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Research Article

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Elaboration and Mechanical Characterisation of Composites Reinforced with Typha Australis Fibre

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Abstract This article is a contribution to a possible new use of Typha Australis plant, an invasive reed whose presence in the Senegal river valley is subject to numerous health and fishing problems. The objectives of this study are to extract Typha fibres, to elaborate Typha fibres reinforced polymer (TFRP) composites and finally to characterise their mechanical properties. Thus, long Typha fibres extracted manually with a plastic comb from the middle area of Typha leaves are used as composite reinforcements impregnated in an epoxy matrix. Tensile tests are carried and results showed that the incorporation of long Typha fibres increased the tensile strength and the Young's modulus of the epoxy from 14.9 to 51.4 MPa (250%) and from 2.2 to 5.4 GPa (145%) respectively. Nevertheless, it has to be noticed that the elongation at break of the epoxy matrix was higher than the TFRP which is quite low (around 0.1%).

Keywords Mechanical characterisation, composites, reinforcements, Typha australis fibres.

1. Introduction

Typha Australis study of the Senegal River Valley is motivated by the potential use of natural plant reinforcements in composites to replace synthetic reinforcements in various fields. This problematic plant whose proliferation is worrying at several levels, namely public health, security of water supplies, biodiversity, economic activities i.e fishing, agriculture, etc. [1] could represent a local alternative as a composite reinforcement, such as flax, hemp and sisal fibres.

More and more researches [2]–[5] have been done on plant fibre reinforced polymer composites in various fields such as automotive, mechanics of materials, aerospace, sports, …. This study investigates the possibility of developing new composites incorporating senegalese Typha Australis fibres for use in furniture, partitioning, etc. The scientific objective of this paper is to determine the average tensile strength, Young's modulus and elongation at break of TFRP composites. To do so, in the first part the elaboration of such biocomposites has been described. the second part concerning the mechanical characterisation of TFRP composites was then detailed. Finally, results and conclusions are discussed.

2. Materials and Equipment Used

Elaboration of composites reinforced with Typha Australis fibre

The Typha Australis fibres used as reinforcements were extracted from Typha leaves, located in the middle zone of plants harvested in Hann Maristes, in the suburb of Dakar-Senegal, according to the Senegalese Typha plant cutting standard NS 02 - 061 [6]. The Typha Australis fibres shown in figure 1, were manually extracted by the use of a plastic comb [7] and sun-dried for 3 days to remove their moisture [8].

Figure 1: Fibres obtained after combing

For composite manufacturing, the resin used was an epoxy supplied by Ozyx composite company. The epoxy resin has been mixed with a hardener in the weight ratio of 10:6 (10 grams of epoxy resin to 6 grams of hardener).

The NF-EN-527-5 type A standard [9] for long fibres composites was used for the elaboration of biocomposites samples. Five TFRP specimens of 150 mm long, 15 mm large and 1.32 mm thick, were realized as shown in Figure 2. Fibres were aligned along the length of specimen. The production of the TFRP specimens was done manually using the compression moulding process. A first layer of resin was spread on the surface of the lower mould, then the fibres were pinched at their ends on both edges of the mould. A glass plate was used as upper mould and has been placed on top. The assembly was then compressed using clamps on outer sides of the mould to fix it together. All this experimental process has been carried out, at ambient temperature of approximately 27°C and a relative humidity of 49 %. Samples were removed from moulds the following day. The section of the specimens were quite constant all along the length. No post curing of TFRP was performed. The fibre fraction was of 48% in weight.

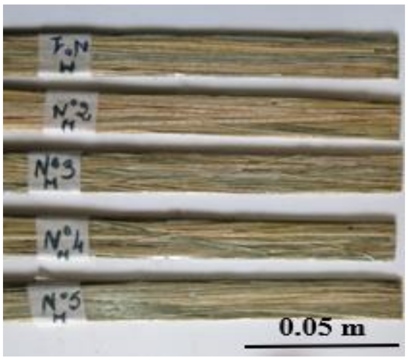

Figure 2: Five specimens of composites reinforced with Typha Australis fibre

Samples made of resin bars, without any reinforcement, were also elaborated as shown in Figure 3. Their fabrication was done in the same experimental conditions than for TFRP composites, with the same nominal dimensions.

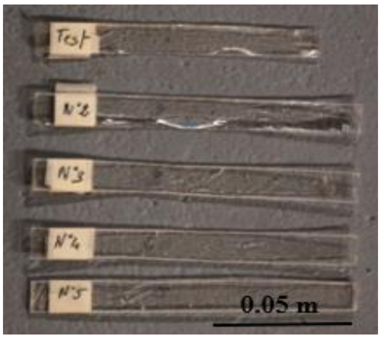

Figure 3: Batch of five Epoxy resin samples

Tensile test

The composite specimens were tested under tensile loading in an INSTRON 5569 universal tensile machine, with a crosshead speed of 2 mm/min in accordance with NF-EN-527-5 type A [9]. To measure strains, the gauge length of the mechanical extensometer was about 50 mm for the TFRP and 12.5 mm for the epoxy specimens. A 5 kN cell force was used to perform the tests. Figure 4 depicts the tensile test setup.

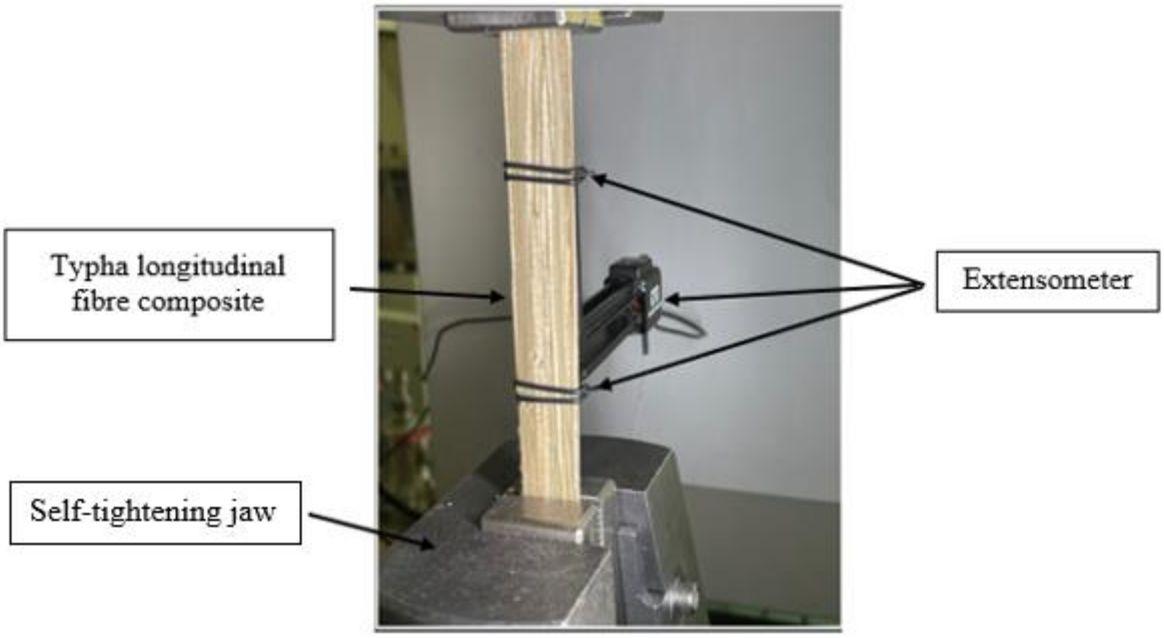

Figure 4: Tensile test setup of TFRP specimens

3. Results and Discussion

The tensile curves (stress versus strain) were plotted for the 5 specimens. The Young's modulus E corresponding to the stress-strain curve initial slope, was calculated, the tensile strength Rm and the elongation at break A% are also determined. The standard deviations of each parameter are given in brackets. The results obtained from composite specimens and epoxy bars ones are presented in Table 1. Besides, the experimental data of the fibre alone [10] have been added in Table 1.

Table 1: Test results

Samples	Young's Modulus E (GPa)	Tensile strength Rm (MPa)	Elongation at break A (%)
TFRP	5.4 (0.21)	51.4 (7.87)	0.097(0.04)
Epoxy	2.23 (0.3)	14.93 (0.75)	0.438 (0.17)
Fibre	11.02 (1.29)	100.55 (48.6)	0.14 (0.085)

Overall, the results of the mechanical tests show much higher values for TFRP composites than for epoxy samples. The maximum tensile strengths of 51.4 and 14.9 MPa for the TFRP composites and the epoxy, respectively show an important difference. The tensile strength of TFRP composites being about 4 times higher than that of the epoxy alone. Similarly, we observe the same trend in the Young's modulus measurement, with a higher value for the TFRP composites (5.4 GPa) compared to the epoxy samples (2.2 GPa). Young's modulus measurement has approximately 3 times higher than that of the epoxy samples.

The use of Typha fibres as reinforcement was beneficial in increasing the strength and Young's modulus of the composite. In addition, other important parameters also played a role in this increase in strength: the length of the fibres, their arrangement and also the fibre ratio. Indeed, the orientation of the fibres with respect to the applied mechanical loading has a significant influence on the mechanical properties of biocomposites as explained by Nouri [11], who states that biocomposites with unidirectional long fibres parallel to the loading direction have generally a higher tensile strength than composites loaded with randomly oriented short fibres. Furthermore, Islam et al., ([11], [12]) found that aligned hemp fibre/epoxy composites provided 14% and 21% higher tensile strength and tensile modulus respectively compared to their randomly oriented fibre-filled counterparts.

We have also noticed that the present results for unidirectional long Typha fibres untreated reinforced epoxy composites provide better results compared to Typha fibres randomly arranged reinforced epoxy. This is the case of the study of Rizal and al., [13] showing a maximum value of 37.4 MPa and 29.2 MPa, for treated Typha fibre with NaOH for 4 hours reinforced polymer and for untreated Typha reinforced polymer, respectively. Fibres are randomly arranged.

The fibre loading rate also influences the mechanical strength of composites. Ramanaiah and al. [14] have shown that as the fibre content of Typha Angustifolia reinforced polyester matrix composites increased, the tensile strength increased consequently. For a maximum fibre volume content of 35.5 %, the tensile strength percentage of these composites increase of 57.5 % compared to pure polyester.

Nevertheless, despite the good results observed (tensile strength and Young's modulus) for TFRP composites compared to epoxy samples, the elongation at break of the later was higher. The maximum strain of 0.44 % shows that the epoxy is not a very ductile material, but less than the other composite. The standard deviations observed for the epoxy alone shows less scattering than the TFRP composites. The fibre alone shows a very low elongation at break (0.5 %). The value of 0.1 % is quite surprizing; it could be interesting to see more accurately the adherence between resin and fibres.

It is still observed that each composite adheres quite well after breaking. This is quite logical as we have quite rough surfaces for the fibres due to the manual extraction method used.

4. Conclusion

The elaboration of biocomposites with unidirectional arranged Typha Australis fibres reinforced with an epoxy matrix was done manually using the compression moulding method. It has been clearly observed that the addition of Typha fibres has considerably increased the mechanical strength (E and A%) even if the elongation at break A % is quite weak.

Firstly, tensile test of long Typha fibre reinforcements suggested that it is possible to use these fibres. It is worth working on the potential of the use of TFRC. Indeed, knowing that when fibres used are perfectly straight and single with an optimum volume ratio generally not exceeding 40% on average, better results could be achieved.

Ultimately, several applications could be found; Typha Australis fibres can be used in composites for use in Senegal in goods such as furniture, certain civil engineering structures such as partition panels or partition walls, etc.

However, it would be important to take into account certain parameters for better results, namely the maturity of the Typha plant, the extraction method for good individualisation of the fibres while avoiding damaging them, the arrangement and the fraction of the fibres in the resin and finally the industrial process to elaborate this kind of composites.

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