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Comparative study on GFRP and steel tube reinforced GFRP composite in terms of strength to weight ratio

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ABSTRACT

Composite materials with high specific strength and specific modulus properties are mainly used in the automotive and aerospace industries. Currently, a lot of research is happening on advanced composite materials in order to improve these properties. The objective of the present work focused on, the studies related to the effect of laterally reinforced hypodermic steel tubes in Glass Fiber Reinforced Plastic (S-GFRP) composite by estimating strength to weight ratio. These specimens were prepared using hand layup process. From experimental data, mechanical properties like ultimate compressive ultimate strength, stiffness, strength to weight ratio determined. The experimental results show that a GFRP specimen with lateral reinforcement of hypodermic steel tubes (S-GFRP) give high stiffness and high strength to weight ratio compared to that of plane fiber reinforced plastic (GFRP).

Keywords— *GFRP, S-GFRP, Strength to Weight Ratio*

1. INTRODUCTION

A composite material is a non-uniform solid structure consisting of more than one material with similar or dissimilar constituents that are mechanically bonded together. By varying composition of constituents in material, the properties can be changed. Therefore composite structure has many advantages and applications over conventional materials. Generally, the composite material consists of two phases: One is the matrix phase and the other is the reinforcement phase. The matrix is a continuous phase and the reinforcement phase is a discontinuous one. Epoxy resin, polyesters Vinyl esters etc. used as a matrix phase. Glass fibre, Carbon fibre, Aramid fibre etc. are the most common materials used as a reinforcement phase. Matrix phase is having less strength compared to reinforcement phase and it will provide a proper bond to the reinforcement phase and also it acts as a load transformer to the fiber. The function of reinforcements phase is to withstand maximum load and provide high strength to the whole composite structure. There is a lot of research studies carried out in order to improve properties of the composite material (especially by considering weight factor of composite material). All research studies concluded that properties of the composite material can be improved by reinforcing the suitable foreign material in the composite material.

Glass Fiber Reinforced Polymers (GFRPs) is a fiber reinforced polymer made of a plastic matrix reinforced by fine fibers of glass. Fiberglass is a lightweight, strong, and robust material used in different industries due to their excellent properties. Although strength properties are somewhat lower than carbon fiber and it is less stiff, the material is typically far less brittle, and materials are much less expensive. Its bulk strength and weight properties are very favorable when compared to metals, and it can be easily formed using molding processes. Nowadays natural fiber such as sisal and jute fiber composite materials are replacing the glass and carbon fibers owing to their easy availability and cost [1]. The idea of reinforcement of steel tubes in GFRP was generated based on the reinforcement of steel tubes in civil concrete structures in order to improve properties like stiffness and specific strength of the structure [2]. Specific strength is an important property of the composite material compared to that of conventional materials. The composite material consisting of high specific strength and high modulus compared to conventional materials [5] and [6]. The main objective of this present work is to study the effect of hypodermic steel tubes in GFRP composites in terms of strength to weight ratio and it was found that there were no studies done on this particular area. Hypodermic steel tubes are chosen for reinforcement in GFRP composite because of its superior property compared to other metals in terms of stiffness and strength. There are some conditions are need to be followed based on R and D in order to improve properties of GFRP composite with lateral reinforcement of hypodermic steel tubes are as follows; i) Bonding between Steel tubes and GFRP composite material must be perfect. ii) In the case of laterally reinforced GFRP composite specimens, Length of steel tubes must be equal to the thickness of the GFRP specimen and the hypodermic steel tubes reinforced must be exactly perpendicular to the GFRP composite.

2. MANUFACTURING OF SPECIMENS

There are many methods used for fabrication of Composite structure like Autoclave, Filament winding, Hand layup process etc. Selection of each method depends on many aspects like the type of material selected, Environmental conditions, the application of a structure, and availability of Man, Material, Money, and Machine. Among all the different methods Hand layup process is most economical, commonly used and ease method to fabricate the composite specimen. The Fiber-reinforced polyesters can be processed by many methods. In this project work, Hand lay-up technique is used to prepare the specimen. The materials used are glass fibers, polyester resin and steel tubes of small diameter. Following list of Materials are required to manufacture GFRP specimens. Reinforcement material i.e. Glass woven fabric, Matrix material (Polyester resin), Steel tubes (OD=2mm) Hardener and catalyst, Mold material, Releasing Agent, Wooden rectangular pieces, C-clamps, Metal bonding, Safety measures like Hand gloves face scarf etc.

Specimen specifications the specimens are prepared approximately according to ASTM D638 [1] which defines the dimensions of a composite specimen for compression test as shown in Table 1.

Table 1: Dimensional specification for GFRP and S-GFRP composite specimens

Type of specimens	Length in 'mm'	Width in 'mm'	Thickness in 'mm'
GFRP without steel tube(GFRP)	13	13	11
GFRP with reinforcement of steel tube	13	13	11

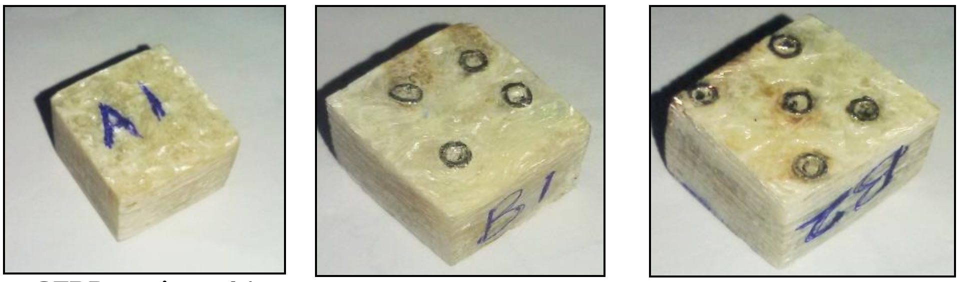
2.1 Hand lay-up method

Hand lay-up is a simplest and easy method for manufacturing composite compared to other methods. It is used mainly to fabricate specimens used for experimental purposes. As its name indicates, Hand layup is a manual fabrication process of the composite which is done by composing successive layers of fiber and matrix materials. GFRP Specimen without the reinforcement of steel tube (GFRP) and GFRP specimens with reinforcement of steel tubes(S-GFRP) were prepared with at most care as shown in figure 1. Composite was cured at room temperature.

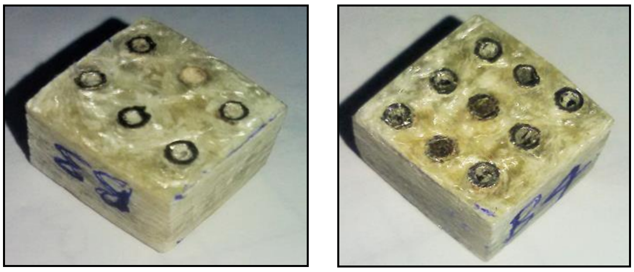
Fig. 1: Manufacturing of GFRP and S-GFRP using Hand lay-up method

2.2 GFRP and S-GFRP specimens

After curing, specified specimens are prepared from the composite as shown in figure 2.



GFRP specimen A1 **S-GFRP specimen B1** **S-GFRP specimen B2**



S-GFRP specimen B3 S-GFRP specimen B4

Fig. 2: GFRP and S-GFRP composite specimens

2.3 Testing

After preparation of specimens, the weight of each specimen was noted using the micro weighing machine and it was observed that weight of the specimen which reinforced by the maximum number of steel tubes higher than the other specimens. After weighing of specimens, compression test was conducted for each specimen using Universal Testing Machine (UTM) as shown in figure 3 and all data were noted.

Fig. 3: Compression testing for GFRP and S-GFRP using UTM

3.RESULTS AND ANALYSIS

3.1 Experimental Results

Each specimen is subjected to compression test and results were represented in terms of Load v/s displacement graph as shown in figure 4.While testing, ultimate load of each respective specimen was noted and calculation was made in terms of ultimate strength and strength to weight ratio for each specimen with their weight as shown in Table 2 and finally graphical representation of strength to weight ratio against the number of steel tube reinforced in S-GFRP shown in figure 5.

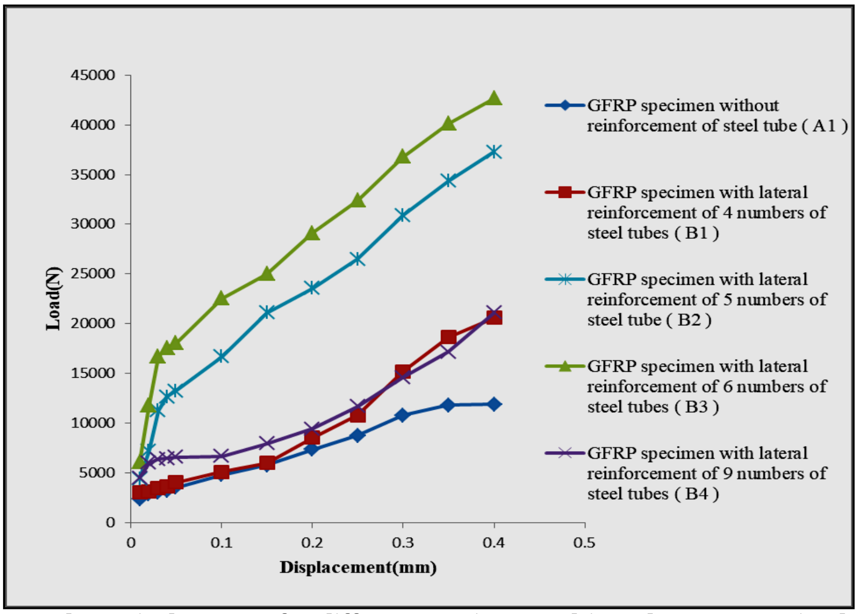


Fig. 4: Load v/s Displacement for different specimens subjected to compression loading

Table 2: Strength to weight ratio for different types GFRP composite specimen

Specimen name	No.of steel tube	Ultimate load(N)	Ultimate strength (σ_{ult})in MPa	Weight (W) of specimen in grams	Weight per unit area (W_A=W/A_s) in grams/mm²	Strength to Weight ratio (σ_{ult}/W_A) in N/grams	% change in strength to weight ratio compared to specimen A1
A1	0	52.5*10³	400.2689	3.48	0.026532	**15086.27**	-
B1	4	64.7*10³	504.933	3.84	0.029965	**16850.76**	**11.89 (↑)**
B2	5	67.30*10³	524.738	3.90	0.030408	**17256.58**	**14.38 (↑)**
B3	6	74.5*10³	586.5282	4.23	0.033302	**17612.40**	**16.74 (↑)**
B4	9	69.5*10³	558.978	4.31	0.034664	**16125.60**	**6.88 (↑)**

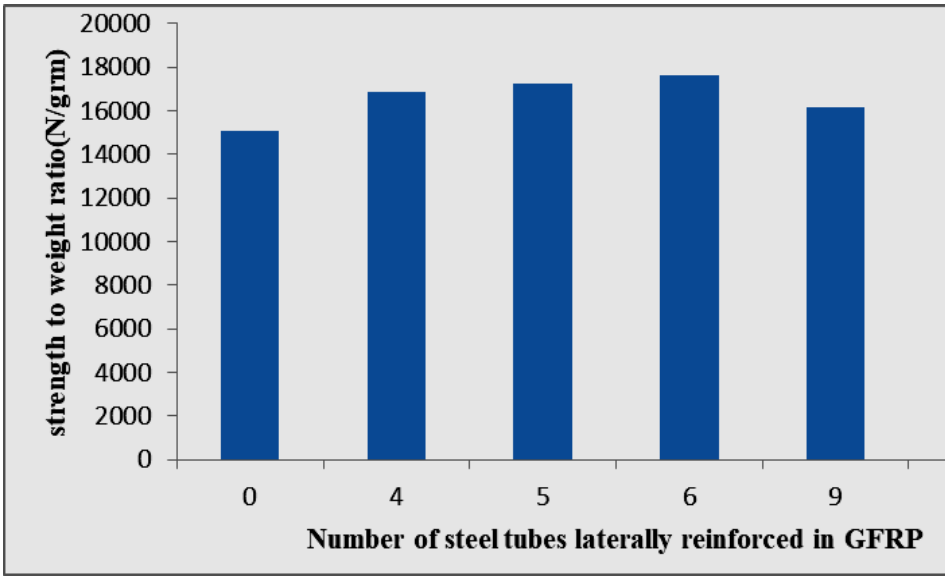


Fig. 5: Strength to weight ratio v/s Number of hypodermic steel tubes laterally reinforced in GFRP

3.2 Analysis of Results

Detail analysis was made based on results shown in figure 4, figure 5 and table 2 as follows:

From figure 4 shows, a graph plotted between Load v/s Displacement for different specimens. The following analysis was made:

- GFRP composite specimen with lateral reinforcement of steel tube(S & GFRP) has the ability to carry more loads compared to GFRP composite specimen without the reinforcement of steel tube for the same displacement.
- The graph clearly shows that the load carrying capacity gradually increases in the order of specimen B1, B2, B3 and then decreases for specimen B4 compared to specimen B2 and B3.
- This graph also explains that reinforcement of more than 6 i.e. 9 numbers of steel tubes decreases the Load to displacement ratio compared to that of reinforcement of 6 numbers of steel tube for specified specimens; this is because of reduced effective cross-sectional area of composite material and inclined reinforcement of hypodermic steel tubes which cuts the layers of glass fiber and cause delamination effect and leads to failure of composite.
- The initial slope is very high for specimen B2 and B3; subsequently, the slope is constant for all specimens.

From table 2 and figure 5 following observations were made;

- The strength to weight ratio is more for S-GFRP specimens B1, B2, B3, and B4 (with lateral reinforcement of steel tubes) compared to that of GFRP specimen A1(without the reinforcement of steel tube)
- It is observed that strength to weight ratio of S-GFRP composite specimen B4 (with lateral reinforcement of 9 numbers of steel tubes) decreased compared to that of S-GFRP specimens B1, B2 and B3 because of increased density of B4.

4. CONCLUSION

The experimental results concluded that S-GFRP can be replaceable material for GFRP due to its increased strength to weight ratio, high specific strength, and high stiffness. Due to its improved properties of S-GFRP, it can be used in automobile and aerospace industry to create mold structure where high strength to weight ratio is required. For optimality, further researches are needed to be conducted on this particular area for better results.

NOMENCLATURES

GFRP : Glass Fibre Reinforced Plastic polymer
S-GFRP : Steel tube reinforced GFRP
A1 : GFRP specimen without reinforcement steel tube
B1 : GFRP specimen with lateral reinforcement of 4 steel tubes
B2 : GFRP specimen with lateral reinforcement of 5 steel tubes
B3 : GFRP specimen with lateral reinforcement of 6 steel tubes
B4 : GFRP specimen with lateral reinforcement of 9 steel tubes

5. REFERENCES

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