Study of Quasi-Static Compression Behaviour of Hollow Tubes Made of Glass/Epoxy Composite

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Abstract. Composite materials have been used widely in various engineering fields. Composite materials possess low weight, corrosion resistance property, and specific strength, and due to these facts, composite materials are becoming popular among researchers and scientists. Now a day, the glass fibers offer the potential to acts as a reinforcing material for composites alternative to the use of glass fiber, carbon fiber and other man-made fibers. In present work hallow tube composites of epoxy – glass fiber was prepared by hand lay-up technique. Mechanical characterizations of prepared hollow tube composites were carried out. Mechanical results were improved; we considered the hollow tubes of glass fiber and epoxy in different proportions such as 50% of glass fiber and 50% of epoxy, 60% of glass fiber and 40% of epoxy, 66% of glass fiber and 34% of epoxy. The maximum compression strength was obtained in the ratio of 50:50 that is 57.69N/mm², the maximum load at the peak was obtained in the ratio of 60:40, that is 14.61kN and the maximum deformation at the peak was obtained in the ratio of 60:40 that is 8.03mm.

1. Introduction
Fibre-reinforced polymers receive more attention in various structural applications. Conventional materials used in fibre-reinforced polymer composites, such as carbon fibres and glass fibres have great features in high tensile strength, chemical resistance, dimensional stability as well as excellent insulation properties. Today, the use of fiber reinforced composite materials are more selective material rather than metal as seen in many applications of technology, present knowledge has reached a good level in some of the field related to composite. The composite material is a combination of two or more materials which is known as a structural material that consists of two or more combined constituents that are combined at a microscopic level and are not soluble in each other [1]. The reinforcement phase is one of the important constituents in composite material whereas another phase is matrix material in which the first constituent is added. Fibers, flakes, and particles are used as material for reinforcement in composite material [2]. In the fabrication of a composite continuous matrix phase may be considered. The matrix acts as a protection layer for fiber reinforcement from environmental harms, fibers which are the main load barring agents in composites and this matrix phase even acts as stress transferring agent to fibers and makes the orientation and location of fibers for desired specification. N. Movahedi et al. [3] studied on Quasi-static compressive behavior of the ex-situ aluminum-alloy foam-filled tubes under elevated temperature and concluded that the ex-situ ordered aluminium cellular structure filled tubes gives excellent compression properties compared with the empty tubes. Foam filled tubes gives excellent energy absorption, axial & radial compression properties [4]. The axial crushing tests of empty and partially foam-filled thin-walled circular and square columns were performed by Altin et al. [5]. The impact of physical measurement on the crashworthiness of these structures was investigated.
Measurements of the internal cylinder were found to have huge effect on the basic crashworthiness of froth filled twofold cylinders. The arrived at the midpoint of pound power, explicit vitality ingestion, vitality assimilation per stroke and vitality engrossing viability factor of flimsy walled roundabout structures are higher than those of dainty walled square structures, individually. Froth filled single and twofold round cylinder structures are prescribed as crashworthy structures because of their high pulverize power effectiveness and vitality engrossing proficiency [6]. Many researchers have investigated compressive strength of different types of thin walled tubes which are honeycomb type [7], natural/glass hybrid [8], metal-composite [9] and natural fiber. Analysis of crashworthiness performance of thin-walled cylindrical tubes was carried out by Rezvani M J et al. [10]. Many composites are prepared by reinforcing epoxy and steel embedded with natural fibers and synthetic fibers in vinyl ester etc. The study of Albahash and Ansari [11] on natural jute fiber with Kevlar fiber in the application of energy absorption hollow tube, from their investigation it’s shows that the hybrid natural/synthetic fiber-reinforced polymer have a better result in crashworthiness efficiency compared with single natural jute fiber. They determined that foam-filled square columns show highest crash performance. These types of models were validated experimentally by Abramowicz and Jones [12]. Alexander [13], Pugsley [14], Abramowicz [15] and Abramowicz and Jones [16], Singace et al. [17] and Wierzbicki and Bhat [18] to predict the crush behavior of the circular tubes. The common main observation of these studies was that the energy absorption capacity can be increased by using metallic foams. The compression properties can be improved or can be enhanced by using some best metal tubes based on the application. Hybrid composites can be made using composition with carbon/aramid tubes [19] with glass. Glass fiber reinforced plastic (GFRP) thin-walled tubes have excellent mechanical properties and highly feasible design ability, and thus have been shown many applications in oil and construction industrials.

The strength of the composite is enhanced due to existence of fiber reinforcement Synthetic fibers such as E-glass fibers are used in various applications from centuries by mankind. Many possibilities of using E-glass fibers have been explored, by utilizing the useful mechanical properties. Production of hard boards, particle boards, sandwich panels and hollow tubes were done by using most of the E-glass fibers. Researchers have developed new dimensions of using synthetic fibers for the production of polymer Synthetic fiber based composites has become important materials in day today uses and also in other applications like air craft, spacecraft etc. due to the light weight, high strength to weight ratio, corrosion resistance and other advantages.

2. Materials and Fabrication

To fulfill the objective of this research work, the compression behaviour of glass fiber reinforced polymer composite tubes manufactured with three different compositions were analysed.

2.1 Materials

2.1.1 E-Glass Fiber

E-glass or electrical grade glass was originally developed for standoff insulators for electrical wiring. It was later found to have excellent fiber forming capabilities and is now used almost exclusively as the reinforcing phase in the material commonly known as fiber glass.

2.1.2 Epoxy resin

Epoxy resin has high strength and mechanical adhesiveness properties due to which these are commonly widely used in industrial applications. It has good temperature and chemical resistant as it is a good solvent. Atul Ltd. Lapox L–12 is used for our composite material.

2.1.3 Hardener

Lapox K-6 is a light yellow aliphatic polyamine hardener suitable to cure epoxy resin at ambient Temperature. When cured with epoxy resin it provides short pot life and faster cures speed. Due to very low viscosity and low dosage, it finds suitable for applications like adhesive, motor and casting of small electrical component. E-Glass fiber, Epoxy resin and Hardener materials are shown in ‘Figure.1’.
2.2. Fabrication
In the present work E-glass fiber is taken as reinforcement in composite where as matrix resin used is epoxy for preparation of composite hollow tubes. The E-glass fiber mat cut around 350mm to 450mm and also specimens are prepared according to the ASTM standards. In the present work specimens are prepared for three different compositions. The table 1 shows the compositions used for fabrication of composite hallow tube. The moulds from selected materials are prepared to required dimensions. The Prepared moulds are then cut to specified dimension by using hacksaw blade for the fabrication of required composite material.

2.2.1 Hand layup method
The prepared mould is then fixed to lathe machine running at low speed for hand layup method. Outer surface of the mould is wrapped with polythene sheet for better finish and easy removal, a thin layer of epoxy resin is applied. One layer E-glass fiber mat is wrapped on the epoxy applied followed by a layer of epoxy resin. The same process is continued until the required thickness of the composite tubes for the application is met, then cured it for 12 to 24 hours. The prepared composite is cut to the required dimension for testing using hacksaw blade. The hacksaw blade cutting process doesn’t give perfect dimension for the specimen so the cut specimen is then filed for getting exact dimension as per ASTM standards. The ‘Figure.2’ shows the fabrication of a glass fiber composite hollow tube.

| Table 1. Composition of Testing Specimens |
|------------------------------------------|
| Configuration | Reinforcement (E-Glass) | Matrix (Epoxy Resin) |
|----------------|--------------------------|----------------------|
| 1              | 50                        | 50                   |
| 2              | 60                        | 40                   |
| 3              | 66                        | 34                   |

Figure 1. Materials used for Fabrication, (a) E-Glass, (b) Epoxy Resin and (c) Hardener K-6

Figure 2. Hand Layup method of fabrication
3. Experimentation

This test procedure covers the determination of compressive strength of hollow tubes made of glass-epoxy composite. ASTM-D3410 standard is used for preparing specimens in this present work. The specimen dimension used is 250mm length and 50mm diameter as shown in ‘Figure.3’. The standard used entails the compressive properties determination in the form of circular test specimens. The test is conducted for specimens by considering three configuration specimens and the results are discussed in next section.

![Compression Test Specimen and Experimental setup of compression test](image1)

**Figure 3.** a) Compression Test Specimen, b) Experimental setup of compression test

The compression test is conducted according to the ASTM standards. Each test specimens of hollow tube are 250mm length, 50mm inside diameter and 2mm thickness were prepared and for this test UTM of capacity 1000kN used. Testing machine is calibrated before use. After testing of specimens, the readings are taken and calculated the required mechanical properties and tabulated. ‘Figure.4’ shows the different configuration specimens after compression testing.

![Specimens after testing a) configuration 1, b) configuration 2, c) configuration 3](image2)

**Figure 4.** Specimens after testing a) configuration 1, b) configuration 2, c) configuration 3

4. Results and Discussion

It is very important to know the mechanical properties of the polymer composites before any application; it is one of the most important aspects to determine the mechanical properties like stiffness, strength, elastic modulus etc. Mechanical properties of fiber reinforced composites depend on the nature of matrix material, the distribution and orientation of the reinforcing fibers, the nature of the fiber-matrix interfaces. A very small change in the physical nature of the reinforcement for a given matrix may result in prominent changes in the overall mechanical properties of composites. The results obtained for compression test are shown and discussed individually.

4.1. Compression test results for different compositions

Figure 5 shows load v/s Deformation curve for a composite hollow tube made up of E-glass fiber and epoxy resin. The maximum load of the tested machine is 1000kN and specimen cross-section area is 233.67mm². Output data of the configuration 1, configuration 2 and configuration 3 are, load at peak is 13.9kN, 14.6kN and 12.67kN, deformation at peak load is 7.45mm, 8.15mm and 7.29mm respectively.
Observations can be clearly noted from that; peak load and deformation was highest for 60-40 composition as compared to other compositions.

Figure 5. Load v/s Deformation curve for a composite hollow tube Made up of E-glass fiber and epoxy resin (a) Configuration 1, (b) Configuration 2 (c) Configuration 3

4.2. Comparison between different configuration

The comparisons of load at the peak, deformation at peak load and compression strength for three configurations are listed in Table II. These comparisons are illustrated graphically in ‘Figure.6’ as shown below.

Figure 6. (a) Load v/s Deformation of different configurations, (b) Compression Strength of different configurations
The compressive properties of models like square tube made of metals and composites were compared from the work done by Ma Quanjin et al. [19] Chamila Batuwitage et al. [20] Daniel Paul et al. [21] H.R. Zarei et al. [22] and J.M. Babbage et al. [23] and aluminum composite [23] showed a peak load between a range of 24kN to 47kN. Foam filled aluminum tube [22] showed a range of 65kN to 71kN. The results were compared with glass-epoxy composites with addition of hollow glass tubes which showed a range of 8kN to 14.5kN with different composition where as in our work we got a range of 12.67kN to 14.61kN as peak load for crushing.

5. Conclusions
In this work, the comparison between three different compositions of hollow tubes was made up of glass fibre and epoxy polymer composite. The experiments are conducted to evaluate the mechanical properties such as the quasi-static compression test of prepared polymer hollow composite tubes. The compositions used are 50% of matrix material and 50% of fibre fraction, 40% of matrix material and 60% of fibre fraction, and 34% of matrix material and 66% of fibre fraction. The following observations are made and conclusions are drawn based on the limited test results.

It is observed that matrix material has a significant influence on the load-displacement relationship of the glass fibre epoxy polymer hollow composite tube. Load carrying capacity increased when there is a good adhesion property between fibre and matrix. From the results, we can conclude that glass fibre of 60% and epoxy of 40% have higher yielding capacity then compared to the other two ratios of the composite. Compression strength observed for the first composition of 50% fibre and 50% epoxy was 57.69N/mm² is higher compared to other two compositions. Deformation at the peak for 60% of fibre and 40% of matrix composite is 8.15mm which is high compared to other two compositions.

By comparing the quasi-static compression test, it can be concluded that for forecasting the average crushing force of compression test of hallow tubes, 9 layers of samples with a depth of 50mm and thickness of 2mm with a fiber layout, it can be used to the mean force of the quasi-static test. It is also possible to predict that the mean force values and degree of destruction of these specimens under axial dynamic test through the gradient of displacement force.

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