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ANALYSIS OF STEEL STRUCTURE WITH COATED GLESS FIBER REINFORCEMENT POLYMER

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ABSTRACT

The reinforcement in many structures plays the important role to overcome pure tensile & compression stresses. Steel has its own material properties to deal with these actions, and also it has some limitations of strength. As external forces goes on increasing naturally required steel also increases.

Circular hollow steel tubes are used as columns in many structural systems and a common failure mode of such tubes when subjected to axial compression and bending. Tubular poles tend to fail in flexure by local buckling. Increasing the wall thickness would solve this problem, but at a significant material cost. Tubes are failed due to local buckling near a column end. For example, hollow steel tubes are used as bridge piers and such bridge piers suffered extensive damage and even collapses. In typical tubular members, buckling appears after yielding. A number of methods have been proposed for the retrofit of hollow steel tubes as piers. But each method suffers from some limitations.due to various failures FRP have been used in the present work. The main obejective is to investigate the behavior of hollow circular steel section coated with the Glass Fiber Reinforced Polymer under compression & tension test , this type of steel can be introduced practically in steel structures.

Keywords-. *FRP , Glass Fiber Reinforced Polymer*.

Introduction

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Circular hollow steel tubes are used as columns in many structural systems and a common failure mode of such tubes when subjected to axial compression and bending. Tubular poles tend to fail in flexure by local buckling. Increasing the wall thickness would solve this problem, but at a significant material cost. Tubes are failed due to local buckling near a column end. For example, hollow steel tubes are used as bridge piers and such bridge piers suffered extensive damage and even collapses. In typical tubular members, buckling appears after yielding. A number of methods have been proposed for the retrofit of hollow steel tubes as piers. But each method suffers from some limitations.

Fiber reinforced polymer (FRP) are composites used in almost every type of advanced engineering structure, with their usage ranging from aircraft, helicopters and space-craft through to boats, ships and offshore platforms also in automobiles, sports goods, chemical processing equipment, civil infrastructure such as bridges and buildings. FRP composites are lightweight, no-corrosive, exhibit high specific strength and specific stiffness, are easily constructed, and can be tailored to satisfy performance requirements. Due to these advantageous characteristics, FRP composites have been included in new construction and rehabilitation of structures through its use as reinforcement in concrete, bridge decks, modular structures, formwork, and external reinforcement for strengthening.

Fiber Reinforced Polymer (FRP)

Fiber Reinforced Polymer is a composite material made up of a polymer matrix reinforced with fibers. The fibers are usually glass, carbon, aramid, or basalt. The polymer is usually an epoxy, vinyl ester or polyesterthermosetting plastic, and phenol formaldehyde resins. Composite materials are made from two or more constituent materials with significantly different physical or chemical properties, which remain separate and distinct within the finished structure. Most composites have strong, stiff fiber in a matrix which is weaker and less stiff. The objective is usually to make a component which is strong and stiff, often with a low density. Commercial material commonly has glass or carbon Fiber in matrices based on thermosetting polymers.

Manufacturing process of fiber glass

Melting

The batch is prepared & it fed into a furnace for melting. The furnace may be heated by electricity, fossil fuel, or a combination of the two. Temperature must be precisely controlled to maintain a smooth, steady flow of glass. The molten glass must be kept at a higher temperature (about 1371 °C) than other types of glass in order to be formed into fiber. Once the glass becomes molten, it is transferred to the forming equipment.

Forming into fibers

Several different processes are used to form fibers, depending on the type of fiber. Textile fibers may directly formed from molten glass, or the molten glass may be fed first to a machine that forms glass marbles of about 0.62 inch (1.6 cm) in diameter. These marbles allow the glass to be inspected visually for impurities. In both the direct melt and marble melt process, the glass or glass marbles are fed through electrically heated bushings (also called spinnerets). The bushing is made of platinum or metal alloy, withanywhere from 200 to 3,000 very fine orifices. The molten glass passes through the orifices and comes out as fine filaments.

Continuous-filament process

A long, continuous fiber can be produced through the continuous-filament process. After the glass flows through the holes in the bushing, multiple strands are caught up on a high-speed winder. The winder revolves at about 3 km a minute, much faster than the rate of flow from the bushings. The tension pulls out the filaments while still molten, forming strands a fraction of the diameter of the openings in the bushing. A chemical binder is applied, which helps to keep the fiber from breaking during later processing. The filament is then wound onto tubes. It can now be twisted and plied into yarn

Staple-fiber process

An alternative method is the staple fiber process. As the molten glass flows through the bushings, jets of air rapidly cool the filaments. The turbulent bursts of air also break the filaments into lengths of 20-38 cm. These filaments fall through a spray of lubricant onto a revolving drum, where they form a thin web. The web is drawn from the drum and pulled into a continuous strand of loosely assembled fibers. This strand can be processed into yarn by the same processes used for wool and cotton.

Chopped fiber

Instead of being formed into yarn, the continuous or long-staple strand may be chopped in to short lengths. The strand is mounted on a set of bobbins, called a creel, and pulled through a machine which chops it into short pieces. The chopped fiber is formed into mats to which a binder is added. After curing in an oven, the mat is rolled up. Various weights and thicknesses give products for shingles, built-up roofing, or decorative mats.

Glass wool

The rotary or spinner process is used to make glass wool. In this process, molten glass from the furnace flows into a cylindrical container having small holes. As the container spins rapidly, horizontal streams of glass flows out of the holes. The molten glass streams are converted into fibers by a downward blast of air, hot gas, or both. The fibers fall onto a conveyor belt, where they interlace with each other in a fleecy mass. This can be used for insulation, or the wool can be sprayed with a binder, compressed into the desired thickness, and cured in an oven. The heat sets the binder, and the resulting product may be a rigid or semi-rigid board, or a flexible bat.

Protective coatings

In addition to binders, other coatings are required for fiberglass products. Lubricants are used to reduce fiber abrasion and are either directly sprayed on the fiber or added into the binder. An anti-static composition is also sometimes sprayed onto the surface of fiberglass insulation mats during the cooling step. Cooling air drawn through the mat causes the antistatic agent to penetrate the entire thickness of the mat. The anti-static agent consists of two ingredients a material that minimizes the generation of static electricity, and a material that serves as a corrosion inhibitor and stabilizer.

Forming into shapes

Fiberglass products come in a wide variety of shapes, made using several processes. For example, fiberglass pipe insulation is wound onto rod-like forms called mandrels. The mold forms, in lengths of 91 cm or less, are then cured in an oven. The cured lengths are then de-molded lengthwise, and sawn into specified dimensions. Facings are applied if required, and the product is packaged for shipment.

Advantages of FRP reinforcement includes High longitudinal tensile strength (varies with sign and direction of loading relative to fibers), Corrosion resistance (not dependent on a coating), Nonmagnetic, High fatigue endurance (varies with type of reinforcing fiber), Lightweight (about 1/5 to 1/4 the density of steel), Low thermal and electric conductivity (for glass and aramid fibers)

Disadvantages of FRP reinforcement includes No yielding before brittle rupture, Low transverse strength (varies with sign and direction of loading relative to fibers), Low durability of glass fibers in a moist environment., Low durability of some glass and aramid fibers in an alkaline environment, High coefficient of thermal expansion perpendicular to the fibers, relative to concrete and May be susceptible to fire depending on matrix type and concrete cover thickness.

The Objectives of the present work is to investigate the behavior of hollow circular steel section coated with the Glass Fiber Reinforced Polymer under compression & tension test. Study of young's modulus & tensile load carrying capacity of GFRP sheet based on their layers and orientations.Study of young's modulus & tensile load carrying capacity of steel plates & hollow circular section based on their coating of GFRP layers. Study of young's modulus & compressive load carrying capacity of hollow circular section based on their coating of GFRP layers.

METHODOLOGY

Study completed in following stages

1. Specimens were prepared to perform the tests. Specimens of different dimensions & varying thickness of FRP.
2. Tension & compression tests performed on specimens. First hollow steel sections are tested. Afterwards the same steel sections with GFRP coating were tested. From the tests engineering properties of composite section evaluated.
3. The truss is analyzed using ETABS. The truss considered as members of steel & composite member of GFRP & steel.
4. Results of two materials are compared.

Fabrication of specimen

There are two basic processes for molding or fabrication of fiber composite i.e. hand lay-up and spray-up. The hand lay-up process is the simplest fabrication method.

Plastic sheet kept on the plywood table and a thin film of polyvinyl alcohol was applied as a releasing agent by the use of spray. Laminating of rectangular sheets starts with the application of a gel coat (resin and hardener) deposited in the mould by brush, whose main purpose was to provide a smooth external surface and to protect fibers from direct exposure from the environment. Steel round pipe was used as roller to remove the air bubbles. Layers of sheet are applied and gel coat was applied by brush. For different orientation sheets are glued together in unidirectional 0º and 90º orientation angle. 2 sets of each 2 & 4 layer plates with different orientation is prepared for tensile testing. Again a Polyvinyl alcohol is applied inside plastic as releasing agent. Then specimens kept between flat plywood and above that heavy metal mould are kept for maturity. Following samples are prepared for test

Table No 1 – Tension test specimen of fiber plate

Sample	**No. of layers**	**Fiber orientation**	**Gauge Length (mm)**	**Thickness (mm)**
	2 layers	0º	150	2.1

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GFRP Plate No – 1	4 layers	0º	150	3.5
GFRP Plate No – 2	2 layers	90º	150	2.2
	4 layers	90º	150	3.6

Table No 2 – Test specimens (hollow circular members)

Sample no	External Diameter (mm)	Internal Diameter (mm)	GFRP layers	Length of specimen (mm)	Test performed
Sample 1	30	28	0	450	Compression Test
	33	28	1	450	Compression Test
	34	28	2	450	Compression Test
	39	28	3	450	Compression Test
Sample 2	41	39	0	450	Compression Test
	43.1	39	1	450	Compression Test
	44	39	2	450	Compression Test
	46	39	3	450	Compression Test
Sample 3	39	28	3	300	Compression Test
Sample 4	24	21	0	300	Compression Test
	29	21	2	300	Compression Test
Sample – 5	26.4	21	1	300	Tension Test

Table No 3 – Tension test specimen of steel Plate with GFRP coating

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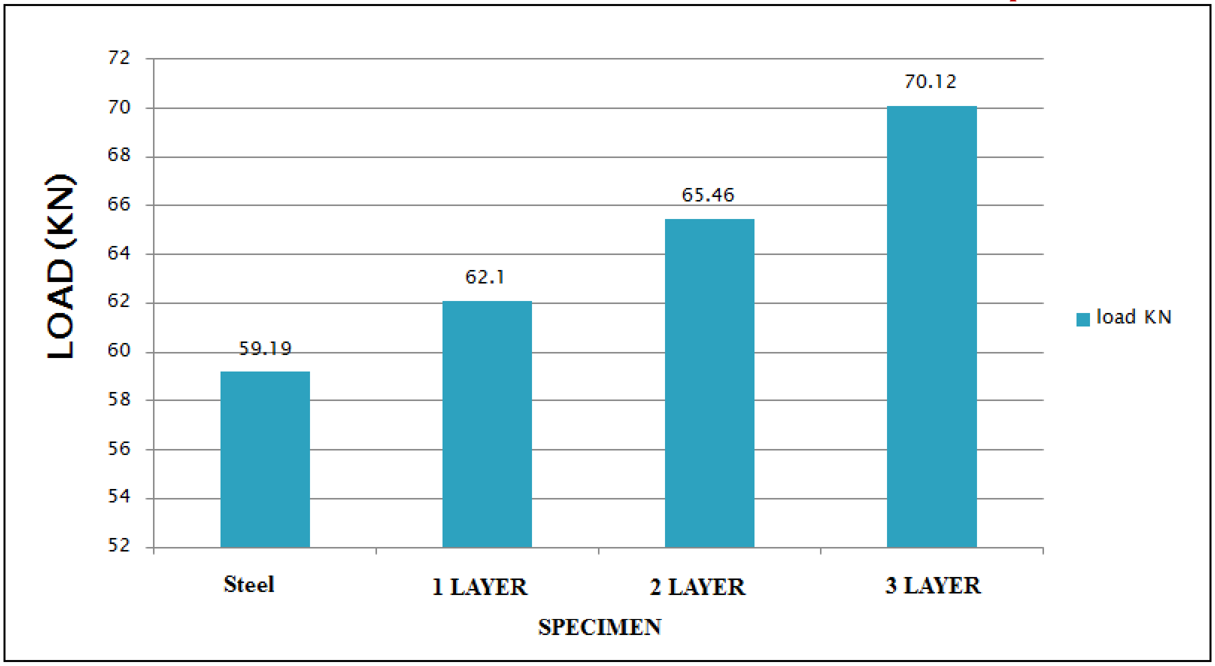
Sample	Width (mm)	Thickness (mm)	Length (mm)	GFRP layer	Gauge length (mm)
Plate no - 1	21	2	450	0	150
	23.3	2.3	450	1	150
Plate No – 2	25	2	450	0	150
	27.1	2.2	450	1	150
Plate No – 3	40	2	450	0	150
	42.3	2.3	450	1	150
Plate No – 4	40	2	450	0	150
	43.1	3.1	450	2	150

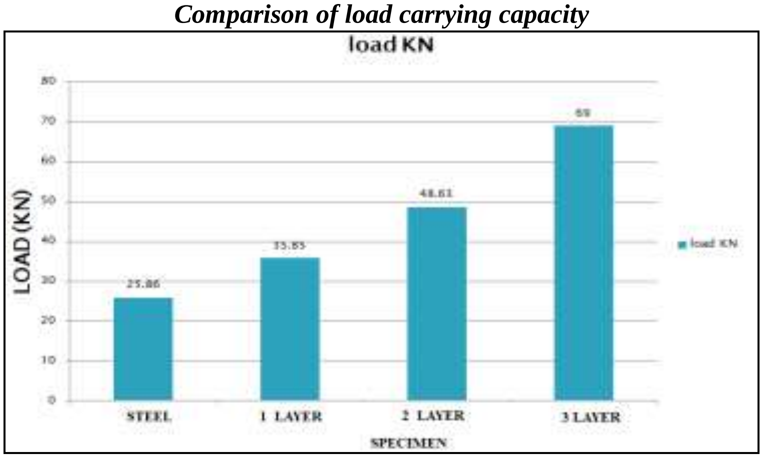
Table No 4 - Load Carrying Capacity & Compressive strength of test sample

Sample	GFRP layers	Length mm	Diameter		Area mm^2	Fc N/mm^2	Load carrying capacity N
			Outer mm	Inner mm			
Sample 1	0 Layer	450	30	28	91.1064	283.844	25860
	1 Layer	450	33	28	239.547	149.657	35850
	2 layer	450	34	28	292.1688	166.445	48630
	3 layer	450	39	28	578.8398	119.204	69000
Sample 2	0 Layer	450	41	39	125.664	471.018	59190
	1 Layer	450	43.1	39	264.373494	234.895	62100
	2 layer	450	44	39	325.941	200.834	65460
	3 layer	450	46	39	467.313	150.049	70120
Sample 3	3 layer	300	39	28	578.8398	140.402	81270
Sample 4	0 Layer	300	24	21	106.029	418.282	44350
	1 Layer	300	29	21	314.16	156.035	49020



Sample – 1 Increased Load Carrying Capacity for 0, 1, 2, & 3 layers respectively

Comparison of load carrying capacity



Tensile test on GFRP plates gives value of ultimate stress, ultimate load and young's modules which is in below table:

Table No 5 - Value of ultimate stress, ultimate load and young's modules for GFRP plate

No. of layers	Fiber orientation	Ultimate Stress (MPa)	Ultimate Load (KN)	Young's Modulus (MPa)
2 layers	0º	7.08	0.1457	3653
4 layers	0º	7.56	0.4162	4429
2 layers	90º	166.2	4.212	9493
4 layers	90º	209.6	9.386	10018

CONCLUSION

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The behaviour of tubular steel members with & without Glass Fiber Reinforced Polymer coating was tested. This study is aimed to find out the increase in tension as well as compression capacity of steel column

After the testing of tubular steel members the following conclusion can be drawn:

1. It has been found that the GFRP can used to increase tension as well as compression load carrying capacity of tubular steel members.
2. Tensile strength of the fabricated plate increases with the increasing number of layers of GFRP, for 1 layer of coating strength increased by 5%, for 2 layer it increased by 10%.
3. Axial load carrying capacity of the tubular steel member increases with the increasing number of layers of GFRP, for 1 layer of coating strength increased by 5%, for 2 layer it increased by 10% & for 3 layer it increased by 15%.
4. As thicknesses are kept constant it can be conclude that the steel with coating of the GFRP gives same value of young's modulus of elasticity.
5. It has been found that by keeping the same layer of coating % increase in strength also remains same.
6. As the coating of GFRP increases, the demand – capacity ratio of members decreases.
7. Ultimate Stress, Ultimate Load and Young's Modulus for specimens of 90º orientation give better results as compared to the 0º orientation.

For better tensile strength unidirectional glass fiber reinforced polymer in longitudinal direction can be used

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