcio, 80, Rio De Janeiro 22290-270, Brazil

A. R. G. Azevedo (✉)
LECIV—Civil Engineering Laboratory, UENF—State University of the Northern Rio de Janeiro, Av. Alberto Lamego, 2000, Campos Dos Goytacazes, Rio De Janeiro 28013-602, Brazil
e-mail: afonso@uenf.br

F. M. Margem
LEPROD—Production Engineering Laboratory, UENF—State University of the Northern Rio de Janeiro, Av. Alberto Lamego, 2000, Campos dos Goytacazes, Rio De Janeiro 28013-602, Brazil
e-mail: fmargem@uenf.br

Z. Peng et al. (eds.), *Characterization of Minerals, Metals, and Materials 2024*, The Minerals, Metals & Materials Series, https://doi.org/10.1007/978-3-031-50304-7_57

1.0 and 3.0% in relation to the Portland cement mass. From the results, it was verified that there was a reduction in the consistency index and mass density and an increase in the content of air incorporated in the mortars according to the addition of fibers. Thus, based on these results, the present study seeks to present the alterations of some properties in the fresh state caused by the addition of this natural reinforcement.

Keywords Açaí fibers · Reinforcement · Mortars

Introduction

The increasing demand for "green" products is related to a greater diffusion of sustainable development and circular economy concepts and understanding of their global positive impacts [1]. The usage of these products in civil construction is a promising strategy, since the sector is related to a large global share of CO_2 emissions, large consumption of natural resources and intense need for materials, such as steel, which require a lot of energy in its manufacturing process [2–4].

In this scenario, the growing interest of companies and researchers in composites with natural fibers is observed, boosting the development of less costly products that contribute to sustainable practices in civil construction [5–8]. The great availability of this type of fiber in the Brazilian Amazon region, derived from açaí agro-industrial residues, stands out (*Euterpe oleracea Mart*). According to data provided by the most recent statistical yearbook in Brazil [9], the production of açaí in the country in 2021, largely concentrated in the regions of Amazonas and Pará, reached 1.5 million tons, of which part is consumed by national industries and the great remainder destined for the global market. According to Domingues et al. [10], every 100 tons of fruit generate 80 tons of waste, which correspond to seeds and fibers. There is still no specific destination for all this material, most of which are discarded in landfills or even accumulated in the streets, sewage networks and rivers of the region, causing risks to the health of the population due to environmental contamination or the proliferation of transmission agents of illnesses [11].

Plant fibers incorporation into cementitious materials has already proven to be an effective method for improving several parameters, such as tensile strength, ductility, fracture toughness and relatively low density [12–14]. However, two issues that have been extensively studied related to these natural materials are its hydrophilicity and durability in alkaline environments [15–17]. Treatments carried out on the surface of the fibers tend to reduce these disadvantages and are the subject of current research studies [18, 19].

Tannic acid is a natural polyphenol that occurs in various plants and fruits [1]. It is characterized as a promising substance that modifies polymeric biocomposites that combines antioxidant and antibacterial properties and presents advantages such as biodegradability, high adhesion, non-toxicity, low cost and high availability [1]. Despite these benefits, this acid is still poorly studied as a type of surface treatment for plant fibers [1].

This paper aims to evaluate the performance of mortars in the fresh state with the addition of açaí fibers without and with surface treatment based on tannic acid. In this way, this research contributes to the development of new sustainable products for civil construction, also helping to reduce environmental problems related to fruit production in the Amazon region.

Materials and Methods

The açaí fibers were collected from the seed of the fruit, a by-product of the pulping of an agroindustry located in the municipality of Alto Rio Novo (Espírito Santo, Brazil). The açaí produced in this region is similar to that processed in the Amazon region, previously proven by Azevedo et al. [6]. The fibers were obtained manually and, after processing, the material was washed in running water and dried in an oven at 60 °C for a period of 24 h. After drying, part of the amount of fibers was subjected to surface treatment based on tannic acid [1].

Portland cement composed of blast furnace slag specified in Brazil as CP II-E-32 (equivalent to ASTM Type I SM) was used. The fine aggregate used was quartz sand from the Paraíba do Sul river, located in Campos dos Goytacazes, state of Rio de Janeiro, Brazil. This sand was homogenized and prepared to enable its application in mortars.

Seven types of mortar were produced in the proportion of 1:1:6:1.35 (cement: lime: sand: water/cement factor) with addition of fibers in relation to Portland cement mass (Table 1). The preparation of each mix followed the Brazilian normative procedure of NBR 16541 [20] for mixing, homogenizing and preparing mortars. The addition of açaí fibers occurred at the time of introducing the other components of the mixture, in order to avoid agglomeration of this material.

Mortars were characterized in the fresh state regarding consistency index—NBR 13276 [21], incorporated air content determined by the pressiometric method and mass density according to NBR 13278 [22]. It is very important to mention that all fresh state tests were with instantaneous measurements (without repetitions), as recommended by the Brazilian technical standard. Thus, the results must be expressed

Table 1 Mortars mixing ratio

Mortars	Content
Ref	Reference (0%)
1.5UT	1.5% untreated fibers
3UT	3.0% untreated fibers
5UT	5.0% untreated fibers
1.5TA	1.5% treated fibers
3TA	3.0% treated fibers
5TA	5.0% treated fibers

by the values obtained in a single repetition, without the need for a statistical evaluation. The analysis of these studies must consider the values of the reference mixtures as a direct comparison.

The flow table tests designated here in this study as a consistency index NBR 13276 [21], involves filling the standard conical mold (*d*1 ¼80 mm, *d*2 ¼ 125 mm, *h* ¼ 65 mm) in three layers compacted with 15, 10 and 5 punches of the standard hammer for the first, second and third layer, respectively. Then the mold is lifted, and 30 falls are applied (1 cm height, one fall per second). The spread of the mixture is defined based on the average of three diameters measured using a caliper. The ideal spreading diameter for laying and coating mortars, according to the regulations, is equivalent to 260 ± 5 mm [21]. The water content for the reference mortar was adjusted to present spread within the established range. After this adjustment, the water cement factor was fixed for the other mortars mixing ratio.

Results and Discussion

The horizontal spreading of mortars is closely related to the fluidity of the mixtures, and consequently to the workability, a property that favors its application as a coating for walls and ceilings. According to Fig. 1, it appears that there was a reduction in this scattering with the addition of a natural fiber, as well as with the increase in its percentages. The greater amount of fibers present in the matrix causes an increase in mass stability, providing greater internal cohesion of the system [23]. It is also observed that the surface treatment provided an even more pronounced reduction in the consistency index, with the exception of the 1.5%TA treatment.

According to Pawlowska et al. [1], tannic acid creates a coating on the surface of the fibers capable of increasing the durability of this material in an alkaline environment and reducing its hydrophilicity. However, from the results presented in Fig. 1, it is assumed that this layer created on the açaí fibers can cause an increase in chemical adhesion between the fiber and the matrix and, consequently, a reduction in the fluidity of the mixtures.

Thus, as expected, for the use of açaí fibers in the composition of coating mortars, it is essential to use plasticizing additives that will have the function of improving the workability of these matrices, without compromising their applicability.

Based on the results of Fig. 2, it appears that all mixtures had incorporated air levels within the range established by the literature, between 7 and 17% [24]. This limit indicates an acceptable zone of values that will not compromise properties in the hardened state of the mortar. It is observed that the incorporation of fibers caused an increase in the incorporated air content of the mixtures, since it is propitious that in the region of the interface between the surface of the fiber and the mortar the formation of voids occurs [25].

Void content of the mixtures with the addition of treated fibers was lower than that of the matrices with the presence of untreated fibers, remaining, however, above the reference value. It is inferred that the cement grains in the paste approached the

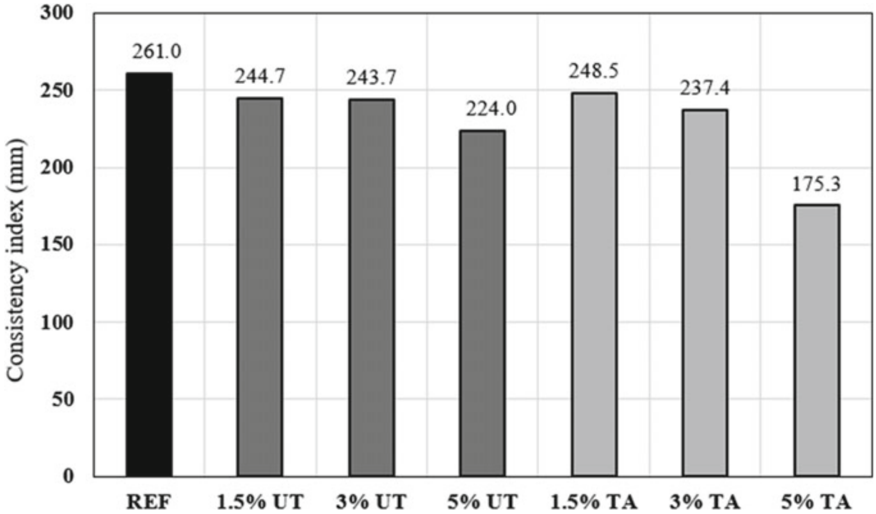

Fig. 1 Consistency index results of each mortar mixing ratio

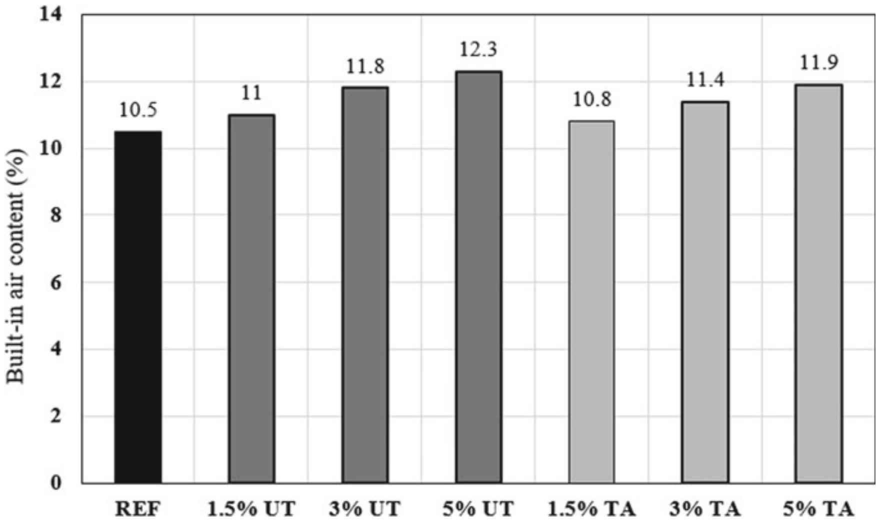

Fig. 2 Incorporated air content index results of each mortar mixing ratio

fibers, reducing the interfacial transition zone. Unlike the treatment with NaOH, in which there is an interfibrillar increase that causes the cement to migrate into the empty spaces between the fibrils, the tannic acid creates a layer that surrounds the fiber (insert reference). Thus, it is suggested that this coating created chemically attracts the cement grains from the paste, reducing the air content.

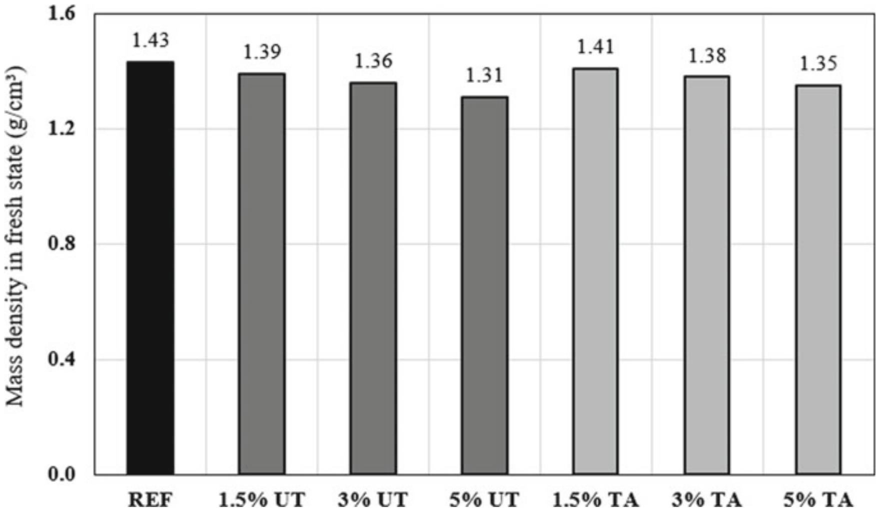

Fig. 3 Incorporated air content mass density index results of each mortar mixing ratio

Mass density results are shown in Fig. 3. It is verified that there is a reduction of this property in the fresh state for all the mixes with fiber addition, making the application of these mixtures contribute to the reduction of the specific weight of the building. This is due to the fact that the density of the açaí fiber is relatively lower compared to Portland cement [26]. It is also observed the effect that occurs after the surface treatment of the fibers with tannic acid, which led to an increase in the individual specific mass of the material.

Conclusion

This paper aimed to evaluate the performance of mortars in the fresh state with the addition of açaí fibers without and with surface treatment based on tannic acid. Tannic acid has shown to be useful to promote chemical adhesion between fiber/matrix, affecting results obtained by the analyses carried out.

It was verified that treated fibers incorporation caused a reduction in consistency index and mass density and an increase in the content of air incorporated in the mortars, validating its use and its consequent positive effects. Thus, based on these results, the present study presented changes in some properties in the fresh state caused by the addition of this natural reinforcement.

Acknowledgements This research was funded by the State University of the Northern Fluminense (UENF), partially financed by CAPES (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior—Brazil), CNPq (Coordenação Nacional de Pesquisa) and FAPERJ (Fundação de Apoio à Pesquisa do Estado do Rio de Janeiro). The participation of A.R.G.A. was sponsored by FAPERJ through the research fellowships proc.no: E-26/210.150/2019, E-26/211.194/2021, E-26/211.293/2021, E-26/201.310/2021 and by CNPq PQ2 307592/2021-9.

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