

GSJ: Volume 6, Issue 10, October 2018, Online: ISSN 2320-9186 www.globalscientificjournal.com

Study on effect of longitudinally reinforced steel tubes in GFRP composite in terms of specific strength under bending and tensile load

Avinash G Hiremath av.gh08@gmail.com BMSCE,Bengaluru Nagraj Biradar <u>Biradarnagu458@gmail.com</u> Dr.AIT,Bengaluru Sharangouda <u>Sharangouda4@gmail.com</u> BMSCE,Bengaluru

ABSTRACT

Composites are advanced materials which are finding increasing applications in aerospace, automobile, sporting and numerous applications. Composite materials are using everywhere due to their excellent properties like high strength to weight ratio but still research are need to be conduct to improve the same so that, composite materials can resist future challenges. Recent study shows that steel tube reinforced GFRP(S- GFRP) has potential to improve strength to weight ratio compared to GFRP composite under compression loading; On extending this idea present work focused on study of effect of steel tubes in GFRP(S -GFRP) in terms of strength to weight ratio under bending and tension loading compared to without reinforcement of steel tube in GFRP (GFRP). In this work steel tubes of different diameter were longitudinally reinforced in GFRP. Specimens of S & GFRP and GFRP were prepared using hand layup process and specimens subjected to bending and tensile loading using UTM. From experimental data, mechanical properties like ultimate compressive ultimate strength, stiffness, strength to weight ratio and specific strength were determined. The experimental results shows that, a GFRP specimen with longitudinal reinforcement of hypodermic steel tubes (S-GFRP) achieved high strength to weight ratio , high specific stiffness and other improved mechanical properties compared to that of plane fiber reinforced plastic (GFRP).

Keywords: *GFRP*, *S*- *GFRP*, strength to weight ratio, polyester resin, S type glass fibre, steel tube, specific strength, specific stiffness etc.

1. INTRODUCTION

Composites are made of two or more materials such as reinforced plastics, metals or ceramics. Composites mainly defined by their superior properties like high strength to weight ratio (specific strength), high specific modulus and high specific stiffness compared to that of conventional materials. Composite materials are answer to all advanced structures to meet future needs in the areas like aerospace industry and automobile industry which are demanding more and more such composite structures which can ability to have high strength to weight ratio, high stiffness and other mechanical

properties in order to improve life cycle of the structure and in order to save energy consumption for reducing overall cost of the work. Specific strength can be defined as the ratio of ultimate strength to density of the material; Specific stiffness defined as ratio of stiffness to that of density of the material and Specific modulus can be defined as ratio of modulus of elasticity to that of density of the material. So one thing is clear from the definitions that strength and density are the major properties to build effective composite structures.

Composite is made up of reinforcement and matrix material; the reinforcement may be in the form of fibres, particles, whiskers are incorporated a suitable matrix, thereby providing a material combines the most useful properties of the constituents. Generally properties of a composite are superior to those of its individual constituents. High structural strength glass fibre reinforced plastics were developed in the early 1940's and then technology of reinforced plastics has progressed significantly. In a typical glass fibre reinforced plastic composite, the strength sand stiffness are provided by the glass fibres while the temperature capabilities of the composite is governed by the plastic matrix. Based on applications there are different types of glass fibres are available such as E type Glass fibre, S type Glass fibre, C type glass fibre etc. Due to high structural applications S type glass fibre reinforced in a polyester matrix composite materials were used in the car bodies, appliances, boats etc. Recent studies shows that apart from fibre and matrix material if other suitable constituents added to the same then still there are chances to improve properties according to requirement.

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 [3]. Specific strength is important property of the composite material compared to that of conventional materials. The composite material consisting high specific strength and high modulus compared to conventional materials [7] and [8].

Recent study from the current authors shows that steel tube reinforced GFRP can improve the strength to weight ratio, specific strength, and specific modulus under compression loading. In that study authors fabricated different specimens of laterally reinforced steel tubes in GFRP and experimental data were generated for each specimen by testing under UTM for compression test. After analysis over experimental data it was observed that steel tube reinforced GFRP can withstand maximum load and also high strength to weight ratio compared to that of GFRP specimens without any reinforcement of steel tube. This study creates lots of scope for further investigation of behavioral approach of steel tubes reinforced in GFRP in terms of mechanical properties under different loading like tensile and bending [1]

The main objective of this present work is to study the effect of hypodermic steel tubes in GFRP composites in terms of specific strength, specific stiffness and other mechanical properties compared to GFRP specimens without reinforcement of steel tune under tensile and bending .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. From the observations there are some conditions are needed in order to improve properties of GFRP composite with longitudinal reinforcement of hypodermic steel tubes, the following discussed observation are need to follow follows;

- i. If steel tubes were not properly adhered to glass fibre then, when load was applied on specimen chances are that reinforced steel tubes may slip from the layers of glass fibre and delamination effect may cause, so in order to avoid this bonding between steel tubes and GFRP composite material must be perfect.
- ii. Length of the steel tube reinforced and length of the GFRP specimen maintained as same.

Properties of different materials used in this work as shown in table 1.

Table 1. Properties of different materials

Material	Modulus of elasticity in GPa	Density in Kg/m ³
S type glass fibre	87	2490
Polyester resin	92	1400
Steel tube 304 grade	210	7840

2. MANUFACTURING OF SPECIMENS

The methodology adapted here basically consists of two main tasks

- i. Fabrication of standard GFRP specimen without and with desired level of steel tube reinforcements (for conducting test under bending and tension loads).
- ii. Experimentally loading the specimen and subjecting the same to bending and tension loads in order to obtain the stiffness, strength and hence specific stiffness and specific strength.

The study is parametric in nature in which the steel tube diameter and number of steel tubes are varied.

2.1 Selection of materials

The required materials to manufacture GFRP specimens are reinforcement material i.e. S type glass woven fabric, matrix material (Polyester resin), steel tubes (OD=3mm and 2mm) Hardener and catalyst, Mold material, releasing agent, Wooden rectangular pieces, C-clamps, metal bonding, safety measures like hand gloves face scarf etc. The size of the specimens was as shown in table 2.

Table 2 Dimensional specification for GFAT and 5-GFAT composite specificity				
Type of test		Length in	Width in	Thickness in
		'mm'	'mm'	'mm'
	Without reinforcement of steel tube			
Tensile	With reinforcement of steel tube	265	30	10.5
	Without reinforcement of steel tube			
Bending	With reinforcement of steel tube	280	40	9.5

Table 2 Dimensional specification for GFRP and S-GFRP composite specimens

2.2 Hand lay-up method –Specimen preparation

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 composite which is done by composing successive layers of fibre and matrix materials. GFRP Specimen without reinforcement of steel tube (GFRP) and GFRP specimens with reinforcement of steel tubes(S-GFRP) were prepared with at most care.in order to fabricate the specimens a uniformed high surface finish material selected a mold material. On that mold material thick plastic polythene was placed in order avoid sticking problem between mold and specimen. Wax pole (which acts like a releasing agent) pasted on polyethylene sheet in order to avoid sticking issues between specimen and polythene. The polyethylene sheet is used to remove the air gaps from the specimen to get better surface finish. The S type Glass fiber as shown in fig.1.a with required dimensions were prepared. Based on the required thickness of specimen number of glass fibre layers prepared. These glass fibers are having high strength and low density. These glass fibers are much cheaper and are relatively strong. These fibers are having insulation capacity. In this study matrix material used as polyester resin which is in the liquid form at room temperature. Proper volume fraction of resin is added to glass fibre to produce effective composite materials. In this work 35% volume fraction of matrix material was

GSJ: Volume 6, Issue 10, October 2018 ISSN 2320-9186

used including hardener and accelerator .In order to produce proper curing, hardener and accelerator were added to the polyester resins prescribed by the manufacture. Now first apply the resin using brush on the polyethylene sheet which was placed on the mould and then place one layer of glass fibre on it. Now again apply resin on the first layer of glass fibre and place another layer of glass fibre on it. Continue this cycle until required thickness will achieved. This is for GFRP specimen without reinforcement of steel tubes. For producing longitudinally reinforced GFRP(S-GFRP), same processes is followed but on any mid layer of glass fibre required number of steel tube were placed such that equidistance between steels tube was maintained. After completion of layup again one more polyethylene sheet was covered on the last layer and one more flat uniform mold is placed on it in order to create uniformability in the composite structure. Two molds were rigidly held with the help of C-clamps. Once this was finished now composite structure required allow for to curing at room temperature for 30 hours. After proper curing, molds were disengaged and specimens with tube and without tubes were prepared. There will be separate specimens were prepared for bending and tensile test using same hand layup process. A bird view of fabrication of specimens of GFRP and S-GFRP as shown in fig.1.Sevral specimen with varying number of longitudinal reinforcement of steel tubes in GFRP was fabricated and compared the result with GFRP specimens without reinforcement of steel tube for both bending and tensile test.



a) mold with polyethylene sheet



b) S type glass fibre



c) steel tubes



d) Reinforcement of steel tubes in S type glass fibre

e) Resin applying on the glass fibre layers



f) GFRP with longitudinal reinforcement of steel tube



g) Uniform load applied on upper mold



h) Specimen sample

Fig.1 Manufacturing of GFRP and S-GFRP using Hand layup method

Following specimens were prepared for bending and tensile test

For Bending test	For Tensile test		
B1-GFRP specimen without reinforcement of steel tube	T3-GFRP specimen without reinforcement of steel tube		
B2-GFRP specimen with 4 number of longitudinally	T4-GFRP specimen with 4 number of longitudinally		
reinforced steel tubes (S-GFRP)	reinforced steel tubes (S-GFRP)		
B4-GFRP specimen with 8 number of longitudinally	T6-GFRP specimen with 8 number of longitudinally		
reinforced steel tubes(S-GFRP)	reinforced steel tubes(S-GFRP)		

Table 3.Specimen description

2.3 Testing

After preparation of specimens, weight of the each specimen was noted using 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 bending and tensile test for respective specimens was conducted as shown in fig.2 and fig.3 respectively and all necessary data were recorded.



Fig.2 Three point bending test



Fig.3 Tensile test

3. RESULTS AND ANALYSIS

3.1 Experimental results of bending test:

Three point bending test was carried out for both GFRP and S-GFRP specimens(B1,B2 and B4) using UTM as shown in Fig.3.All data were recorded in the form of load ,deflection and ultimate load for respective specimen was recorded. Recorded data were plotted in the graph as shown in Fig.4. Specific strength was calculated as shown in Table 3.Specific strength can be calculated using following standard formula.

Specific strength=Ultimate strength/density

Specimen	No.of steel tubes	Outer diameter	Ultimate	Specimen	Ultimate	Specific
name	longitudinally	of the tube in	load	density in	strength in	strength in
	reinforced in	mm	in	g/m ³	N/m ²	N-m/gram
	GFRP specimen		Ν			
B1	0	0	4022.1	1490000	413700000	277.65
B2	4	3	5199.3	1660000	534780000	322.15
B4	8	3	10791	1720000	604411860	351.40

Table 4 Ultimate strength and Specific strength of GFRP and S & GFRP specimen under bending test



Fig.4 Load v/s Displacement plot of GFRP and S-GFRP specimen for bending test

3.2 Experimental results of tensile test:

Specimen T3, T4 and T6 were tested for tensile loading using UTM. Respective data were recorded for each specimen in terms of displacement and load and other parameters were calculated as done in the case of bending test.. Table 5 shows the ultimate load, ultimate strength and specific strength for respective specimens under tensile test.

Specimen	No.of steel tubes	Outer diameter	Ultimate	Specimen	Ultimate	Specific
name	longitudinally	of the tube in	load	density in	strength in	strength in
	reinforced in	mm	in	g/m ³	N/m ²	N-m/gram
	GFRP specimen		Ν			
T3	0	0	27468	1250000	78120000	62.496
T4	4	2	62594	1340000	172911602	129.03
T6	6	2	80396	1360000	222088397	163.30

Table 5 Ultimate strength and Specific strength of GFRP and S & GFRP specimen under tensile test



Fig.5 Load v/s Displacement plot of GFRP and S-GFRP specimen for Tensile test

3.3 Analysis of results

From the above experimental results following observations were made

- i. From the table 4. it was observed that longitudinally reinforced steel tubes in GFRP specimen (S-GFRP) bear maximum ultimate load compared to that of GFRP specimen without reinforcement steel tubes under bending and it was also observed that as number of steel tubes reinforced in the GFRP increases strength of the composite was also increased.
- ii. From the Fig.4, it is cleared that as number of steel tube increased in GFRP specimen stiffness also increased.
- iii. From the table 5, it was observed that ultimate tensile strength of S-GFRP specimens T4 and T6 increased compared to that of GFRP specimen T3 without reinforcement of steel tube.
- iv. From the Fig.5 it was also observed that specimen T4 and specimen T6 have high stiffness compared to that of specimen T3.
- v. Fig. 6 that represents the specific strength against number of steel tube reinforced in GFRP specimen under bending. It was observed as number of longitudinally reinforced steel tube increased in GFRP specimen, specific strength also increased compared to that of GFRP specimens without reinforcement of steel tubes. Under bending, S-GFRP specimens B2 and B4 have increased their strength to weight ratio(i.e. specific strength) compared to that of GFRP specimen B1 as shown in Fig.6
- vi. Similarly Fig. 7 that represents the specific strength against number of steel tube reinforced in GFRP specimen under tensile loading. Here also specific strength of GFRP specimen T4 and T6 shows increased specific strength compared to that of GFRP specimen T3 as shown in Fig.7.

4 Conclusions

The experimental results concluded that steel tube can contribute effectively for increasing strength to weight ratio and other mechanical properties of composite materials. The study shows that longitudinally reinforced steel tubes in GFRP(S-GFRP) not only improves ultimate strength of the composite but also it has high strength to weight ratio (specific strength) under both bending and tensile test when compared to without reinforcement of steel tubes in GFRP. It was also concluded that by reinforcement of steel tubes in GFRP ability to have high stiffness compared to GFRP specimen without reinforcement of steel tube. Still further investigation need to be conduct on this particular area and

need to study the effect of steel tubes on GFRP under fatigue loading and fracture toughness. S-GFRP composite can be become alternative material to GFRP composite.



Fig. 6 Specific strength v/s no. of steel tube reinforced in GFRP specimen for bending



Fig. 7 Specific strength v/s no. of steel tube reinforced in GFRP specimen for tensile loading

Nomenclature

GFRP	Glass fibre reinforced polymer composite
S type glass fibre	Structural type of glass fibre
S-GFRP	Steel reinforced in GFRP
UTM	Universal testing machine
B1	GFRP specimen without any reinforcement of steel tubes for bending test
B2	GFRP specimen with 4 number of longitudinally reinforced steel tubes for bending test
B4	GFRP specimen with 8 number of longitudinally reinforced steel tubes for bending test
Т3	GFRP specimen without any reinforcement of steel tubes for tensile test
T4	GFRP specimen with 4 number of longitudinally reinforced steel tubes for tensile
T6	GFRP specimen with 6 number of longitudinally reinforced steel tubes for tensile test

REFERENCES

[1] Avinash G Hiremath Nagraj Biradar et al. Comparative study on GFRP and steel tube reinforced GFRP composite in terms of strength to weight ratio, JJARIIT, ISSN 2454-132X p829-833(2018)

[2] David Tanner et al, An advanced Materials case history, Advance in composite materials, Oxford and IBH publishing Co. Pvt. Ltd New Delhi. P3 (1991)

[3] C.Elliott et al. structural applications of mechanical alloying, ASM International materials park, Chio, U.S.A. p 15(1990)

[4] H.W.Raughetet et al. Ceramic Fibres and Fibre and Fibrous composite materials (Academic press),p180,(1968)

[5] K.Alagarraja et.al. Fabrication and testing of fibre reinforced polymer composites material IOSR Journal of Mechanical and Civil Engineering, ISSN: 2278-1684, PP 27-34, 2013.

[6] Chun-yang ZHU et.al., Mechanical behaviour of concrete filled glass fiber reinforced polymer-steel tube under cyclic loading Journal of Zhejiang University SCIENCE A (Applied Physics & Engineering), ISSN 1862-1775, pp 778-788, (2013-14)

[7] Young-Jun You et.al. Hwang Tensile Strength of GFRP Reinforcing Bars with Hollow Section, Hindawi Publishing Corporation Advances in Materials Science and Engineering, Article ID 621546 (2015).

[8] Patil Deogonda and Vijaykumar N Chalwa Mechanical Property of Glass Fiber Reinforcement Epoxy Composites, International Journal of Scientific Engineering and Research (IJSER), ISSN: 23473878, Volume 1, Issue 4(December 2013).

[9] K. Naresh Kumar et.al. Experimental Investigation on Mechanical Properties of Coal Ash Reinforced Glass Fiber Polymer Matrix Composites, International Journal of Emerging Technology and Advanced Engineering, ISSN2250-2459,ISO 9001:2008 Certified Journal, Volume 3, Issue 8(August 2013)

[10] Autar K. Kaw Mechanics of composite Materials, Published by CRC Press Taylor & Francis Group6000 Broken Sound Parkway NW, Suite 300 Boca Raton, FL 33487-2742(2006)