Piassava Fiber: A Novel Reinforcement for Cement-Based Matrix Composites

Fibra de piaçava: um novo reforço para compósitos de matriz à base de cimento

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ABSTRACT

The addition of 2 and 5 wt% of piassava fiber, a natural lignocellulosic fiber extracted from a Brazilian palm tree botanically named *Attalea funifera*, into cement-based matrix composites was investigated. Both alkali-treated piassava fibers by NaOH and non-treated fibers were embedded in Portland cement, lime, and sand to fabricate mortars intended for civil construction. The non-aged fresh mortars were tested for paste consistency, water retention, and relative volume of incorporated air. Preliminary results showed that the addition of NaOH-treated piassava slightly increased the water retention while decreasing the incorporated air content. Together with these preliminary results, the comparatively low density of the piassava fiber allows the fabrication of novel cement-based composite with the potential to be used as mortar in building construction.

Keywords: Piassava fiber; Cement-based composite; Fresh properties; Mortar.

RESUMO

A adição de 2 e 5% em peso de fibra de piaçava, uma fibra natural lignocelulósica extraída da palmeira brasileira chamada botanicamente de *Attalea funifera*, em compósitos de matriz cimentícia foi investigada. Tanto as fibras submetidas a tratamento alcalino com NaOH quanto as fibras não tratadas foram embutidas em cimento Portland, cal e areia para a fabricação de argamassas destinadas à construção civil. As argamassas frescas não envelhecidas foram testadas quanto à consistência da pasta, retenção de água e volume relativo de ar incorporado. Os resultados preliminares mostraram que a adição de piaçava tratada com NaOH aumentou ligeiramente a retenção de água enquanto diminuiu o teor de ar incorporado. Juntamente com esses resultados preliminares, a densidade comparativamente baixa da fibra de piaçava permite a fabricação de um novo compósito à base de cimento com potencial para ser usado como argamassa na construção civil.

Keywords: Fibra de piaçava; Compósito à base de cimento; Propriedades no estado fresco; Argamassa.

INTRODUCTION

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Os The past decades corresponding to the transition from the 20th to the present 21st century witnessed a surge on research works (AISYAH et al., 2021; FARUK et al., 2014; KARIMAH et al., 2021; MONTEIRO et al., 2009, 2011; PICKERING; EFENDY; LE, 2016; SANJAY et al., 2018; THYAVIHALLI GIRIJAPPA et al., 2019; VIGNESHWARAN et al., 2020; ZHANG et al., 2020) and advanced applications (BENZAÏT; TRABZON, 2018; DUNNE et al., 2016; KUMAR et al., 2019; LI et al., 2020; POTLURI; CHAITANYA KRISHNA, 2020) of polymer matrix composites reinforced with natural lignocellulosic fibers (NLFs). Luz et al. (LUZ et al., 2020) reported exponential growth in world documents related to “Natural fiber and composite”, illustrated in Figure 1, which shows more than one thousand publications per year beyond 2020 along the current decade.

Figure 1 – Publications per year for “Natural fiber and composite” according to Scopus database.

Adapted from LUZ et al. (2020).

For the specific case of the cement-based matrix, only recently the incorporation of NLFs has been considered. Figure 2 illustrates, according to Scopus (), the increase in publications related to “Natural fiber and cement composite”.

Figure 2 – Publications per year for “Natural fiber and cement composite” according to Scopus database.

Scopus (2022).

The justification for this increasing interest in using NLFs in composites, demonstrated in Figures 1 and 2, might be explained by: (1) relatively lower density of natural fiber, which contributes to diminishing the weight of parts and structures; (ii) sustainable nature as compared with synthetic fibers in terms of biodegradability and recyclability; and (iii) the lower cost associated with less abrasion to process equipment (FARUK et al., 2012). On the other hand, NLFs exhibited heterogeneity in physical and mechanical properties. Owing to natural variations in chemical composition, diameter, and cultivation conditions (FRANCK, 2005; THAKUR; THAKUR; GUPTA, 2014). Another disadvantage is their hydrophilic nature, which hinders the fiber adhesion to a composite matrix (BLEDZKI; GASSAN, 1999; SAHEB; JOG, 1999). For this reason, surface pretreatments are performed before incorporation into the matrix to improve interfacial adhesion (MOHANTY; MISRA; DRZAL, 2002; MUKESH; GODARA, 2019).

Several NLFs have already been investigated as a possible reinforcement for cement-based composites (AZEVEDO et al., 2021; KESIKIDOU; STEFANIDOU, 2019; PICANÇO; GHAVAMI, 2008; PIMENTEL et al., 2016; SOLTAN et al., 2017; SOUZA; SOUZA; SILVA, 2020). These research works explored mainly the potential of curaua fiber and textile (PICANÇO; GHAVAMI, 2008; PIMENTEL et al., 2016; SOLTAN et al., 2017; SOUZA; SOUZA; SILVA, 2020) but more recently açai fiber (AZEVEDO et al., 2021), as well as coir (coconut) and jute (KESIKIDOU; STEFANIDOU, 2019), were also investigated as reinforcement in mortars. In spite of these initiatives of using NLFs-incorporation into cement-based composites, numerous natural fibers are yet to be investigated. Among these, the stiff fiber extracted from the Brazilian

palm tree piassava, illustrated in Figure 3, is by its rigid characteristic a promising reinforcement for cement-based composites.

Figure 3 – Piassava fiber: (a) bundle of fibers; and (b) SEM of single fiber

The chemical content of piassava fiber is indicated in Table 1.

Table 1 – Chemical content of piassava fiber

Cellulose (%)	Hemicellulose (%)	Lignin (%)	Ash (%)	Extracts (%)	References
29 - 32	2.5 - 26	45 - 48	1 - 2	1 - 4	(ARCE; GARZÓN; SÁNCHEZ-SOTO, 2019; LERTWATTANARUK; SUNTIJITTO, 2015)

The relevant properties of piassava fibers for its reinforcement action are the mechanical presented in Table 2.

Table 2 – Mechanical properties of piassava fibers.

Tensile Strength (MPa)	Elastic Modulus (GPa)	Elongation at Break (%)	Interval of Diameters (μm)	References
110 - 147	1 - 5	6 - 22	250 - 700	(ARCE; GARZÓN; SÁNCHEZ-SOTO, 2019; LERTWATTANARUK; SUNTIJITTO, 2015)

In view of the rigid characteristic of the piassava fibers, Figure 3, in association with mechanical properties, Table 2, the objective of the present work is to evaluate its application as reinforcement of fresh mortars intended for lining construction walls. Both untreated and NaOH treated piassava fibers added in amounts of 2 and 5 wt% to a common cement/lime/sand paste for mortar were evaluated for consistency, water retention, and incorporated volume of air.

MATERIALS

Piassava fibers shown in Figure 1 were supplied as a leftover from a brown industry in Campos dos Goytacazes, Rio de Janeiro, Brazil. The fibers were cleaned in runny water and dried on a stove at 60 °C for 24 h. The mortar used as a matrix for the fiber incorporation was prepared using a standard mixture of ordinary Portland cement (OPC), lime, and sand in the proportion of 1:1:6, respectively. A Brazilian OPC type III (CPIII) was purchased in the local Campos dos Goytacazes specialized commercial store. The use of lime in mortar provides several advantages, which ensure greater durability under weather exposure in a tropical country like Brazil (29). The sand used as aggregate was naturally collected from the river and sieved to homogenize the granulometry.

COMPOSITES PREPARATION

Piassava fibers were added in relation to the mortar cementitious paste of 2 and 5 wt%, both in their natural condition and alkali-treated with NaOH.

TECHNOLOGICAL TESTS

Technological tests were carried out in the fresh state, just after composite preparation.

The consistency determination was performed by measuring the horizontal spreading of the composite paste on a slump table, which enabled the evaluation of the mortar's workability (LERTWATTANARUK; SUNTIJITTO, 2015).

The water retention was conducted in prismatic 40x40x160 mm specimens (ARCE; GARZÓN; SÁNCHEZ-SOTO, 2019). This allowed obtaining the capacity to fill the internal pores of the mortar with water.

The content of incorporated air was measured by using the pressiometric method, which indicates the volume of air in the mortar. Together with the water retention, it gives the capacity

of the mortar to retain and suction water from the applied substrate (AZEVEDO et al., 2020, 2019; FEDIUK et al., 2017).

RESULTS AND DISCUSSION

Table 3 presents the results of the technological tests in terms of the corresponding parameters.

Table 3 – Technological fresh state parameters for mortars added with piassava fibers.

Composition	Consistency (mm)	Mass density in fresh state (g/cm ³)	Water Retention (%)	Incorporated Air (%)
Reference	264.2	2	95.9	7.5
2% Untreated fiber	257.6	1.95	94.96	8.1
2% Treated fiber	260.2	1.97	95.37	7.9
5% Untreated fiber	246.4	1.89	93.8	8.7
5% Treated fiber	248.9	1.95	94.46	8.3

Based on the results presented in Tabel 3, the corresponding graphical interpretations are shown in Figures 4 to 7. As for consistency results, in Figure 4, only a slight decrease occurred with the incorporation of piassava fiber. Moreover, practically no change occurred as a consequence of fiber NaOH treatment. In principle, one may conclude that the mortar workability is not significantly affected by the addition of piassava fibers up to 5 wt%.

Figure 4 – Consistency results with piassava incorporation.

Regarding the relative volume of incorporated air in Figure 5, there is a moderate increase from the plain mortar (0% fibers) with 7.5% to 8.3-8.5% for the 5 wt% piassavas added mortar. It is also important to note that air incorporation was sensibly higher for the mortar added with NaOH treated piassava fiber. This can be attributed to the effective generation of fiber surface open porosity due to the attack by alkali treatment.

Figure 5 – Results obtained with the incorporation of air in the composite.

The density in fresh state curves shown in Figure 6 displays the expected tendency to slightly decrease owing to the relatively lower density of the piassava fibers. As expected, this decrease in mass density is more effective in mortars with N_2OH treated fibers which tend to lose more wax and lignin.

Figure 6 – Mass density in a fresh state.

Finally, Figure 7 shows the variation of water retention with the addition of piassava fiber to the mortar. Contrary to what one would expect, the presence of piassava fiber caused a decrease in water retention associated with both untreated and treated fibers. A possible explanation is that the piassava fiber promotes a better adhesion with the mortar's OPC as previously suggested by MARVILA et al. (2020) for açai added mortars. In the particular case of piassava fibers, the surface SiO_2 protrusions, Figure 1(b), might be responsible for the improved interfacial bonding with the mortar's cement past as happens with polymer matrix.

Figure 7 – Water retention with the addition of piassava fiber to the mortar.

CONCLUSIONS

The preliminary technical results of piassava fibers incorporated mortar in the fresh state permit to draw the following conclusions:

- The mortar consistency is only slightly reduced without practically no effect due to the piassava NaOH treatment.
- The content of incorporated air is increased with greater change associated with NaOH treated piassava fibers. This is attributed to a higher amount of surface open porosity generated by the alkali attack.
- The mass density in the fresh state is reduced with the addition of piassava fibers owing to their relatively lower density.
- The addition of piassava fibers caused a decrease in water retention despite the hydrophobicity of these natural lignocellulosic fibers. It is suggested that the piassava fibers promote better adhesion to the mortar's cement paste due to their characteristics of surface protrusion.
- Based on these technical findings, it is also possible to conclude that fabrication of mortars added up to 5 wt% of piassava fibers offers a novel material for wall lining in building material.

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