Mechanical Behavior of Fiberglass/Unsaturated Polyester Composites, with Biochar Filler for Carbon Sequestration, Under Three-Point Bending

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Introduction

Glass fiber-reinforced laminated composites have received huge attention due to their high specific strength and modulus. Glass fiber polymer (GFRP) composites have shown great potential to replace metallic materials in a variety of applications, reducing the overall weight of structures and retaining a high degree of importance. The tailorability of these materials is also highly critical to their success. One avenue being explored is the use of these materials to sequester carbon, to prevent its wider release into the environment. Biochar supplied by Passive Remediation Systems Inc. (PRSI) in Armstrong BC Canada, has been used to this end. However, consequence of mechanical properties must be investigated ahead of further implementation. Mechanical properties of GFRPs are crucially dependent on the polymer matrix properties, especially when filler materials are added, usually to reduce net cost of the laminate. In this study, flexural mechanical properties are investigated by applying alumina trihydrate (ATH) filler and biochar particles at different volume fractions and compared with a control sample of fiberglass and unsaturated polyester (UPE) resin.

Fabrication process

A hand lay-up process was performed to manufacture the composite materials with different mass fractions. Mechanical properties of the composites were studied through three-point bending tests performed on UPE, E-glass fiber/UPE with ATH particles as well as glass/UPE wet mixed with biochar particles. In order to prepare the biochar particles, raw biochar product (Fig. 1(a)) was received and then pulverized using a jaw crusher (Fig. 1(b)). The crushed biochar was then sieved as shown in Fig. 1(c) resulting in batches of different particles sizes (<80um, 81um-160um, 161um-320um, >321um) as shown in Fig. 2. UPE reinforcement was prepared by adding the weighted particles (10 %wt., 20 %wt. and 30% wt. for alumina trihydrate (ATH) particles and 10% wt. and 20% wt. for those containing biochar particles) for the and hand-rolling on the fiber glass fabrics in layer sequence. Finally, rectangular test specimens were extracted with 180mm x 15mm x 2.8mm dimensions using the abrasive waterjet cutting process.

Mechanical Testing

Instron testing system was used to perform the three-point bending tests on the fabricated composites. A span length of 143mm was considered and the tests were performed following ASTM D790 standard. A displacement rate of 4 mm/min was set for all of the experiments and load-displacement curves were recorded during the tests. Moreover, each test was repeated four times (n=4) to evaluate reliability of the results.

Results

The stress-strain curves obtained from the bending tests are presented in Fig. 3. The samples are labeled in a way that those containing ATH and biochar particles are labeled as A and B respectively and those with UPE are signified by C followed by their mass fractions. Stress strain curves are representative of post-yield hardening behavior for all the samples before a catastrophic failure mainly occurred after 4% bending strain.

(a) (b) (c)

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Fig. 1. The process followed for preparing biochar particles (a) as purchased biochar (b) Jaw crusher for pulverizing biochar (c) the sieving system used for separating specific particle sizes.

Fig. 2. Biochar particles with different sizes separated through sieving process.

Moreover, elastic properties of the fabricated composites are compared in Fig. 4. As can be seen, increasing the volume fraction of ATH from 10 to 20 %wt. has increased both bending strength and modulus while increasing from 20 to 30 %wt. diminished mechanical performances. However, increasing biochar content was observed to increase the mechanical strength and modulus. In addition, the less properties were found for UPE sample. Overall, in can be concluded that through controlling the mass fraction, higher mechanical properties can be achieved by introducing ATH into the fiber glass/UPE composites.

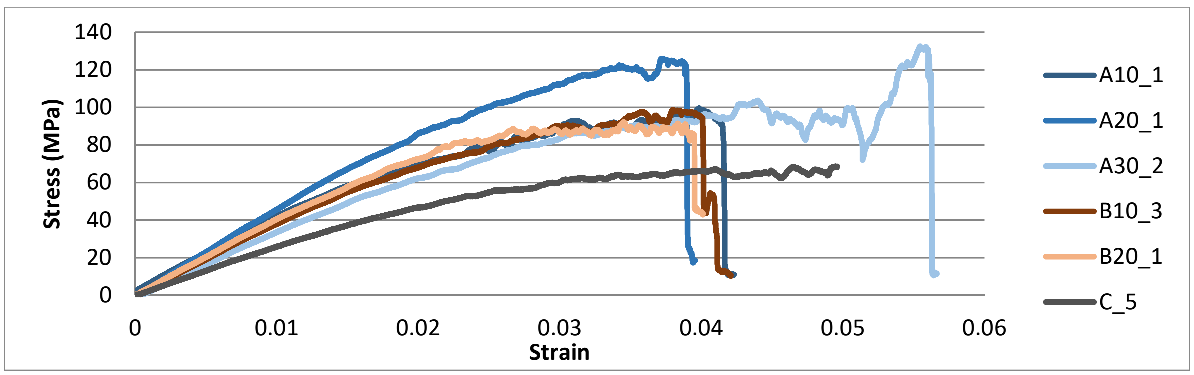
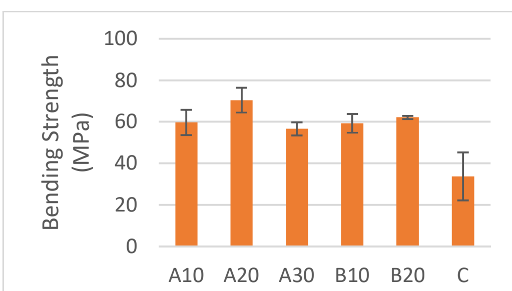
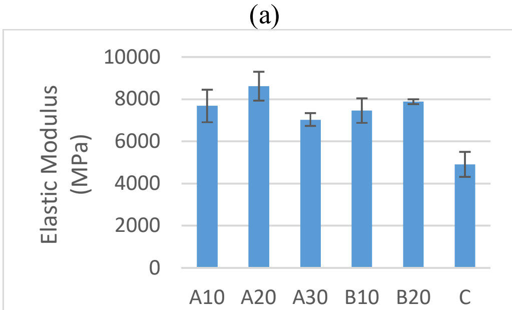


Fig. 3. Stress-strain curves obtained for the fiber glass/UPE composites under three-point bending test.



(a)



(b)

Fig. 4. Comparing the bending strength and elastic modulus obtained from stress strain curves.

References

[1] Li W, Dichiara A, Zha J, Su Z, Bai J. On improvement of mechanical and thermo-mechanical properties of glass fabric/UPE composites by incorporating CNT–Al2O3 hybrids. Composites Science and Technology 2014;103:36-43.

[2] Seretis GV, Kouzilos G, Manolakos DE, Provatidis CG. On the graphene nanoplatelets reinforcement of hand lay-up glass fabric/UPE laminated composites. Composites Part B: Engineering.

[3] Sarasini F, Tirillò J, Ferrante L, Valente M, Valente T, Lampani L, et al. Drop-weight impact behaviour of woven hybrid basalt–carbon/UPE composites. Composites Part B: Engineering 2014;59:204-20.

[4] Vieira LMG, dos Santos JC, Panzera TH, Rubio JCC, Scarpa F. Novel fibre metal laminate sandwich composite structure with sisal woven core. Industrial Crops and Products 2017;99:189-95.

The authors would like to acknowledge the contributions towards this research by NRC IRAP.