Effect of Span Length on Flexural Strength of Glass Fiber Reinforced Polymer Matrix Composite

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Abstract. Investigation and assessment of mechanical properties for FRP (Fiber Reinforced Polymer) composites have been instrumental in qualifying it for the final use. Pronounced among mechanical properties is flexural strength which diversifies with varying test span length, Specimen depth and temperature for different materials. Current work focuses on unearth the optimum span length of epoxy Glass fiber reinforced composites for which flexural strength is to be scrutinized. Investigations for flexural test in accordance to ASTM Standard D790 are executed by altering the span lengths to acknowledge the functioning of the flexural modulus and strength thereby acquiring an optimum span length, which, can be employed by the composite designers and manufacturers to engineer meliorated testing procedures. From the experimental results it is found that the composite failed by shear mode at lower span lengths.

1. Introduction

A composite material comprises reasonable blend of at least two constituents which are consolidated at a plainly visible level and insoluble in one another. The fortifying stage material might be as particulates, fibers/filaments, particles or flakes. The continuous constituent material is matrix [1, 2]. Lately, the polymer matrix composites with continuous fiber reinforcement are presently finding appropriate materials for different applications in electrical, building, packaging and automobile sectors due to their numerous practical advantages such as quick production, ease of fabrication and less manufacturing expenses over conventional materials [3]. One of the foremost difficulties for the material analysts is the improvement of high strength to weight proportion materials for the complex formed structures like car structures, aerospace and turbine blades [4]. Flexural property is one of the important utilized property in describing the mechanical properties of composite materials. The flexural property reveals to the maximum stress magnitude experienced inside the test specimen material at its point of fracture. The flexural or bend test quantifies the amount of force needed to bend the specimen under three or four point bend test. This information is commonly used to identify materials for products that will uphold loads without the flexing. Epoxy composite reinforced with glass fibers found to be a blend of mechanical and physical properties which can't be gotten by other conventional materials [5-13]. Other researchers also carried out work on nanocomposites [14-21]. These are generally utilized because of simplicity of accessibility of glass strands/fibers and easy of preparing methods received for creation of parts. Research is in progress to tailor their properties for various conditions of loading. The primary aim of this paper to evaluate the effect of span length on
the flexural strength of glass fiber reinforced composite in detail in order to evaluate the failure mode of composite.

2. Experimental

2.1. Materials

In this current research work LY 556 epoxy as base material and Aradur 5200 as hardener were utilized as reinforcements. E-glass 1200 Tex glass fiber tows were utilized as reinforcement. Filament winding technique was used in preparing composite.

2.2. Material processing

The materials needed for the manufacturing are set up as per the prerequisites. The essential constituents are the matrix and reinforcement. For the fabrication of a lamina with glass fiber, creel stand setup is used to support fiber spools. The fiber tension needed for the glass fibers/filaments is given near the creel stand so the fiber winding cycle can be completed with no issue of lose filaments during winding [7, 8]. The matrix material with the fundamental constituents which are epoxy and hardener/curing agent is prepared for the manufacturing process. The proportions are blended at 100:27 by weight. All the instruments should be thoroughly cleaned with acetone for the preparation of matrix mixture. The hardener/curing agent, epoxy resin and dilatants are measured independently using measuring flask as per the standard requirement and blended completely with a stirrer (figure 1).

The epoxy is the base or matrix material of the composite. In the preparation of laminate hardener acts as curing agent. The diluents diminish the matrix viscosity so that the impregnation of epoxy mixture on to the glass fiber can be done easily. The epoxy mixture (base matrix) is then filled into the resin bath apparatus of one-liter limited capacity where the glass fiber picks up the epoxy mixture. The epoxy resin bath set up comprises drum, comb, scraper blade and doctor blade. The glass fiber spool setup is fixed on the creel stand is gone through the arrangements furnished with a tension applied through the resin bath on to the filament shown in figure 2, where the drum/mandrel is utilized for the fiber winding. The doctor blade is used to keeps up a uniform/constant thickness of epoxy mixture over the mandrel and the glass fiber is wound over the mandrel which is partially dipped in the resin bath. The cylindrical drum moves as the glass fiber is wound over the mandrel that picks up resin. The scraper blade arrangement, which is arranged after the drum, drains the extra resin mixture from the glass fiber it ensures is a uniform/constant resin mixture distribution on to the glass fiber. The extra resin is removed by using scraper blade which is fixed after the mandrel in filament winding machine.
These glass fibers are wrapped on a cylindrical drum of the filament-winding machine and are sliced to get a required laminate. This laminate is sliced into several test specimens as per the number of plies and desired orientations of laminas. The mould is then kept in a hydraulic press at a 15 bar pressure for the drain of excess resin along with curing process i.e., 80oC for 60 minutes and 120oC for next 360 minutes. The standard time and temperature for polymerization are 360 minutes and 120oC respectively. Test specimens were taken/cutout from laminate as per ASTM D790 standard. In the present composite the volume fraction of fibers found to be 58.63%.

2.3. Flexural testing

Rectangular cross sectional area composite test specimens with an average approximate thickness of 3mm, width 10mm and span lengths of 30, 40, 60, 80 and 100mm were used to evaluate effect of span length on flexural strength. In this three point bend test the composite specimen lies on a two roller supports and the load is applied at the centre of the specimen which results in 3 point bending at 2mm/min cross head speed according to ASTM D790 and performed at ambient temperature. These specifications of test specimen are according to ASTM standard D790. The test is said to be complete when the specimen fracture occurs. The 3 point bending test provides data to calculate the flexural behavior of the composite. The basic advantages of a this test is the testing and specimen preparation. The testing facility used in this work is shown in figure 3.

This test conducted by using UTM which is attached with standard test fixture. Results of this test mainly depend on accuracy of test specimen preparation, temperature of test environment. Flexural strength (\(\sigma_f\)) of three point bend test (rectangular cross-sectional specimen) calculated by using the following relation.
\[ \sigma_f = \frac{1.5FL}{bd^2} \]

Where, \( \sigma_f \) is flexural strength, \( F \) is maximum load, \( L \) is span length, \( b \) is width, \( d \) is thickness of tested beam.

3. Results and Discussion

All the test composite specimens were tested according to ASTM standard D790 and five specimens were tested in each case. For each composite test specimen, rectangular dimensions were accurately noted, and then peak load at which fracture of the specimen takes place (\( F \) and it also produces flexural stress in the specimen. The equation to find out flexural strength is given in the previous section. The average flexural strength value obtained for glass fiber composite of span length 30mm is 342.032MPa, for 40 mm span length is 480.93MPa, for 60 mm span length is 579.17MPa, for 80 mm span length 447.99 MPa and for 100 mm span length the flexural strength is 428.15 MPa. The load versus deflection data obtained from UTM is shown in figures 4 and 5. For the sake of clarity only 2 curves are (30mm span length-figure 4 and 80 mm span length- figure 5) shown.

![Figure 4](image1)

**Figure 4.** Flexural strength variation of load and deflection (span length 30 mm)

![Figure 5](image2)

**Figure 5.** Flexural strength variation of load and deflection (span length 80 mm)

The above results obtained on the variations in the flexural strength with different span lengths under 3 point bend loading. Two distinct modes of fracture are observed first, the tensile failure when the span length is 100mm. Second, the shear failure occurred when the span length is less than or equal to 60mm. And, a mixed mode of tensile and shear fracture at span length of 80mm. Specimens with 30 mm underwent significant damage (visible crushing and crumbling) under the lower loading pins and as, a result, a large variation in flexural strength is observed. Hence, data pertaining to 30 mm span is cannot considered for any further analysis, except for noting the fact that the mode of failure is shear. And for specimens with remaining span lengths i.e., 40mm, 60mm and 80mm are observed to be failed due to mixed mode (tensile and shear). Only in the specimens with 100 mm span length are observed tensile failure. Hence, for this glass fiber reinforced composite the valid flexural strength value is 428.15MPa. Specimen geometry and experimental values are included in table 1.
### 4. Conclusions
1. The glass fiber reinforced composite was successfully fabricated by using filament winding technique.
2. In this project work, three point bend test was conducted to evaluate the flexural strength value of glass fiber reinforced composite with varied span lengths.
3. At lower span lengths (30mm) shear failure is observed and at higher span lengths (100mm) tensile failure is observed. These results clearly reveal that span length plays a significant role in the failure mechanism or mode of failure.
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