Effects of chopped hemp on mechanical and thermal properties of epoxy resins

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ABSTRACT: Low cost composite materials are widely used in civil and structural engineering applications. This project uses Epon and chopped hemp to plasticize a commonly used resin, epoxy resin to lower the cost of the composite and to find out the mechanical and thermal properties of the plasticized epoxy resin to see if it is suitable for the said applications. Epon and chopped hemp were mixed together in the ratio of 85 % to 15 % by weight. Three point bending tests were carried out to evaluate the flexural properties of the plasticized resins. Dynamic mechanical thermal analysis is used to evaluate the thermal properties of the plasticized epoxy resin. The study with epoxy and Epon plus chopped hemp showed that the mechanical properties of the epoxy composite formed were lowered but its ability to dissipate

1 INTRODUCTION

The emergence use of fibre composite materials and technologies in civil and structural engineering has created opportunities in the development of 'smarter' new polymers and polymer additives. The composite research centre of the University of Southern Queensland developed projects for creating new materials suitable for civil and structural engineering applications. One of the difficulties faced by the centre in using composites is the brittleness of thermosetting resins, even though the mechanical properties of these resin-based composites are good. This means that most civil engineering structures manufactured from thermosetting resin based composites are strain- rather than strength-limited. Consequently, a major focus of polymer research work was conducted at the centre to improve the toughness of thermosetting resins. There are many well-established techniques used to toughen these resins. These approaches are always cost-prohibitive for civil engineering composites. This study uses EPON plus chopped hemp to plasticize and reduce the brittleness as well as lowering the cost of the resins. Different percentage by weight of EPON plus chopped hemp was added to epoxy resin in steps of five percent. The ratio by weight of EPON to chopped hemp is always 85% to 15%, which is the highest percentage by weight of chopped hemp that still makes the composite easily cast into shapes.

2 MATERIALS

The resin used is Hyrez 201, part 'A' of the centre-developed epoxy resin, Hyrez 202. It is a blend of different commercially available epoxy resins developed and mixed by the centre. It is a resin normally used for composite preparation. The hardener used was developed by the centre and is a blend of three hardeners. This results in a gel time and cost compatible with civil engineering applications. EPON plus chopped hemp is a plasticizer for epoxy resins.

3 FLEXURAL AND FRACTURE TESTS

Three point bending test as depicted in Figure 1 will be used in this project. In this test, the area of uniform stress is quite small and concentrated on the centre loading point (Shackelford 1992).The standard used is ISO 14125:1998(E) because the results can then be compared with the work of others (ISO 14125:1998E 1998). The centre uses a universal machine MTS Alliance RT/10 at 10 kN couple with the software TESTWORK 4. The dimensions of the specimens of resins were 250 mm × 10 mm × 4 mm and tested at a crosshead speed of 4 mm/min. Fracture tests were conducted at room temperature, in the three-point bending mode at a crosshead displacement rate of 4 mm/min, using the MTS alliance RT/10 mentioned above. The standard used for values of K_{IQ} is ISO 13586:2000 (ISO 13586:2000 2000). The linear elastic fracture mechanics (LEFM) approach, for single- edge-notch bending (SENB) geometry was employed to determine of fracture toughness because the resin used can readily meet the requirements for LEFM (Wikipedia 2006).

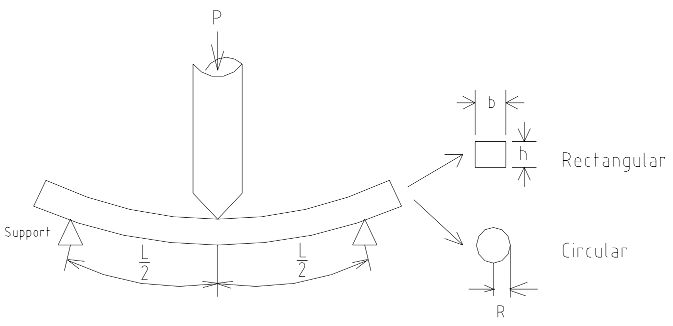

Figure 1. A schematic diagram for three point bending test.

4 DYNAMIC MECHANICAL THERMAL ANALYSIS

Dynamic mechanical thermal analysis (DMTA) is an important technique used to measure the thermal properties of elastomers. It provides information on the ability of materials to store and dissipate mechanical energy upon deformation, which is used to determine which materials can be used in dynamic applications, such as rollers or wheels. Many materials, including polymers, behave both like an elastic solid and a viscous fluid, thus the term viscoelastic. Polymeric materials, which are viscoelastic in nature, are subject to time, frequency and temperature effects on mechanical properties which can be analysed by this method. The machine used is DMA Q800 and is shown in Figure 2. The dimensions of the samples used for analysis are 60 mm x 10 mm x 4 mm. The mode used here is 'dual cantilever'; the sample is clamped at both ends and flexed in the middle. If the sample is clamped at one end, then it is single cantilever, which is a good general-purpose mode for evaluating thermoplastics and highly damped materials (elastomers). Dual cantilever mode is ideal for studying the cured thermosets. For this study, the temperature change was 3°C per minute. While heating, the composite is deformed (oscillated) at constant amplitude (strain) with a fixed frequency of 1 Hz and the mechanical properties measured.

The basic properties obtained from a DMTA test include elastic modulus (or storage modulus, E'), viscous modulus (or loss modulus, E") and damping coefficient (tan δ) as a function of temperature, frequency or time. Results are typically provided as a graphical plot of E', E", and tan δ versus temperature. DMA identifies transition regions in plastics, such as the glass transition, and may be used for quality control or product development (Redjel 1995).

5 RESULTS AND DISCUSSIONS

Figure 3 illustrates the flexural modulus of hemp-EPON plasticized epoxy resin. It can be found that the flexural modulus of hemp-EPON plasticized epoxy resin dropped slightly with increasing percentage by weight of epoxy resin. The drop was drastic at 30 % by weight of hemp-EPON.

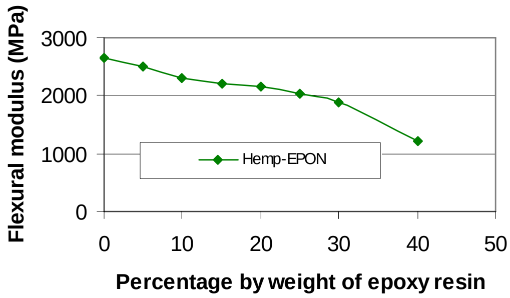

Figure 2. Flexural modulus vs. percentage of Hemp-EPON

The glass transition temperature of hemp-EPON plasticized epoxy resin decreases significantly after 20 percent by weight of epoxy resin as depicted in Figure 4. This also provides an indication of the change of morphology.

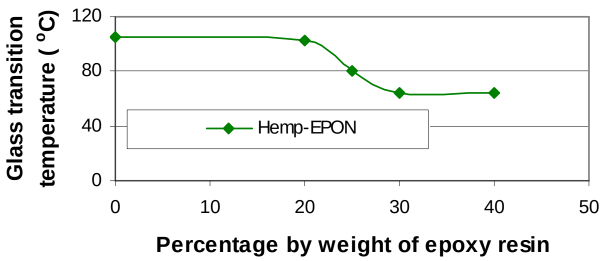

Figure 3. Glass transition temperature vs. percentage of Hemp-EPON

Figure 5 shows the fracture toughness of epoxy resin plasticized by hemp-EPON. The drop in fracture toughness was abrupt with the addition of hemp-EPON. It dropped to a low value of 0.85 MPa$\sqrt{m}$ at 15% by weight of hemp-EPON and then flattened from 20% to 30% by weight of hemp-EPON.

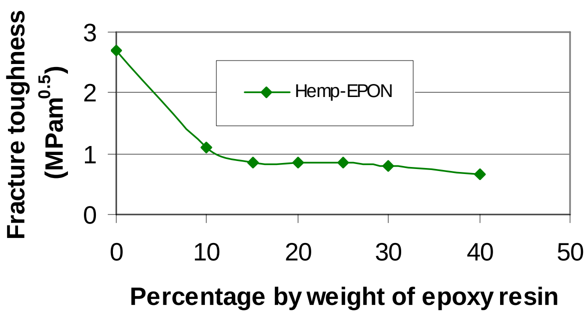

Figure 4. Fracture toughness vs. percentage of Hemp-EPON

6 CONCLUSIONS

The flexural modulus and fracture toughness decrease with increasing percentage by weight of hemp-EPON in the epoxy resin, i.e. the mechanical properties were reduced by the addition of hemp-EPON, a plasticizer. On the other hand, the loss tangent increased with increasing EPON by weight in epoxy resin. A change in morphology with 20 % by weight of hemp-EPON was supported by the fact that the change in fracture toughness and glass transition temperature was abrupt at this percentage by weight of hemp-EPON. The addition of hemp-EPON to epoxy resin seems to reduce the mechanical and thermal properties of the composite except the flexural modulus.

7. REFERENCES

ISO 14125:1998(E). 1998. Fibre reinforced plastic composites – determination of flexural properties.

ISO 13586:2000.2000. Plastics -- determination of fracture toughness (G_{IC} and K_{IC}) -- linear elastic fracture mechanics (LEFM) approach.

Redjel, B.1995. Mechanical properties and fracture toughness of phenolic resin, Plastics, rubber and composites processing and applications, (24): 221-228.

Shackelford, J. F. 1992. Introduction to materials science for engineers, 3rd edition, Macmillan, 435-437, 459.

Wikipedia. 2006. The free encyclopedia, epoxy resin, http://en.wikipedia.org/wiki/Epoxy_resin.