INVESTIGATIONS ON TENSILE AND FLEXURAL STRENGTH OF WOOD DUST AND GLASS FIBRE FILLED EPOXY HYBRID COMPOSITES

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ABSTRACT

Experimental investigation of the mechanical properties of hybrid composites consisting of epoxy reinforced with glass fibre and filled with pine wood dust (PWD) particles have been studied in the present work. The hybrid composites were prepared by using hand layup technique. Four identical specimens were prepared with different volume fraction of reinforcement particles (6.5Vol%, 11.3Vol%, 26.8Vol%, and 35.9Vol% of PWD and 9.6Vol% of glass fibre) to determine the mechanical properties such as tensile and flexural strength of hybrid composites. In this study, mechanical properties such as tensile and flexural strength were measured using same Universal testing machine (UTM) i.e. Instron Model 1122 testing machine (Instron Corp., Conton, MA). The experimental results showed that incorporation of glass fibre in pine wood dust filled epoxy resin improved strength both in tensile and flexural modes of neat epoxy. With addition of 6.5Vol%, 11.3Vol%, 26.8Vol% and 35.9Vol% of PWD and 9.6Vol% of glass fibre, the tensile strength of epoxy resin improved by 115%, 105%, 76.5%, and 63.1% and flexural strength of epoxy resin improved by 110.5%, 103.4%, 97.3%, and 78.9% respectively.

Key words: Epoxy, Glass fibre, Hybrid Composite, Mechanical properties, Pine wood dust.

1. INTRODUCTION

Recently, thermoplastic and thermoset polymers are combined with natural fillers to produce the composites, which possess better strength and good resistance to fracture. Due to an excellent property profile, these composites find wide applications in packaging, building and civil engineering fields. Natural fibre as a replacement to synthetic fibre in polymer matrix is the focus of many scientists and engineers. The reason for focus on natural fibre reinforced polymer matrix is because of its low cost eco-friendly, low energy consumption, non abrasive nature, and good insulator of heat and sound. In recent years, major industries such as automotive, construction and
packaging industries have shown enormous interest in the development of new bio-composite materials and are currently engaged in searching for new and alternate products to synthetic fibre reinforced composites. It has also become very attractive mainly because of the good mechanical properties that can be obtained at relatively low cost, highly available and renewable with low density and high specific properties as well as biogradable.

2. LITERATURE REVIEW

The objective of this work is to investigate the tensile and flexural properties of pine wood dust filled epoxy composite reinforced with glass fibre. Numerous theoretical and experimental approaches have been developed to investigate these properties. Agarwal et al. [1] derived an equation to find out the theoretical density of composite materials in terms of weight fraction. Liang et al. [2] studied the interfacial properties and its impact on tensile strength in unidirectional. Rong et al. [3] have investigated the effect of fibre treatment on mechanical properties of unidirectional sisal reinforced epoxy composites. Sreekala et al. [4] found the significant decrease in the flexural strength was observed at the highest EFB fibre volume fraction of 100% which was due to the increased fibre – to – fibre interactions and dispersion problem which results in low mechanical properties of composite. Premlal et al. [5] used rice husk as organic filler in polypropylene and observed that these composites exhibit relatively lower yield strength, Young’s modulus, flexural modulus and higher elongation at break as compared to those of talc filled composites. Yamamoto et al. [6] reported that the structure and shape of silica particles have significant effects on the mechanical properties such as fatigue resistance, tensile and fracture properties. Yang et al. [7] prepared a composite sample with polypropylene as the matrix and rice husk floor as the reinforcing filler and studied the physical, mechanical and morphological properties. Singha et al. [8] reported a study on the synthesis and mechanical properties of new series of green composites involving Hibiscus Sabdariffa fibre as a reinforcing material in urea – formaldehyde (UF) resin based polymer matrix. Mahapatra et al. [9] described the development of multi-phase hybrid composites consisting of polyester reinforced with E-glass fibre and ceramic particulates. Lionetto et al. [10] evaluated the effect of a new preservative/consolidant system on the mechanical properties of worm-eaten walnut wood. Aruniit et al. [11] studied to find out how the filler percentage in the composite influences the mechanical properties of the material. Ibrahim [12] investigated the effects of reinforcing polymer with glass and graphite particles on enhancing their flexural properties. Dedeepya et al. [13] measured mechanical properties such as tensile strength, tensile modulus and thermal conductivity of natural fibre typha angustifolia reinforced composite using Universal testing machine and Guarded hot plate apparatus. Ismail et al. [14] studied the solid particle erosion characteristics of the CSP filled C – E composites and compared the experimental results with those of unfilled C – E composites. Reem et al. [15] studied the mixture rule of composite material and the effect of volume fraction of coconut fibres on the mechanical properties of the composite.

3. EXPERIMENTAL DETAILS

3.1. Matrix material (Epoxy)

Epoxy (LY 556) resin and the corresponding hardener (HY 951) are mixed in a ratio of 10:1 by volume supplied by Hindustan Ciba Geigy (India) Ltd.

3.2. Filler material (Pine wood dust)

Pine wood dust has chosen as the filler material mostly for its very low thermal conductivity (0.068 W/m-°K) and low density (0.52 gm/cc). It is also renewable, eco-friendly, available at low cost, non toxic and basically considered as waste product.
3.3. Fibre material (E – glass)

Cross piled E – glass fibres (supplied by Saint Gobain Ltd. India) are reinforced separately in PWD epoxy resin to prepare a set of glass – epoxy – PWD hybrid composite slab.

3.4. Composite preparation

The low temperature curing epoxy resin and corresponding hardener were mixed in a ratio of 10:1 by volume as recommended. Pine wood dust (PWD) particles with average size 100µm were reinforced in epoxy resin (density 1.1 gm/cc) to prepare the composites. Further, cross piled E – glass fibers (supplied by saint Gobain Ltd. India) were reinforced separately in PWD filled epoxy resin to prepare a set of glass – epoxy – PWD hybrid composite slabs. E – Glass has an elastic modulus of 72.5GPa, density of 2.59 gm/cc and thermal conductivity of 0.04 W /m °K at room temperature. The fabrication of these composite slabs was done by conventional hand – lay – up technique. The fillers were mixed thoroughly in the epoxy resin before the glass – fiber mats (9.6vol %) are reinforced into the matrix body. A stainless steel mould having dimensions of 210 × 210 × 40 mm was used for this purpose. Silicon spray was used to facilitate easy removal of the composite from the mould after curing. The cast of each composite was cured under a load of about 50kg for 24 hours before it was removed from the mould. Then this cast was post cured in air for another 24 hours. The specimens were prepared having dimension of 165mm×19mm with thickness of 3.2mm for tensile test and 55mm×10mm with thickness of 4mm for flexural test.

3.5. Determination of Tensile Strength

Tensile strength is the maximum ability of a material to withstand forces that tends to pull it apart. The tensile test is generally performed on flat specimens. During the test a uni-axial load is applied through both the ends of the specimen. In this experiment the tensile test was determined according to ASTM D638-97 standard test method using Universal Testing Machine (UTM) i.e. Instron Model 1122 testing machine (Instron Corp., Conton,MA). The cross head speed for the test is maintained at 5mm/min and the test is repeated five times for each sample to get the mean value of the tensile strength. It was calculated according to the following equation:

\[ \sigma_t = \frac{F_{\max}}{A} \]  

Where \( \sigma_t \) = Tensile strength (N/m²), \( F_{\max} \) is the maximum (peak) load (N), A is the cross sectional area (m²).

Specimen dimension

Width of narrow section - 13mm, Width overall – 19mm, Gage length – 50mm
Length of narrow section - 57mm, Length overall – 165mm, Radius of fillet – 76mm
Distance between grips – 115mm, Thickness – (3.2±0.4) mm

![Fig. 1. Specimens for Tensile test measurement](image-url)
3.6. Determination of Flexural strength

Flexural strength describes the ability of the material to withstand bending forces applied perpendicular to its longitudinal axis. The three point bend testing method was used to determine the flexural strength according to ASTM D 790 – 97 using the same UTM machine i.e. Instron Model 1122 testing machine (Instron Corp. Canton, MA). The cross head speed for the test is maintained at 5mm/min and the test is repeated five times for each sample to get the mean value of the flexural strength. The test specimen for composite sample had nominal dimensions of 55×10×4 mm. The data recorded during the 3 – point bend test was used to evaluate the flexural strength (F.S) using the following equation

$$\sigma_f = \frac{3PL}{2bt^2}$$  \hspace{1cm} (2)

Where, $\sigma_f$ is the flexural strength, $P$ is the maximum load, $b$ the width of the specimen, $t$ is the thickness of the specimen and $L$ is the span length of the specimen.
4. RESULTS AND DISCUSSION

4.1. Tensile strength

Comparative picture of the tensile strength values for different filler content with and without glass fibre is shown in fig. (5). It has been found that with no addition of glass fibre, as the content of pine wood dust particles increases the tensile strength of the composite decline gradually when compared with the neat epoxy. With addition of 6.5 Vol%, 11.3 Vol%, 26.8 Vol% and 35.9 Vol% of pine wood dust and without glass fibre, the tensile strength of epoxy resin dropped by 8%, 9.8%, 17.3% and 27.4% respectively. There are two reasons for this decline. One is that PWD particles and the matrix may be too weak to transfer the tensile load; the other is the corner points of the irregular – shaped PWD particles resulting stress concentration in the epoxy matrix. However with the incorporation of glass fibre, the tensile strength improved substantially when compared with neat epoxy. With addition of 6.5 Vol%, 11.3 Vol%, 26.8 Vol% and 35.9 Vol% of pine wood dust and 9.6 Vol% of glass fibre the tensile strength of epoxy resin increased by 115%, 105%, 76.5% and 63.1% respectively. The values of tensile strength and flexural strength with and without addition of glass fibre for the composites with two components i.e epoxy and PWD are given in Table 1 and Table 2 respectively.

Fig. 5. Tensile strength of composites of different filler content with and without glass fibre reinforcement
4.2. Flexural strength

The flexural strength obtained from the experimental study for the particulate filled epoxy composite with varied proportion of pine wood dust with and without glass fibre is shown in fig.(6).

It is observed that the flexural strength of the composite with no addition of glass fibre is reducing gradually when compared with neat epoxy. With addition of 6.5 Vol%, 11.3 Vol%, 26.8 Vol% and 35.9 Vol% of pine wood dust particles the flexural strength of epoxy resin reduced by 5%, 10.4%, 21.6% and 24.1% respectively. However with addition of glass fibre, the flexural strength increased substantially comparing the neat epoxy. With addition of 6.5 Vol%, 11.3 Vol%, 26.8 Vol% and 35.9 Vol% of PWD and 9.6 Vol% of glass fibre the flexural strength of epoxy resin improved by 110.5%, 103.4%, 97.3% and 78.9% respectively.

![Fig. 6. Flexural strength of composites of different filler content with and without glass fibre reinforcement](image)

Table 1 Measured Tensile and Flexural strength values of composites without glass fibre

<table>
<thead>
<tr>
<th>Composite Sample No.</th>
<th>Glass fibre Content (Vol %)</th>
<th>PWD Content (Vol %)</th>
<th>Tensile Strength (MPa)</th>
<th>Reduction of Tensile strength with respect to neat epoxy (%)</th>
<th>Flexural Strength (MPa)</th>
<th>Reduction of Flexural strength With respect to Neat epoxy (%)</th>
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Table 2 Measured Tensile and Flexural strength values of composites with glass fibre

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<th>Glass fibre Content (Vol %)</th>
<th>PWD Content (Vol %)</th>
<th>Tensile Strength (MPa)</th>
<th>Improvement of Tensile strength with respect to neat epoxy (%)</th>
<th>Flexural Strength (MPa)</th>
<th>Improvement of Flexural strength With respect to Neat epoxy (%)</th>
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5. CONCLUSION

- Fabrication of hybrid composites consisting of glass – fibre reinforcement in epoxy resin filled with particulate pine wood dust is possible in simple hand lay up technique.
- An environmental waste like pine wood dust can also be gainfully utilized for the composite making purpose.
- The incorporation of glass fibre in PWD filled epoxy resin improved strength both in tensile and flexural modes of neat epoxy.
- Thus the incorporation of glass fibre serves the dual purpose of providing strength, both in tensile and flexural modes and for reducing the thermal conductivity of neat epoxy, thereby improving its thermal insulation capability.
- With light weight and improved mechanical properties like tensile and flexural strength, pine wood dust and glass fibre filled epoxy hybrid composite can be used for applications such as electronic packages, insulation board, food container, thermo flask etc.

REFERENCES


