Structural Performance of Square Hollow Structural Steel (Shs) Tubular Section under Axial Load using Carbon Fiber Reinforced Polymer Fabrics

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Abstract: *Square Hollow Section (SHS) have been used for many years in highway signs, guard rails, power transmission towers, oil rigs and other structures. Because of its high strength-to-weight ratios, excellent compression support characteristics and excellent torsional resistance, is now used in construction industry. Traditionally, the most common method to repair and/or rehabilitate a steel structure has been by welding additional steel plates. This not only adds weight to the structure, but the heat involved in welding can affect the stress distribution and may be critical for structures exposed to fatigue loads. In addition, steel plates would be exposed to corrosion damage and frequently this repairing method requires the use of scaffolding and heavy machinery as well as long periods of service interruption. In contrast, rehabilitation methods using carbon fiber reinforced polymer (CFRP) composites do not exhibit any of these drawbacks. The advantages of CFRP over steel plates are the low weight of the bonded material, easy applicability and the capacity to cover areas with limited access.*

Keywords: SHS, CFRP, FABRICS, REHABILITATION

1. INTRODUCTION

Cost effective rehabilitation and strengthening of steel structures currently demanded by the telecommunications industry and transportation departments. Rehabilitation is often required due to cross-section losses resulting from corrosion damage and strengthening may be required due to changes in the use of a structure. Current strengthening techniques have several disadvantages including their cost, poor fatigue performance and the need for ongoing maintenance due to continued corrosion attack. The research program makes use of new high modulus types of carbon fiber for strengthening steel structures. The research program, currently in progress, includes phases to determine the appropriate resin and adhesive for wet lay-up of carbon fiber reinforced polymer (CFRP) sheets and bonding of CFRP strips, respectively. Test results of three scaled monopoles showed significant stiffness increases prior to yield. A significant stiffness as well as ultimate strength increase was found for the first steel-concrete composite girder tested in the program. Specialist ultra-high modulus CFRP (with tensile modulus of 420 GPA or more) is one of the few practical methods of strengthening cast-iron beams. In typical use, it is bonded to the tensile flange of the section, both increasing the stiffness of the section and lowering the neutral axis, thus greatly reducing the maximum tensile stress in the cast iron. When used as a replacement for steel, CFRP bars could be used to reinforce concrete structures; however, this application is not common.

1.1 Advantage of Carbon Fiber Reinforced Polymer

➢ Cut the fiber in to the required shape.
➢ Easy installation.
➢ Minimum labor cost.
➢ High strength to weight ratio and durability.
➢ Corrosion Resistance.
➢ Fatigue resistance.
➢ High tensile strength and stiffness - provide considerable strength improvements to steel structures.
➢ Transportation and handling is very easy.
➢ Less false work required.
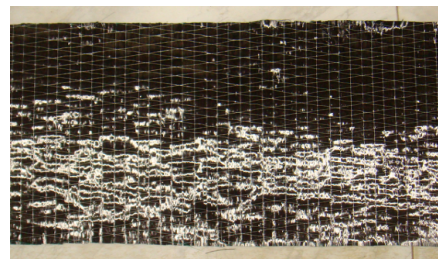➢ Rigidity
➢ Fire Resistance/Not flammable

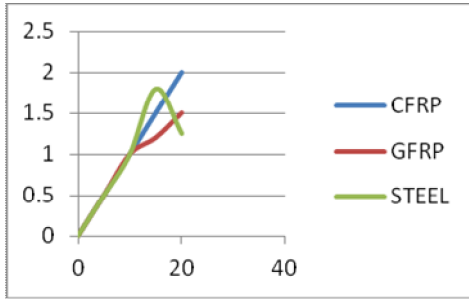**Fig 1.1 Unidirectional Carbon Fiber Sheet**

Fig 1.2 Grapical Representation of Strength of CFRP

1.2 Adhesives

The success of the strengthening technique critically depends on the performance of the epoxy resin used. Numerous types of epoxy resins with a wide range of mechanical properties are commercially available. The Araldite saturant supplied by Huntsman India Inc was used in this study to get sufficient bonding between steel tube and carbon fiber. Araldite saturant - to bond the fiber to the steel tube

- It is a two part systems, a resin and a hardener.
- Mixing ratio was 100:40 (H:R).
- Long open time
- High shear and peel strength
- Easy to apply
- Good resistance to static and dynamic loads
- Electrically insulating

1.2.1 Physical and Chemical Properties of Resin

- Appearance Paste
- Odour Slight odour.
- Solubility Insoluble in water
- Initial boiling point and boiling range(°C)   >200
- Relative density 1.15 - 1.25 @ 25 °c
- Vapour pressure   < 0.1 Pa @ 20 °c
- pH-Value, Conc. Solution Approx 6
- Viscosity   30 - 50 Pas @ 25 °c
- Flash point (°C) 210 CC (Closed cup).

1.2.2 Physical and Chemical properties of hardener

- Appearance Liquid
- Colour Colour less to pale yellow.
- Odour   Slight odour.
- Solubility Insoluble in water
- Initial boiling point and boiling range(°C)   >200
- Relative density 0.95 @ 25 °c
- Vapour pressure   4 Pa @ 20 °c
- Flash point (°C) 110

2. SOFTWARE USED

- ANSYS provide the ability to simulate every structural aspect of a product, including a linear static analysis that simply provides stresses or deformations.
- Modal analysis that determines vibration characteristics, through to advanced transient nonlinear phenomena involving dynamic effects and complex behaviors.
- **ANSYS Structural software** addresses the unique requirements of pure structural simulations without the need for extraneous tools. The product delivers all the power of nonlinear structural capabilities as well as all linear capabilities to deliver high-quality, reliable structural simulation results.

2.1 MODELING PARAMETER

Sections	All dimensions are in (mm)			
	Length (H)	Breath (B)	Depth (C)	Thickness (t)
Steel Section	600	75	75	2

Table 2.1 Dimensions of the SHS

2.2 MATERIAL PROPERTY

S.No.	Properties	Value
1.	Modulus of elasticity	240kN/mm^2
2.	Tensile strength	3800N/mm^2
3.	Weight of C fiber (main direction)	400gm^2
4.	Total weight of sheet	230g/m^2
5.	Density	1.7g/cm^2
6.	Thickness for static design weight / density	0.234mm
7.	Safety factor for static design	1.2

Table 2.2 Properties of CFRP

Table2.3 Properties of Adhesive

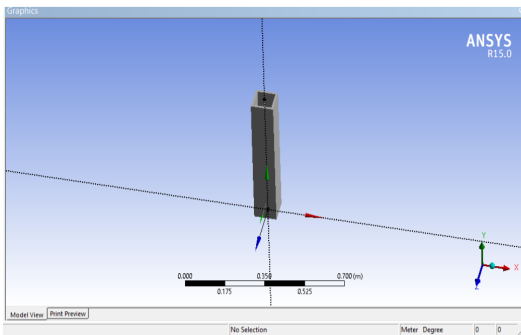| S.No.	Properties	Value
1.	Mixed density(Kg/liter)	1.13±0.03
2.	Mixing ratio(H:R)	100:40
3.	Mixed viscosity at 25°c	4000±500
4.	Setting time	<3 hours at 25°c

3. MODELING
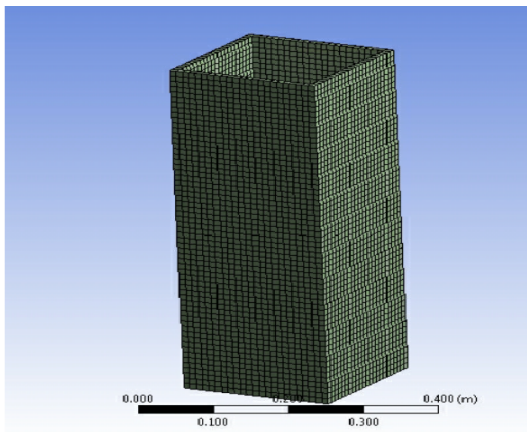

Fig 3.1 Cross Sectional View of SHS
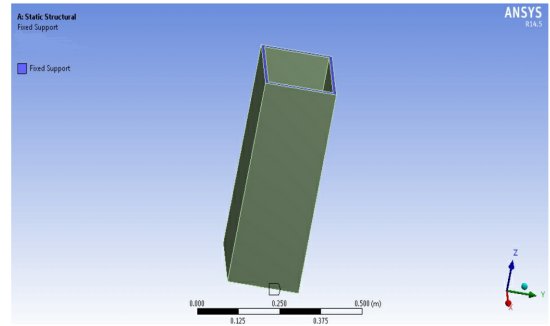

Fig 3.2 Meshing of SHS

Fig 3.3 Applying Support Conditions
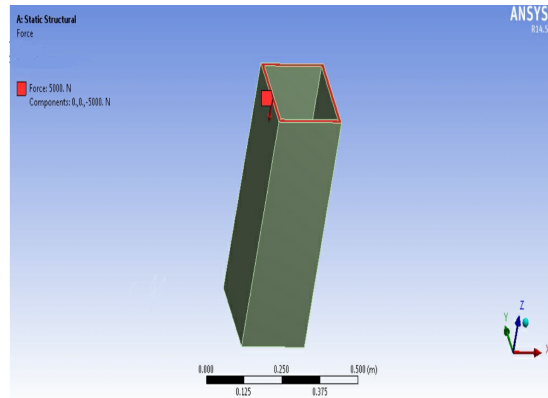
Fig 3.4 Applying Load

3.1 ANALYSIS RESULT
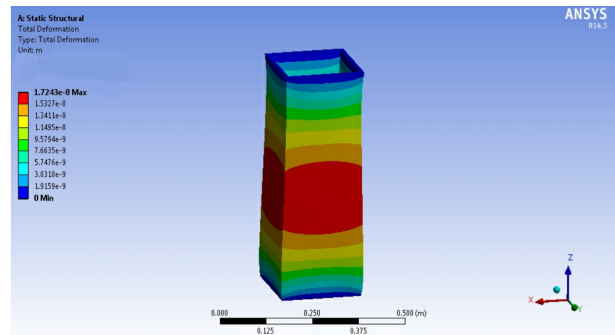
Fig 3.5 Static Deformation

Fig 3.6 Buckling Deformation

4. EXPERIMENTAL ANALYSIS

4.1 Introduction

In this analysis we are using universal testing machine. To determine the strength of square hollow steel section An universal testing machine (UTM , also known as a universal tester, materials testing machine or materials test frame, is used to test the tensile strength and compression strength of materials. The "universal" part of the name reflects that it can perform many standard tensile and compression tests on materials, components, and structures.

4.2 Experimental sections

The following details is about square hollow section used in project,

1. Square hollow steel tube confirming to IS 4923 -1997 - having a dimension of 75 mm x 75 mm x2 mm

2. **Normal Section**
   - Dimension=75mm x75mm x2mm
   - Height=609mm
3. **I-section**
   - Dimension=75mm x75mm x2mm
   - Height=609mm
   - Web=609mm
   - Flange=609mm
4. **Inverted T-Section**
   - Dimension=75mm x75mm x2mm
   - Height=510mm
   - Web=435mm
   - Flange=609mm
5. **Repair and Rehabilitation**
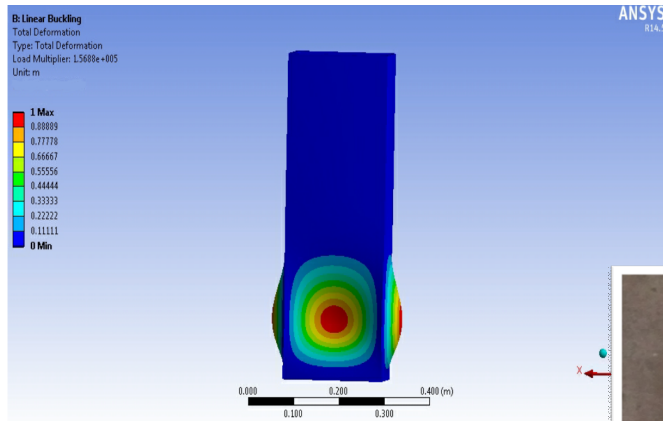
- Dimension=75mm x75mm x2mm
- Height= 430mm

6. The yield strength of the tube provided by the manufacturer was 170kN/mm^2.

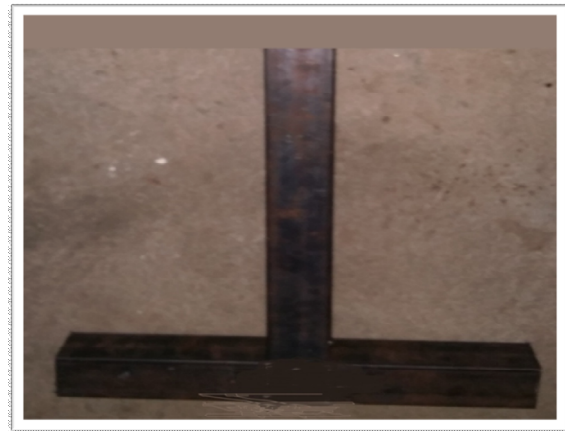**Fig 4.1 Normal Section**

Fig 4.2 I-Section

Fig 4.3 Inverted T- Section

The above build up section such I-Section and T-Section are welded by using electrical arc welding method.

In before those section are cut by using steel cutter for required size to weld the sections.

4.3 Experimental analysis

We are going to analysis the square hollow sections

1. Without binding of CFRP sheet
2. With binding of CFRP sheet

4.4 Without Binding CFRP Sheet

Fig 4.4 Experimental Analysis of Normal Section Without CFRP Sheet

S.NO	DESCRIPTION	LOAD
1.	NORMAL SECTION	170KN
2.	I-SECTION	110KN
3.	INVERTED T-SECTION	145KN
4.	REPAIR & REHABITATED SECTION	134KN

Table 4.1 Experimental Analysis of SHS Without using of CFRP Sheet
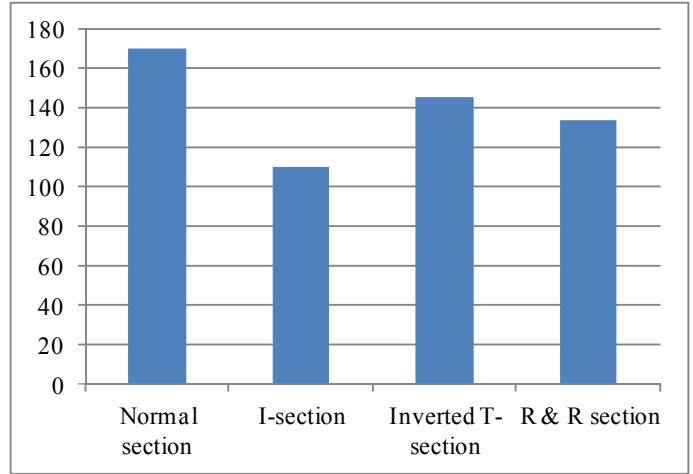

Fig 4.5 Graphical Representation Of SHS Analysis

The above results is about an experimental Analysis of SHS without using of CFRP sheet.

4.4.1 With Binding Of CFRP Sheets

➢ In this analysis we are using the CFRP sheet to bind in the square hollow section. Cutting the CFRP sheet like a strips of 90mm its width and 25mm spacing is provided in between the two strips, binding only one layer.

➢ CFRP sheet binded by using Araldite saturant and primer on the square hollow section, and then the section is cured for period of time and after that period SHS is taken to analysis on the Universal Testing Machine.

Fig 4.6 Experimental Analysis of I-section Using CFRP Sheet

Fig 4.7 Experimental Analysis of I-Section Using CFRP Sheet

From above fig 4.7 we can see the compression acting on the top of flange of I-Section, so the structure get deformed The deformation is occur on the I-Section due the flange is on the tensile zone, so it can't able to resist the compression.

Fig 4.8 Experimental Analysis of Normal Section Using CFRP Sheet

From above fig 4.8 we can see that the compression force acting on the top of the normal section. Force is acting perpendicular to the normal section, so the deflection takes more time to occur.

Fig 4.9 Experimental Analysis of Repair And Rehabilitated Structure

From the above fig 4.9 show the Analysis of repair and rehabilitated structure, that means the steel structure is damaged and repair by using CFRP Sheet and Araldite saturate and primer is used to repair the damaged steel structure.

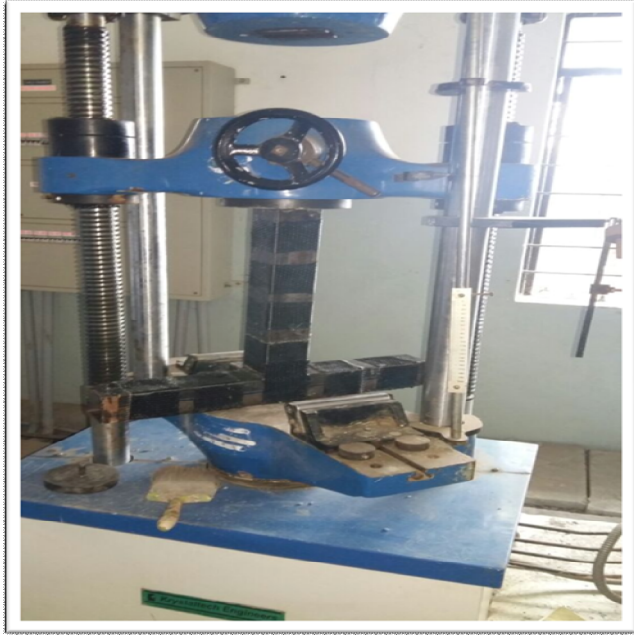**Fig 4.10 Inverted T-Section By Using CFRP Sheet**

Fig 4.11 Experimental Analysis of Inverted T-section By Using CFRP Sheet

S.NO	DESCRIPTION	LOAD
1.	NORMAL SECTION	230KN
2.	I-SECTION	150KN
3.	INVERTED T-SECTION	190KN
4.	REPAIR & REHABITATED SECTION	184KN

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Table 4.2 Experimental Analysis of SHS Using CFRP Sheet

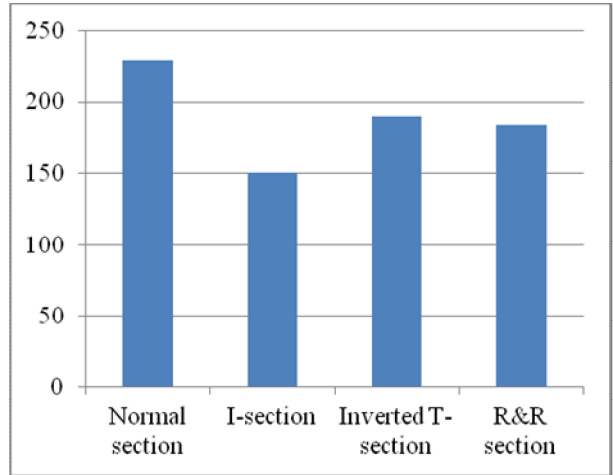**Fig 4.12 Graphical Representation SHS using CFRP Sheet**

S.NO	DESCRIPTION	WITHOUT USING OF CFRP SHEET	WITH USING OF CFRP SHEET
1.	NORMAL SECTION	170KN	230KN
2.	I-SECTION	110KN	150KN
3.	INVERTED T-SECTION	145KN	190KN
4.	REPAIR & REHABITATED SECTION	134KN	184KN

Table 4.3 Experimental Analysis of SHS by Using CFRP And Without Using CFRP Sheet
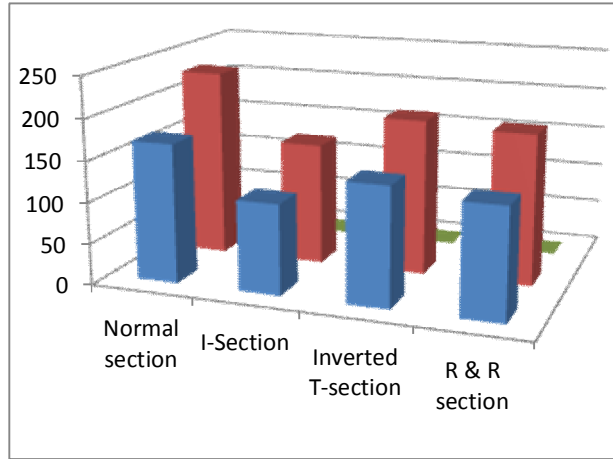
Fig 5.13 Combined Graphical Representation of Using CFRP And Without Using CFRP Sheet

5. CONCLUSION

There are many advantages in favor of the use of CFRP material for repair and rehabilitation of bridges and structures. Cost saving may be realized through labor saving and reduced requirements for staging and lifting material. Due to ease of application disruption of service during construction may be reduced or eliminated. The dead weight added to structure is minimal and there is typically little visual impact on the structure, such that good aesthetics can be maintained

An analytical investigation for the behavior of square hollow steel sections subjected to axial compression was studied and their properties such as deformation, stress strain ,bending are also studied using ANSYS.

An experimental investigation for the behavior of square hollow steel sections subjected to axial compression load on top o the section we studied that the properties of steel such deformation, stress strain ,bending with using of CFRP and without using of CFRP.

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