Investigation of Mechanical properties of Glass Fibre Reinforced Honeycomb Panels

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Abstract. In this paper, detailed study and work have been done on the investigation of mechanical properties of glass fibre reinforced honeycomb panels. In this paper comparison between shredded E-glass fibre reinforced with polypropylene honeycomb panel and Woven E-glass fibre reinforced with polypropylene, honeycomb panel has been done. Fabrication of both types of specimens has been done using hand lay-up method. Specimens are machined into ASTM standards for testing. Tensile, flexural, Compressive, wear tests have been done. The density of the two specimens is calculated and compared. Wear test has been for different loadings (20N, 40N, 60N) and different rpms (200rpm, 400rpm, 600rpm) done on Pinion disk tribometer, flexural bending test has been done on three-point bending test machine. Tension and compression tests are done on a universal testing machine. In tension test, bending test and wear resistance the Woven E-glass fibre reinforced with polypropylene honeycomb panel specimen is having better results when compared with shredded E-glass fibre reinforced with polypropylene honeycomb panel. In compression applications, shredded E-glass fibre reinforced with polypropylene honeycomb panel is better than Woven E-glass fibre reinforced with polypropylene honeycomb panel.

1. Introduction
The exceptional performance of composite materials in comparison with the monolithic materials have been extensively studied by researchers [1-2]. Among the metal matrix composites Aluminium matrix based composites have displayed superior mechanical properties [3]. The sliding distance, weight percentage of the reinforcement material and applied load have a substantial influence on the height damage due to wear of the Al6061 and Al6061-TiO₂ filled composites [4, 5]. Honeycomb sandwich materials are generally used in weight sensitive and damping structures where high flexural rigidity is required, in many fields including the automobile industry, aerospace industry, construction [6, 7]. Honeycomb core sandwich panel is formed by adhering two high-strength thin-face sheets with a low-density honeycomb core possessing less strength and stiffness. By varying the core and the thickness and material of the face sheet, it is possible to obtain various properties and desired performance, particularly high strength-to-weight ratio [8]. Several types of core shapes and core material have been applied to the construction of sandwich structures. In this, the honeycomb core that consists of very thin polypropylene panel in the form of regular hexagonal cells perpendicular to the facings is used [9]. The honeycomb core must be stiff enough to prevent one face panel of the honeycomb sandwich panel from sliding over the other, when a honeycomb sandwich panel subjected to flexural loading. Such rigidities are called the transverse shear stiffness of the honeycomb core. Most honeycomb sandwich panels belong to this category of the core depth much larger than the thickness of the face panels, the transverse shear stiffness of the sandwich plate is almost fully
contributed by its core [10, 11]. For the ease of calculation cellular honeycomb core is idealized as a homogeneous material and its equivalent mechanical properties are used in analysis and design. Therefore, for the analysis and design of sandwich plates, the knowledge of the equivalent transverse shear stiffness of honeycomb is very important. Even if the concept of sandwich construction is very new, it has primarily been adopted for non-strength part of structures in the last decade. This is because dynamically loaded structures have a variety of problem areas to be overcome when the sandwich construction is applied to the design [12]. To enhance the attractiveness of sandwich construction, it is thus essential to better understand the local strength characteristics of individual sandwich panel members [13]. To optimize further the structural design, now a days we apply the principle of flexural rigidity and bending stiffness of sandwich plates. The weight ratio ranges for honeycomb core that is deduced on the basis of optimum mechanical properties offer a principle foundation for designing the structure of honeycomb sandwich panels. All the panels can be prepared easily by using hand layup method if reinforcing by polymer and base materials are resin and hardener. The experimental data agree satisfactorily with the theoretical predictions. The useful results are extended to give an available design tool for sandwich panel’s manufacturers [14]. One of the greatest challenges occurring in material science research is the development of new composite material is the procurement of materials required. Composite materials are better and are used more than the metallic materials because of their properties such as weight light, high stiffness and strength, design flexibility and high corrosion and crack resistance. In the present paper an attempt is made to fabricate polypropylene honeycomb polymer composite material and to study their mechanical and tribological characteristics.

2. Fabrication and Investigational details of FRCs

2.1 Details of matrix and reinforcement materials

The procurement of the materials needed for experimentation was from different sources. The fabrication done is by hand lay-up method. Resin (Araldite LY 556), Hardener (HY 951) was bought from EMAK Industries, Chennai. Two types of E-glass fiber used (Shredded, Woven E-glass fiber) are bought from Fibro Reinforced Industries, Bangalore. The polypropylene honeycomb structures are procured from Ace packing Industries, Bangalore.

2.2 Preparation of resin, E-glass fiber and polypropylene honeycomb panels

Initially polypropylene honeycomb panels are available as one square meter by one square. These panels are cut into 30cm*30cm. As thickness of polypropylene is very less cutting can be done using paper cutter. The both types of E-glass fibers are also cut into 30cm*30cm sheets. Proper care should be taken while storing these fibers because when the fibers are placed on one another directly the fibers may come out and stick to each other. Paper can be used in between so that the above problem stated can be eradicated. As polypropylene honeycomb is having very smooth surface, it is very tough for the resin to stick on the surface, so roughening of the surface is needed. Roughening of polypropylene sheet is done on grinding machine. Proper care should be taken while roughening because the excess stress on the honeycomb structures can be distorted the shape of the honeycomb panels. For every 100gm of resin (LY 556) should be mixed with 5gm of hardener (HY 951) can be changed.

2.3 Hand Layup method

The epoxy resin (LY556) is taken in a clean beaker. The weight of the epoxy taken is measured using weighing machine. 5% by weight of hardener (HY951) is mixed in the resin. Mixing should be done using plastic or wooden stirrer with hand. Proper care should be taken while mixing the hardener because if the stirrer is stirred quickly then resin will harden quickly inside the beaker itself before pouring on to the glass fibres. Initially glass of 3mm thick of 30cm*30cm glass is taken and wax layer is applied on one side of it and allowed for drying. Then layer by layer addition of E-glass fibre (either shredded or Woven) is added. Resin with 5% hardener is applied and spread uniformly on each and every sheet of the E-glass fibre. Four layers of E-glass fibres are placed on one upon another with epoxy for binding and at the center polypropylene sheet is placed above which again four layers of E-glass fiber is placed. On the above also glass with wax and polythene sheet is placed in order to give
the support for the specimen before it gets dried. Heavy weights are placed over it such that there won't be any gap or defects in the specimen. Proper care should be taken care while pouring and spreading the epoxy because epoxy will harden quickly. Hand gloves should be worn while doing the preparation process.

2.4 Experimental details
The specimens are machined according to ASTM standards. The tests performed are tensile test, compressive test, flexural bending test, wear test. The density of the two specimens were also calculated. The machining process was done on wire cutting machine. Proper care should be taken while machining because the accuracy of machining is needed. While machining the E-glass fiber, epoxy comes out as powder particles, so proper care and protection should be taken to cover nose and eyes using mask and safety glasses. The machined specimens are used for comparison of properties such as tensile strength, compressive strength, bending flexural strength, density, wear resistance of both shredded and woven E-glass fiber reinforced with polypropylene honeycomb panels. The tensile, compressive tests are done on universal testing machine, wear test is done on pin on disk tribometer at three different loads (20N, 40N, 60N) and at three different rpm (200rpm,400rpm,600rpm), the sliding distance is kept constant to 2000m. The wear loss in micrometers is measured at every 30 second interval. The flexural bending test was done on three point bending test machine. The mass of the specimens are calculated using digital weighing machine, dimensions such as length, breath, height are measured using digital Vernier calipers.

3. Results and discussions
3.1 Density calculation
As we can observe that woven E-glass fiber reinforced with polypropylene honeycomb panel is having more density value when compared with shredded E-glass fibre reinforced honeycomb panels. The woven fiber panels have 0.8702 g/cc and Shredded fiber panels have 0.86 g/cc.

3.2 Ultimate Tensile Strength (UTS)
The tensile test was conducted on the composites fabricated according to ASTM standards using the universal testing machine (UTM). Tensile load in a gradually increasing manner was applied on the composite and slowly extending it until it fractures. Throughout the tests results were plotted using software. For woven E-glass fibre the tensile strength is continuously increasing until failure. The maximum tensile strength is 63.2MPa. For shredded E-glass fibre the tensile strength is continuously increasing until failure. The maximum tensile strength is 41.9MPa. The percentage elongation is 8.1% and load at yield is 7.76kN. The compression between the two types of specimens have been shown in the above table. We can observe that woven has good tensile strength when compared with shredded E-glass fiber reinforced polypropylene honeycomb panels.

| Type of glass fibre | Tensile strength(MPa) | Percentage elongation(%) | load at yield (kN) |
|---------------------|-----------------------|--------------------------|-------------------|
| Woven               | 63.2                  | 6.5                      | 10.53             |
| Shredded            | 41.9                  | 8.1                      | 7.76              |

3.6 Compressive Test
The compressive test is done for the two types of specimens. Initially the specimens are machined according to ASTM standards. The compressive strength of the shredded E-glass fibre is around 37.9MPa, the load at peak is 2.87kN. The compressive strength of the woven E-glass fibre is 37.1MPa, the load at peak is 2.360kN. we can observe from the table below that compressive strength and load at peak is more for shredded E-glass fibre when compared with shredded E-glass fibre.
### 3.7 Flexural Bending Test

The three point bending flexural test is done for the two types of specimens. Initially the specimens are machined according to ASTM standards. The compressive strength for shredded E-glass fibre reinforced with PP honeycomb is 3.5 MPa and load at peak is 0.37 kN. The compressive strength for Woven E-glass fibre reinforced with PP honeycomb is 5 MPa and load at peak is 0.4 kN. As we can observe from the above table that compressive strength and load at peak is more for woven E-glass fibre when compared with shredded E-glass fibre.

| Type of glass fibre | Compressive strength (MPa) | load at peak (kN) |
|---------------------|---------------------------|-------------------|
| Woven               | 37.1                      | 2.360             |
| Shredded            | 37.9                      | 2.87              |

### 3.8 Wear Test

Initially the specimens are made by machining. The dimensions of the specimen are 2.5 cm x 1 cm. The specimen is kept in pin on disk tribometer. The loads and rpm are varied and wear is calculated. The sliding distance is maintained for 2000 m, the time for which experiment should run is calculated. The diameter of the tribometer is 120 mm. For 200 rpm the calculated time is 30 minutes, for 400 rpm the calculated time is 15 minutes, for 600 rpm the calculated time is 12 minutes. The wear at 200 rpm and 20 N load is done, wear for every 30 seconds is noted and comparison between the two fibres is done as shown in the figure 4 a below. As we can observe that the wear loss is continuously increasing as the sliding distance increases, the wear loss is more for shredded E-glass fibre reinforced polypropylene honeycomb panels.

The variation of volumetric wear loss against the sliding distance has been shown in figure 4a-6c. As the wear increase, the loss also increases.

![Wear at 200 rpm](image)

**Figure 4 a.** The volumetric loss vs sliding distance graphs for 20 N, 200 rpm.
Figure 4 b. The volumetric loss vs sliding distance graphs for 40N, 200rpm.

Figure 4 c. The volumetric loss vs sliding distance graphs for 40N, 200rpm.

Figure 5 a. The volumetric loss vs sliding distance graphs for 20N, 400rpm.
Figure 5 b. The volumetric loss vs sliding distance graphs for 40N, 400rpm. The wear at 400rpm and 40N load is observed and comparison of wear is shown in the figure 4 b. The wear at 400rpm and 60N load is observed and comparison is done in figure 5 c.

Figure 5 c. The volumetric loss vs sliding distance graphs for 60N, 400rpm. The wear test at 20N load and 600 rpm, sliding time is calculated and the value is about 12 minutes.
Figure 6 a. The volumetric loss vs sliding distance graphs for 20N, 600rpm.

The wear at 600rpm and 40N load is observed and comparison of wear is shown in the figure 6 b.

Figure 6 b. The volumetric loss vs sliding distance graphs for 40N, 600rpm

The wear at 600rpm and 60N load is observed and comparison is done in figure 6 c.
4. Conclusions on the studies of mechanical properties of glass fibre reinforced composites

The fabrication of both shredded and woven E-glass fibre reinforced with polypropylene honeycomb as core material was successfully done, specimens were machined according to ASTM standards and were successfully tested. Density for woven E-glass fibre reinforced with polypropylene honeycomb is more than specimen shredded E-glass fibre reinforced with polypropylene honeycomb. In tensile test, bending tests woven E-glass fibre reinforced with polypropylene honeycomb has shown better properties when compared with shredded E-glass fibre reinforced with polypropylene honeycomb. In compressive test woven E-glass fibre reinforced with polypropylene honeycomb are having less load carrying capacity when compared with shredded E-glass fibre reinforced with polypropylene honeycomb. Volumetric loss in wear test is increasing for both types of specimens as the sliding distance increases. Woven E-glass fibre panels is having more wear resistance when compared with shredded E-glass fibre panels because woven E-glass fibre has more directional load distribution when compared with shredded E-glass fibre.

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