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Experimental Investigation of Steel Tube Reinforced Composite L-Joint and T-Joints

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ABSTRACT

In today's growing world composite materials are one type of materials which satisfy the unabated thirst for new materials which has to satisfy the various requirements in various fields. Glass fiber reinforced polymers (GFRPs) is a fiber reinforced polymer made of a plastic matrix reinforced with fine fibers of glass. These fibers are randomly arranged but it is commonly woven into a mat and the plastic matrix is a thermosetting plastic which are epoxy, polyester resin or vinyl ester or a thermoplastic.

Continuous research efforts are being made to improve specific strength / strength to weight ratio of composite structures. The present investigation is one such effort where in the study related to the influence of hollow steel tube reinforced in composites has been made. The study is primarily experimental in nature and the comparison is made on realizing the relatively higher strength to weight ratio of L beam and T beam. Experimental investigation on strength of hollow steel tube reinforced, E-glass polyester composite material T-section and L-section is carried out to increase the specific stiffness of glass/polyester composite material. The main aim of these works is to obtain the stiffness to weight ratio of the material. The research work here is concerned with the fabrication and analysis of steel tube reinforced glass/ polyester composite T-section and L-section, which can be used for several applications purpose. The experimental results are compared for specimen with the without steel reinforced specimens and with steel tube reinforced specimens.

Keywords *- Reinforcement, E-glass, Polyester, Composite material, Stiffness.*

1. INTRODUCTION

In today's growing world, there is an unabated thirst for new materials which has to satisfy the various requirements for applications like electronics, structural, transportation, house-hold , electrical, industrial, medical, aerospace applications, etc. where metals are used in these applications. With the progress in the field of material science and technology which given birth to the fascinating materials called composites. It is impossible for any material to fulfill all the properties by using a single metal alone, hence these new materials has been developed which will satisfy the requirements. Composite materials are heterogeneous at microscopic scale but looks statistically homogeneous at macroscopic scale which meets the requirements of specific design and function.

Composites are formed by constituent materials together to form overall structure that is better than the sum of individual components. The dissimilar materials which forms composite are called constituents or constituent materials which have significantly different properties. The properties of the composites formed may not be obtained from these constituents and they are obtained by combining these components.

Conditions for the component to be called as composite material:

1. When two or more materials are combined to form a composite there should be a significant change in property, one has to see the changes in the properties when one of the constituent material is in platelet or fibrous form.

2. The content of the constituents should be more than 10% by volume and the property of one constituent must be much greater than 5% to the corresponding property of another constituent.

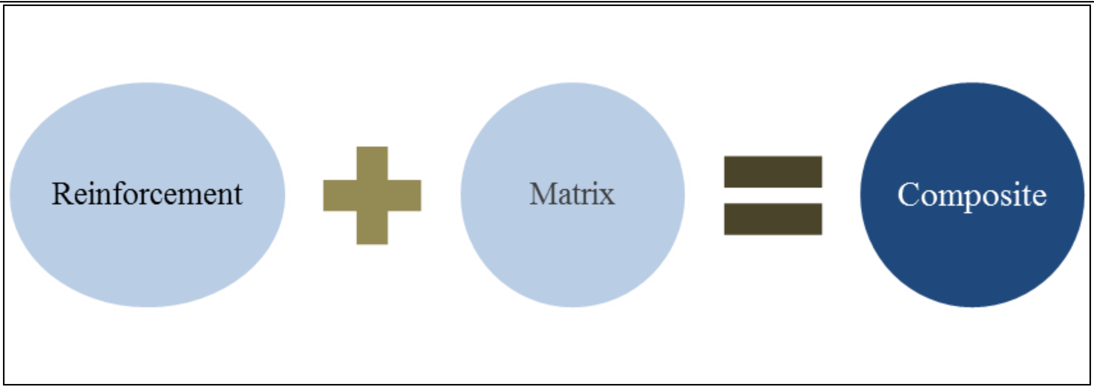


Fig 1: Constituents of Composite Materials.

2. MATERIAL SELECTION

Fibers are the main bulk constituents of the reinforcement material in the structural composites. These fibers are important class in the reinforcements as they transfer strength to the matrix and satisfy the conditions as required. It is defines as material with aspect ratio (i.e. l/d ratio) 10:1, where l-length of fiber, d- diameter of the circular fiber (i.e. lateral dimension). The lateral dimension d is assumed to around less than 254µm. in structural normally the diameter varies from 5µm- 140µm. The used in the manufacturing of some low density fibers are the elements with lower atomic numbers. The elements in the manufacturing of advanced fibers and other conventional fibers are show below.

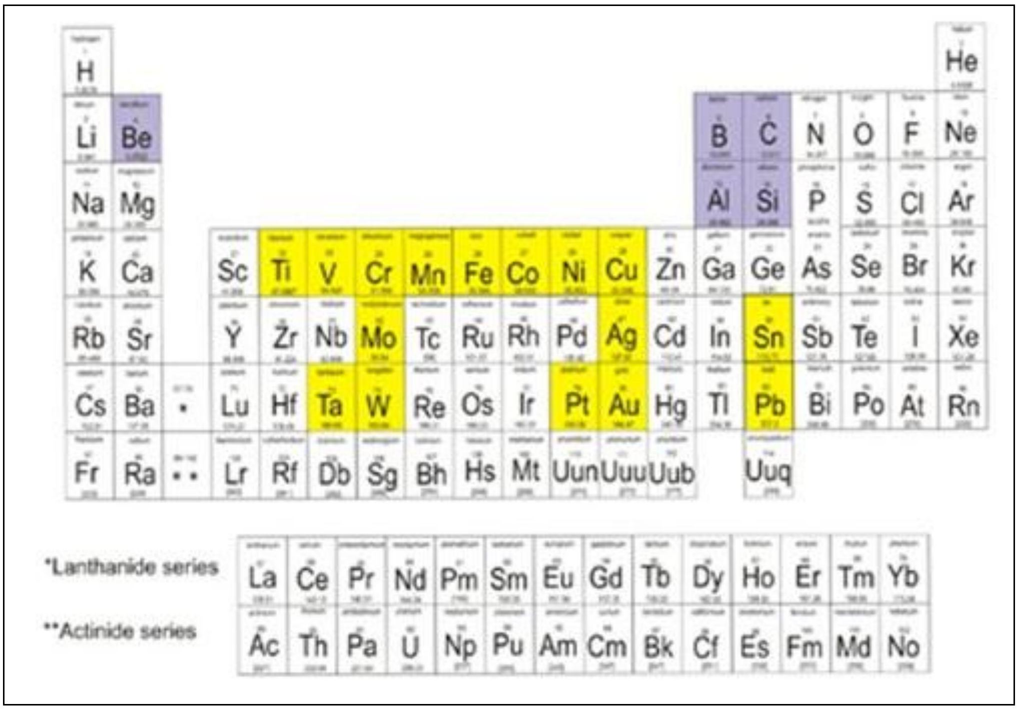


Fig 2: Table Showing the Materials used in Advanced Composites (Blue Blocks) and Conventional Metals (Yellow Blocks).

The properties of fiber such as strength and stiffness properties are significantly higher when compared to bulk material from which fibers are formed. Many of the common fibers are brittle in nature, their tensile strength is lesser than the theoretical strength. It is because these properties are controlled by the size of the flaw material and shape. The flaw size in the bulk material is large. As the size of the fiber diameter is small the size of the flaw will be lesser than the diameter of fiber. The smaller size of flaw in reduces criticality of the flaw and hence the Tensile strength is increased.

2.1 Glass Fibers

Glass fibers are the best known reinforcements in the fiber reinforced composites due its appealing combination of low cost and high strength and stiffness. Low density, insulation capacity, resistance to chemicals and resistance to temperature are the additional properties. The major disadvantage is that it tends to break when subjected to high tensile stresses for long time, whereas it is resistant to short time loading. The glass fibers are produced by extruding molten glass at a temperature around 1200^{0}C through the holes of spinneret with diameter of 1-2mm and then drawing the filaments to produce fibers having diameters usually between 5-15μm. The major constituent of glass fiber is silica which is added with the different types of oxides in varying amounts to obtain different types of glasses.

The types of glass fibers and their key features are as follows:
- E glass - high strength and high resistivity.
- S2 glass - high strength, modulus and stability under extreme temperature and corrosive environment.
- R glass - enhanced mechanical properties.
- C glass - resists corrosion in an acid environment.
- D glass - good dielectric properties.

2.2 Polyester Resins

Most commonly used in glass fiber reinforcement are unsaturated polyesters dissolved in styrene. These polyesters are produced by reaction from alcohol such as propylene glycol or ethylene glycol with various organic acids. Depending upon type of resin to be produced different types of alcohols and acids are used. The polyester/styrene becomes hard and rigid substance on polymerization. This process is commonly called as curing.

3. COMPOSITE FABRICATION

Composite materials are fabricated through a large number of processes. The choice of a specific fabrication method strongly depends on chemical attributes of matrix, and also the nature of final product shape. Thermoset composites are processed either using "wet-forming" processes, or processes which used premixes or prepregs. In wet-forming processes, resin in the fluid form is used to form the final product in which the resin is cured in the in the product. The curing can be done with the help of application of external heat and pressure.

• Typical wet-forming processes include:
Hand layup
Bag molding
Filament winding
RTM (resin transfer molding)
Pultrusion.

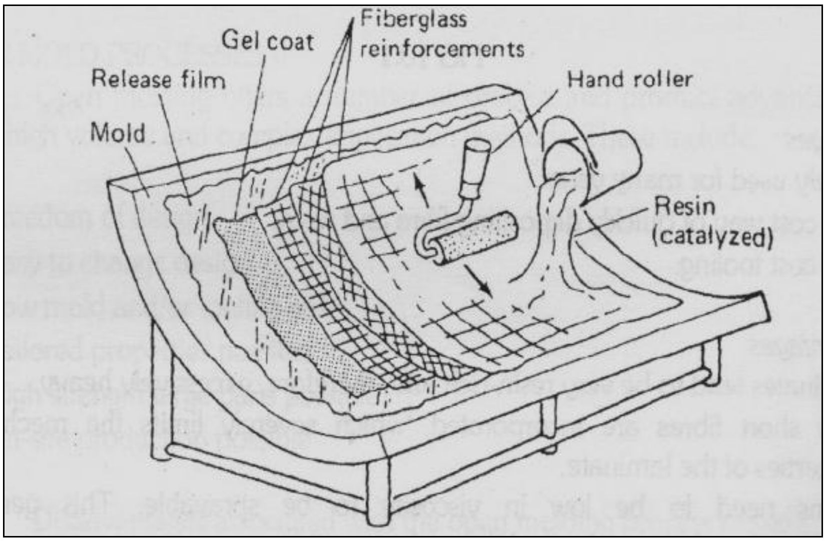


Fig 3: Hand Layup Process.

Hand lay-up technique is the simplest method of composite processing. The infrastructural requirement for this method is also minimal. The processing steps are quite simple. First of all, a release gel is sprayed on the mold surface to avoid the sticking of polymer to the surface. Thin plastic sheets are used at the top and bottom of the mold plate to get good surface finish of the product. Reinforcement in the form of woven mats or chopped strand mats is cut as per the mold size and placed at the surface of mold after perspex sheet. Then thermosetting polymer in liquid form is mixed thoroughly in suitable proportion with a prescribed hardener (curing agent) and poured onto the surface of mat already placed in the mold. The polymer is uniformly spread with the help of brush. Second layer of mat is then placed on the polymer surface and a roller is moved with a mild pressure on the mat-polymer layer to remove any air trapped as well as the excess polymer present. The process is repeated for each layer of polymer and mat, till the required layers are stacked. After placing the plastic sheet, release gel is sprayed on the inner surface of the top mold plate which is then kept on the stacked layers and the pressure is applied. After curing either at room temperature or at some specific temperature, mold is opened and the developed composite part is taken out and further processed. The schematic of hand lay-up is shown in fig 1. The time of curing depends on type of polymer used for composite processing. For example, for epoxy based system, normal curing time at room temperature is 24-48 hours. This method is mainly suitable for thermosetting polymer based composites. Capital and infrastructural requirement is less as compared to other methods. Production rate is less and high volume fraction of reinforcement is difficult to achieve in the processed composites. Hand lay-up method finds application in many areas like aircraft components, automotive parts, boat hulls, diase board, deck etc.

In this work wooden mould is used for hand layup process. Procedure for the composite specimens without reinforcements is as follows. A wooden block of size 4x4x20 inches is used which is made in the form of v-block. During the layup process mylar sheet is used as the releasing film is spread on the wooden block which doesn’t allow the layers to adhere to the wooden mould another releasing agent used is the waxpol which doesn’t allow the mylar sheet to stick to the specimen. Glass fiber mat is cut into the required dimensions of size 30x24 is used. The resin used is the polyester which is taken into the tumbler to which hardener or catalyst and accelerator called cobalt napthanate is mixed in the ratio 100:1. The matrix is stirred well and applied onto the mould by using the brush. After applying the first layer of gel coat fiber is spread on the mould and light pressure is applied by using the roller, next one more layer of gel coat is used and on top of that a layer of glass fiber is applied and this process goes till we obtain the required thickness. In this work we have used 11 layers of glass fibers. Once after applying all the fibers surface mat is used to give the surface finishes which doesn’t add for the thickness of the specimen. Once after completion of the hand layup process the male mould is used which is placed on top of the mould and load is applied by using the C-clamps to squeeze out the excess resin in the specimen. The mould is allowed for curing for one day. During curing the exothermic reaction takes place and the specimen becomes hard. After curing the male mould is removed and the specimen is cut into required dimensions.

For the specimen with reinforcements the procedure remains same as above only change is that the steel tubes are inserted after third and sixth layer of the glass fiber. Some of the specimens with reinforcements and without reinforcements are shown below.

Fig 4: Wooden Mould.

Fig 5: Glass Fiber.

Fig 6: Polyester Resin.

4. EXPERIMENTAL SETUP AND TESTING

In this work the steel tube reinforced composite specimens are compared with the specimens without reinforcement by considering their stiffness to weight ratio. The weight of the specimen is measured by using the standard weighing scale. The stiffness of the specimen is defined as the load by deflection. The load is applied on to the specimen by using the standard weights and the deflection is measured by using the dial gauge. Here two dial gauges are used to measure the deflection on the vertical deflection and the horizontal deflection. The load is applied uniformly at a particular point by using the dead weights. For a particular load applied deflection on both sides are measured and the stiffness is calculated by using the formula.

$$\text{stiffness} = \frac{\text{load}}{\text{deflection}} \text{ (N/mm)} \quad (1)$$

$$\text{stiffness to weight ratio} = \frac{\text{stiffness}}{\text{weight of the specimen}} \text{ (/mm)} \quad (2)$$

The composite specimen is held to the vice by using the C-clamp. By Using the magnetic base of the dial gauge table it is fixed to the base and the dial reader is pointed at a suitable point which reads the deflection at that point. Initially the dial gauge readings are noted down only with weighing pan without any weights. The testing procedure carried out to measure the deflection for the load applied is shown in the following figures:

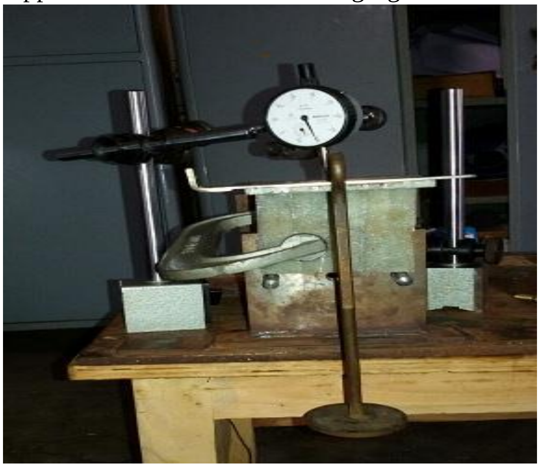


Fig 7: L-joint specimen with loads Fig 8: L-joint specimen without load.

Fig 9: Dial-1 showing vertical deflection Fig 10: Dial-2 showing horizontal deflection.

4.1 Calculations

Trial-1: Specimen L1/0/0

Load applied in newton, P = 9.81N

Vertical deflection in mm $\delta 1$= 0.17mm

Horizontal deflection in mm $\delta 2$=0.05mm

Stiffness for vertical deflection K1= $\frac{9.81}{0.17}$= 57.70588235N/mm

Stiffness for horizontal deflection K2= $\frac{9.81}{0.05}$= 196.2 N/mm

Weight of the specimen W= 1.726N

Stiffness to weight ratio for vertical deflection, K1/W = $\frac{57.70588235}{1.726}$=33.4333038 N^2/mm.

Stiffness to weight ratio for horizontal deflection, K2/W=$\frac{196.2}{1.726}$=113.6732329 N^2/mm.

5. RESULTS AND DISCUSSIONS

In the present work experiments has been conducted for L beams and T beams and the comparisons has been made for the specimens with reinforcement of tubes ant the specimens without reinforcement of steel tubes.

5.1 L Beam Specimens

In the L beam two set of specimens are fabricated by using eleven layers of glass fibers. In the first set of specimen the six numbers of steel tubes are used for reinforced into the specimen in the second set of L beam specimen twelve numbers of steel tubes are reinforced into the specimen.

The convention used for the specimen is written as follows L1/6/1.3 where L1 represents the L beam belongs to first set 6 represents the number of tubes and 1.3 represents the diameter of the steel tubes used. Similarly L2/12/1.3 represents the L beam belongs to second set which is having 12 no of tubes of diameter 1.3mm. In this work the number of layers of glass fibers used for all the sets is constant i.e., 11 layers.

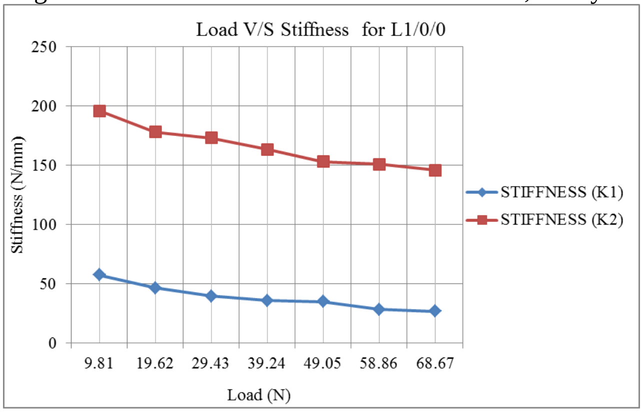
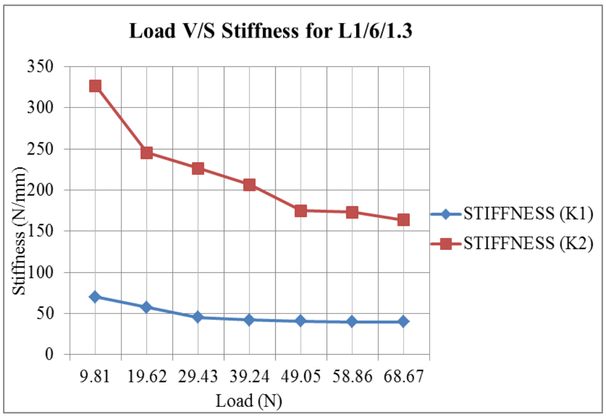


Fig 11: Load V/S Stiffness for L-Joint without Reinforcement for Specimen L1/0/0.

This graph shows the load v/s stiffness for the L-joint without any steel tube reinforcement. The stiffness K1 is the vertical deflection measured by dial gauge for the different dead weights applied and the stiffness K2 is the horizontal deflection measured by another dial gauge mounted. The load is varied from 1kg to 7kg i.e. 9.81N to 68.67N. The stiffness decreases as the load increases. The stiffness for the vertical deflection is 57.707 N/mm for 9.81N. The stiffness for the horizontal deflection is 196.2 N/mm for 9.81N. The stiffness for the horizontal deflection is more than the vertical deflection.



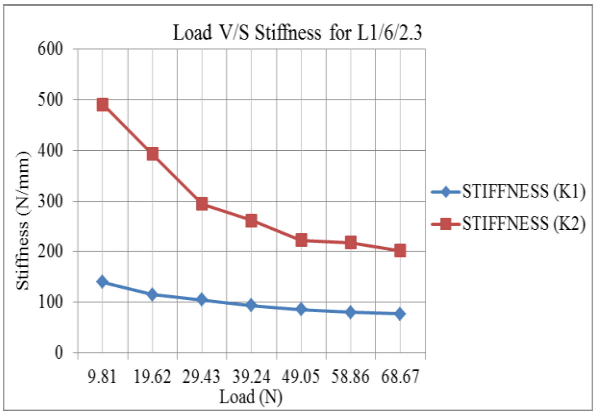


Fig 12: Load V/S Stiffness for L-Joint with Six Number of Steel Tubes of 1.3 & 2.3mm Diameter.

The above graph indicates the load v/s stiffness for the L-joint with six numbers of steel tubes of 1.3 & 2.3 mm diameter reinforced composite specimens. The loads are applied to the specimen at particular point with the other end fixed by using C-clamp. The horizontal and vertical deflections are measured by dial gauges. The vertical stiffness and the horizontal stiffness with respect to the load applied are shown above. The stiffness due to vertical deflection is 140.142 N/mm for 9.81N load which is higher than the specimen without reinforcement and specimen with reinforcement of 1.3mm diameter tube. The stiffness due to horizontal deflection is 490.5 N/mm for 9.81N which is higher than the vertical deflection. This stiffness is much more than the stiffness than the stiffness without reinforcement as well as with reinforcement of 1.3mm diameter tubes.

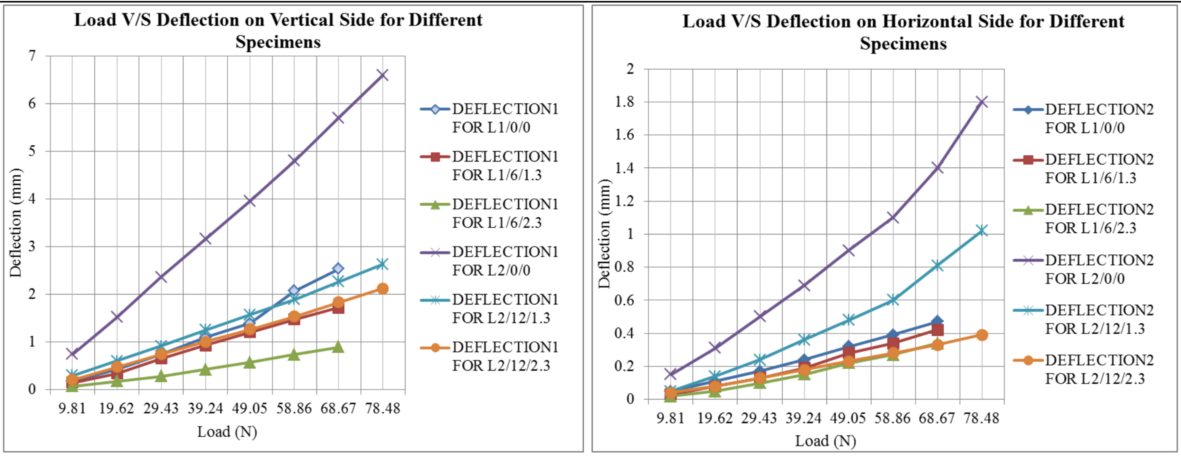


Fig 13: Load v/s Deflections for both Vertical and Horizontal Side for L-joint Specimens.

The above graph shows the vertical and horizontal deflections for different L-joint specimens. The specimen L2/0/0 shows the maximum deflection when compared to the other specimens and specimen L1/6/2.3 shows the minimum deflection. The deflection of the specimens increases with the increase in load. The specimen L1/0/0 deflects uniformly from 9.81 N to 49.05 N when load is increased to 58.86N the deflection increases to the higher limit which is higher than the uniform limit the reason for this is that there will be delamination which causes the increase in the deflection. The deflection for L1/0/0 specimen at 9.81N is 0.17mm. The deflection for L1/6/1.3 specimen at 9.81N is 0.14mm. The deflection for L1/6/2.3 specimen at 9.81N is 0.07mm. The deflection for L2/0/0 specimen at 9.81N is 0.07mm. The deflection for L2/12/1.3 specimen at 9.81N is 0.29mm and the deflection for L2/12/1.3 specimen at 9.81N is 0.2mm.

The deflection for L1/0/0 specimen at 9.81N is 0.05mm is noticed in horizontal case. The deflection for L1/6/1.3 specimen at 9.81N is 0.05mm. The deflection for L1/6/2.3 specimen at 9.81N is 0.02mm. The deflection for L2/0/0 specimen at 9.81N is 0.15mm. The deflection for L2/12/1.3 specimen at 9.81N is 0.05mm and the deflection for L2/12/1.3 specimen at 9.81N is 0.04mm.

Similarly experimental analysis is carried out for T beam specimen and the results are compared for all the cases and final conclusion has been drawn.

6. CONCLUSION

Composite materials are used in different industries such as aerospace, automobile, marine industries etc. Composite I-beams are used in wings of the aircraft. Conventional I-beams are made by joining two flanges and the web. There will be a weak joint at the intersection of the web and the flange. To increase the strength of this weak joint the fabrication process of the I-beam is changed by inserting the steel tube into the specimen which also increases the strength of the specimen.

Here the work is carried out for L-section and T-sections by changing the number of tubes and for the different diameter of the tubes without changing the number of layers of fibers and the strength to weight ratio is compared with specimen without reinforcement of steel tubes. The experimental result shows that the strength of the specimen with reinforcement of steel tubes is higher than the specimen without reinforcement of steel tubes. The specimen with reinforcement of steel tubes will give less deflection when compared with specimen without reinforcement of steel tubes for same load.

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