International Journal of Constructive Research in Civil Engineering (IJCRCE)
Volume 3, Issue 1, 2017, PP 1-10
ISSN 2454-8693 (Online)
DOI: http://dx.doi.org/10.20431/2454-8693.0301001
www.arcjournals.org

A Study on Strengthening of CHS Tubes under Axial Compression Using FRP Composites

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Abstract: *External bonding of Glass fiber reinforced polymer (GFRP) sheets to the periphery of steel circular hollow sections (CHS) is a new technique for structurally improving such sections. This paper involves in analyzing the capacity of GFRP-strengthened steel CHS tubes subjected to bending. The main aim of wrapping GFRP sheets is to reduce the buckling behavior of CHS. Design of GFRP sheets for strengthening tubular steel sections necessitates the prediction of the capacity of confined steel circular sections. This paper presents a design method for evaluating the capacity of GFRP-strengthened steel CHS subjected to bending. The hoop FRP reduces the effect of local buckling by restraining the tube wall. The influence of hoop CFRP is considered in the proposed method by taking its modulus of elasticity as a proportion of the elastic modulus of longitudinal GFRP. The excitation of the longitudinal GFRP minimizes the effect of local buckling in the tube wall, which ultimately increases the local flexural stiffness and strength of the tube.*

Keywords: *Concrete, Compressive strength, Glass Fiber Reinforcing Polymer, Circular Hollow Steel.*

1. INTRODUCTION

Steel sections are very much usage in most of the structures. Especially circular hollow section. A hollow structural section (HSS) is a type of metal profile with a hollow tubular cross section. The term is used predominantly in USA, or other countries which follow US construction or engineering terminology.

HSS members can be circular, square, or rectangular sections, although other shapes are available, such as elliptical. HSS is only composed of structural steel per code.HSS is sometimes mistakenly referenced as hollow structural steel. Rectangular and square HSS are also commonly called tube steel or structural tubing. Circular HSS are sometimes mistakenly called steel pipe though true steel pipe is actually dimensioned and classed differently from HSS. (HSS dimensions are based on exterior dimensions of the profile, while pipes are essentially dimensioned based on interior diameters, as needed to calculate areas for flow of liquids.) The corners of HSS are heavily rounded, having a radius which is approximately twice the wall thickness. The wall thickness is uniform around the section. In the UK, or other countries which follow British construction or engineering terminology, the term HSS is not used. Rather, the three basic shapes are referenced as CHS, SHS, and RHS, being circular, square, and rectangular hollow sections. Typically, these designations will also relate to metric sizes, thus the dimensions and tolerances differ slightly from HSS.

HSS, especially rectangular sections, are commonly used in welded steel frames where members experience loading in multiple directions. Square and circular HSS have very efficient shapes for this multiple-axis loading as they have uniform geometry along two or more cross-sectional axes, and thus uniform strength characteristics. This makes them good choices for columns. They also have excellent resistance totorsion.HSS can also be used as beams, although wide flange or I-beam shapes are in many cases a more efficient structural shape for this application.

2. METHODOLOGY

2.1. Cement

The most common cement used is an ordinary Portland cement. The Ordinary Portland Cement of 53 grades conforming to IS: 11269-1987 isbe use. Many tests were conducted on cement; some of them are consistency tests, setting tests, soundness tests, etc.

Table1. *Properties of Cement*

Sr. No.	Physical Properties of OPC 53Cement	Results	Requirements as Per IS:8112-1989
1.	Specific Gravity	3.14	3.10-3.15
2.	Standard Consistency (%)	31.5	30-35
3.	Initial Setting Time (min)	30	60 Minimum
4.	Final Setting Time (min)	211	600 Maximum
5.	Compressive Strength (at 28 days in N/mm^2)	58	53 N/mm^2 Minimum

2.2. Aggregate

Aggregates are the important and large used constituents in concrete. They give bond to the concrete, reduce shrinkage and effect economy. One of the most important factors for producing workable concrete is good gradation of aggregates. Many tests were conducted on fine aggregate and coarse aggregate are tabulated below. The test results in Fine and coarse aggregate are conforming to IS: 383-1970.

Table2. *Physical Properties of Fine and Coarse Aggregate*

Particular	Fine aggregate	Coarse aggregate
Specific gravity	2.68	2.73
Water absorption (%)	1	0.5
Fineness modulus	2.72	7.32
Bulk density (g/cc)	1.43	-
Percentage of voids	43.29	-
Grading	Zone II	-

2.3. Hollow Steel Section

Square HSS is made the same way as pipe. During the manufacturing process flat steel plate is gradually changed in shape to become round where the edges are presented ready to weld. The edges are then welded together to form the mother tube. During the manufacturing process the mother tube goes through a series of shaping stands which form the round HSS (mother tube) into the final square or rectangular shape. Most American manufacturers adhere to the ASTM A500 or newly adopted ASTM A1085 standards, while Canadian manufacturers follow both ASTM A500 and CSA G40.21. European hollow sections are generally in accordance with the EN 10210 standard.

In this project investigation is done with American standard CS 50 steel tubes made in fabrication plant.

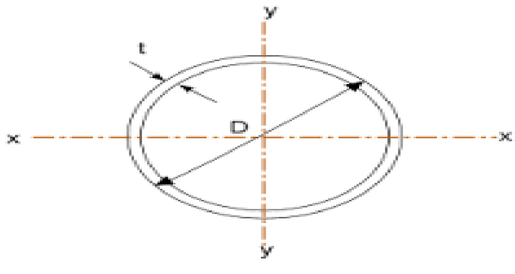

Figure1. *Diameter of circular hollow section*

Figure2. *Circular hollow steel tubes*

2.4. GFRP (Glass Fiber Reinforcing Polymer)

Glass fiber–reinforced polymer, carbon fiber–reinforced plastic or carbon fiber–reinforced thermoplastic (GFRP, often simply glass fiber, or even carbon), is an extremely strong and light fiber-reinforced plastic which contains glass fibers. CFRPs can be expensive to produce but are commonly used wherever high strength-to-weight ratio and rigidity are required, such as aerospace, automotive and civil engineering, sports goods and an increasing number of other consumer and technical applications.

Table3. *Properties of GFRP sheet*

Particular	
Fiber Orientation	Unidirectional
Weight (g/m^2)	200
Density (g/cc)	2.6
Thickness (mm)	0.40
Ultimate elongation (%)	1.5
Tensile strength (N/mm^2)	3500
Tensile modulus (N/mm^2)	285x10^3

Figure3. *GFRP Sheet*

2.5. Mix Design

The mix proportion chosen for this study is M25 grade (1:2.01:3.56) with water-cement ratio of 0.45. Cubes of standard size 150x150x150mm of total 36 no. are casted and cured for 28 days and tested as per code IS: 516-1959.

Table4. *Mix proportion for M25 Grade Concrete*

Unit of batch	**Water (liter)**	**Cement (kg)**	**Sand (kg)**	**Coarse aggregate (kg)**	**Super plasticizer**
Meter cube content	164	375	375	750	3.75
Mix ratio	0.45	1	1	2	1%

3. RESULT AND DISCUSSION

3.1. Compressive Strength Test

For compressive strength of concrete, a standard dimension of 150 mm x 150mm x 150 mm cubes were used. Compressive strength results consist for M25 grade of concrete with maintain constant W/C ratio of 0.45. The compressive test is done after the specimen has been cured for 14 and 28 days. All the cubes were tested in saturated condition, after wiping out the moisture in their surface.

The compressive test is done in compressive testing machine has the capacity of 1000 KN. The compressive strength test is carried out on various specimen like control specimen (C0), warping GFRP sheet in one layer (C1), two layer (C2), three layer (C3) in control specimen. For each specimen was tested in 3 trials.

Compression test was carried out on the specimens on 7$^{th, 14th}$ and 28^{thdays} of curing and the values are tabulated. The compressive strength also calculated and given. In fig 5, the block color values indicate compressive strength of C3 (three layer warping in control specimen). Loading was continued till the readings were revised from the increment values.

The reversal in the reading value indicates the specimen has failed. The machine was stopped and the reading at that instant was the ultimate load. The ultimate load divided by the cross sectional area is the compressive strength.

Compressive strength = P/A (N/mm^2)

Where, P = Load (N/mm^2)

A = Area of the cube = Lxb

Table5. *Compressive strength test results for GFRP*

SL.NO	SPECIMEN	28 DAYS compressive Strength (N/mm^2)
1	Control specimen	31.2
2	One layer of GFRP	31.8
3	Second layer of GFRP	32.5
4	Third layer of GFRP	33.8

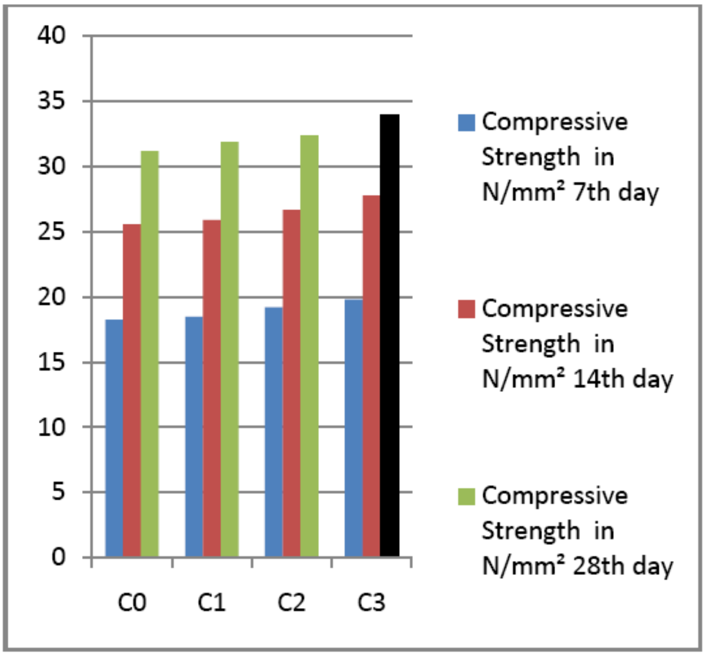

Figure5. *Compressive Strength results for GFRP*

3.2. Flexural Strength

Flexural strength is one measure of the tensile strength of concrete. It is a measure of an unreinforced concrete beam or slab to resist failure in bending. It is measured by loading 6 x 6-inch (150 x 150-mm) concrete beams with a span length at least three times the depth. The flexural strength is expressed as Modulus of Rupture (MR) in psi (MPa) and is determined by standard test methods ASTM C 78 (third-point loading) or ASTM C 293 (center-point loading).Flexural MR is about 10 to 20 percent of compressive strength depending on the type, size and volume of coarse aggregate used. However, the best correlation for specific materials is obtained by laboratory tests for given materials and mix design.

In this paper mainly investigate flexural strength of the beam (vertical member) consists of with and without fibers. The circular steel tube made with fiber by using epoxy adhesive. For this test involves standard steel tube with in filled concrete (control specimen- without fiber), withfiber in 1 layer (CFCT-1), 2 layer (CFCT-2), 3 layer (CFCT-3).For each specimen was tested in 2 trials.The flexural test is done in the loading frame it has the capacity of 1500KN. All the beams were tested in single point loading (@ center). The load is acted at the center of the beam. The dial gauges were used to find the deflection acting on the beam. For finding the load is given to the beam through the proving ring.

The dial gauge readings were recorded at different loads. The load was applied gradually until the first crack was observed. Subsequently, the load was applied. The behavior of the beam was observed carefully. The crack development and propagation were monitored and marked during progress of the test. The crack width was measured. The deflection was recorded for respective load increments until failure.

Figure6. *Control specimen*

Figure7. *First layer of CFCT specimen*

Figure8. *Second layer of CFCT specimen*

Figure9. *Third layer of CFCT specimen*

3.3. Testing Results of Specimens Obtained From UTM

Load and buckling behaviors are obtained for Control, CFCT-1st LAYER, CFCT-2nd LAYER, CFCT-3rd LAYER, by experimentally testing the specimen in UTM. Evaluation of load and displacement for CFCT-1st LAYER, CFCT-2nd LAYER, and CFCT-3rd LAYER are presented below.

Figure10. *Failure for control specimen*

Figure11. *Failure for First layer of CFCT specimen*

Figure12. *Failure for Second layer of CFCT specimen*

Table4. *Load and Deflection*

Designation	Load (kN)		Deflection (mm)	
	Trial 1	Trial 2	Trial 1	Trial 2
Control	940	932	11.63	12.07
CFCT (LAYER-I)	1070	1100	12.31	12.98
CFCT (LAYER-II)	1132	1126	11.84	12.37
CFCT (LAYER-III)	1192	1148	11.79	11.23

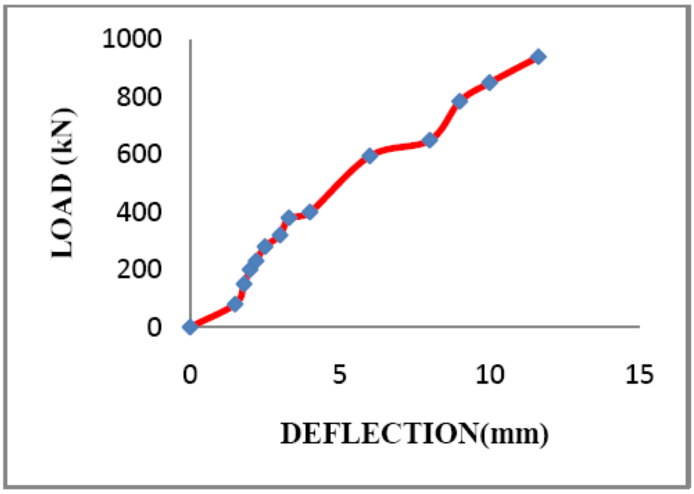

Figure13. *Load Vs Deflection for Control specimen-I*

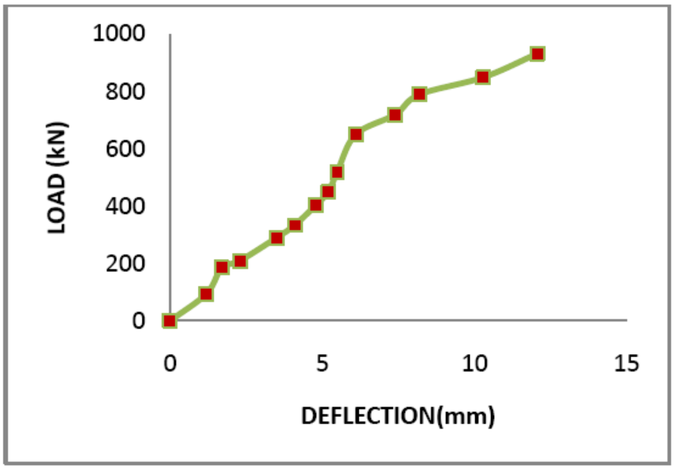

Figure14. *Load Vs Deflection for Control specimen-II*

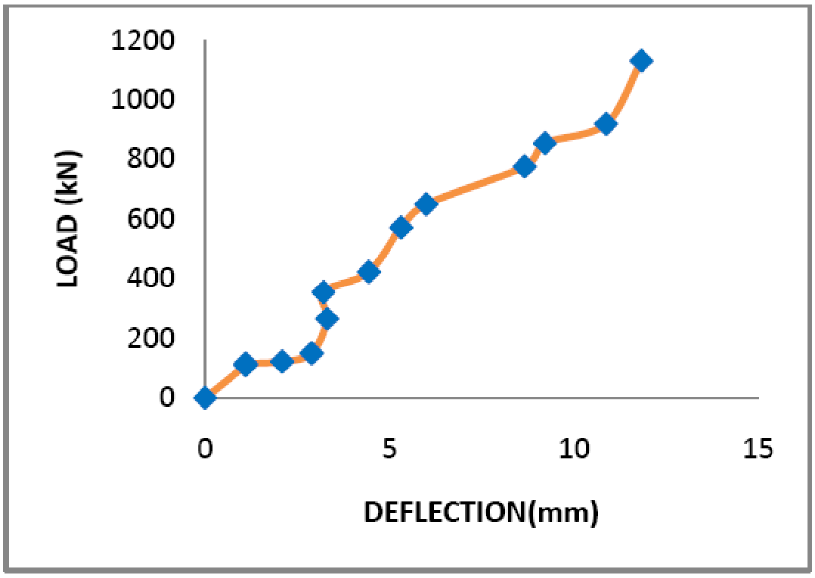

Figure15. *Load Vs Deflection for First Layer CFCT –I*

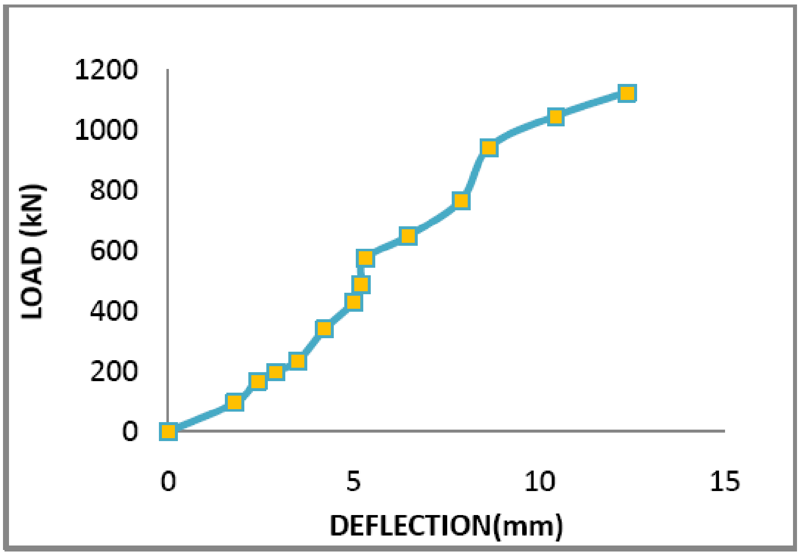

Figure16: *Load Vs Deflection for First Layer CFCT –II*

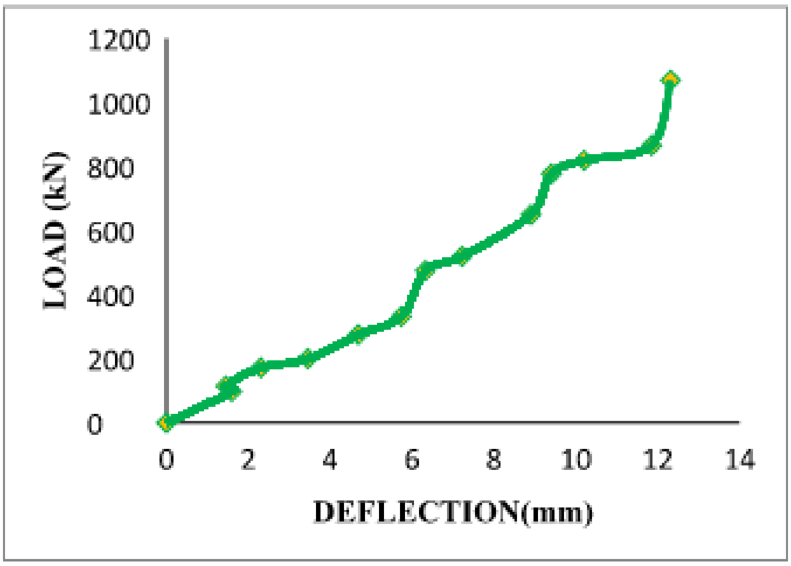

Figure17. *Load Vs Deflection for Second Layer CFCT –I*

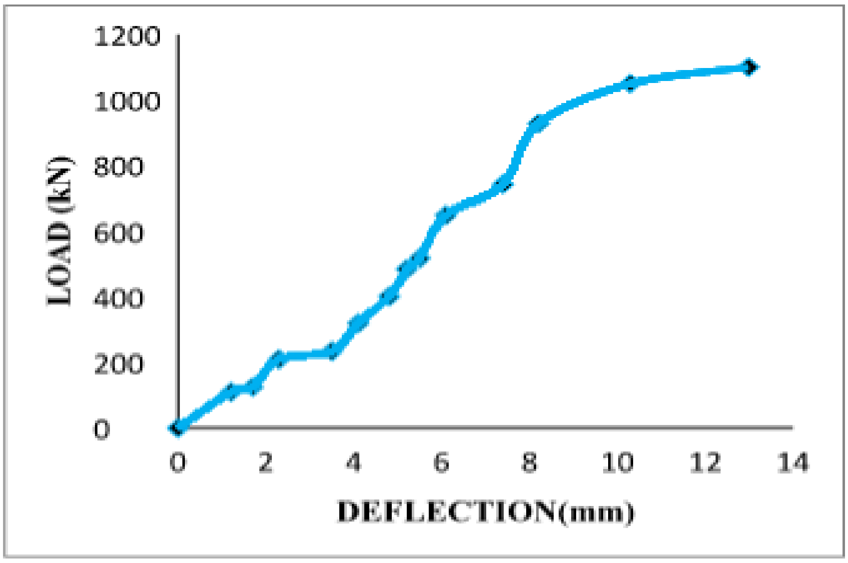

Figure18. *Load Vs Deflection for Second Layer CFCT –II*

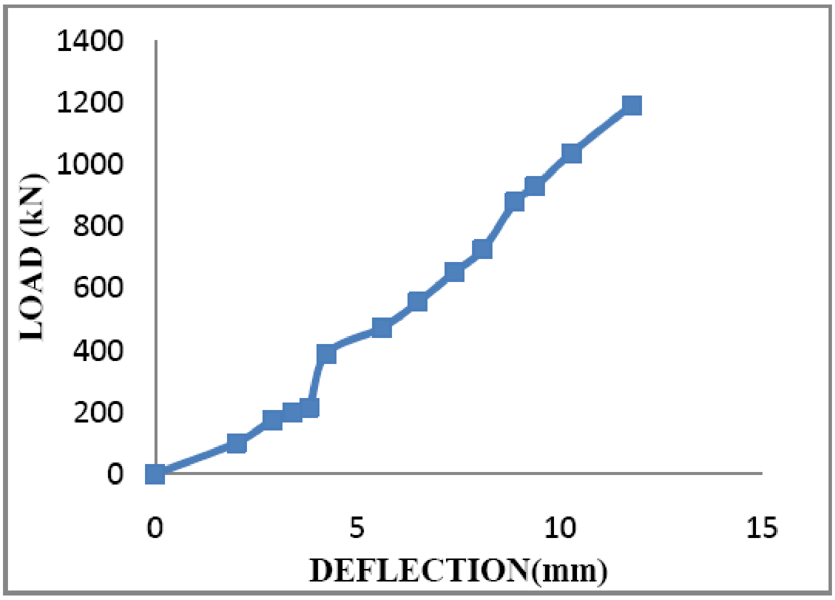

Figure19. *Load Vs Deflection for Third Layer CFCT -I*

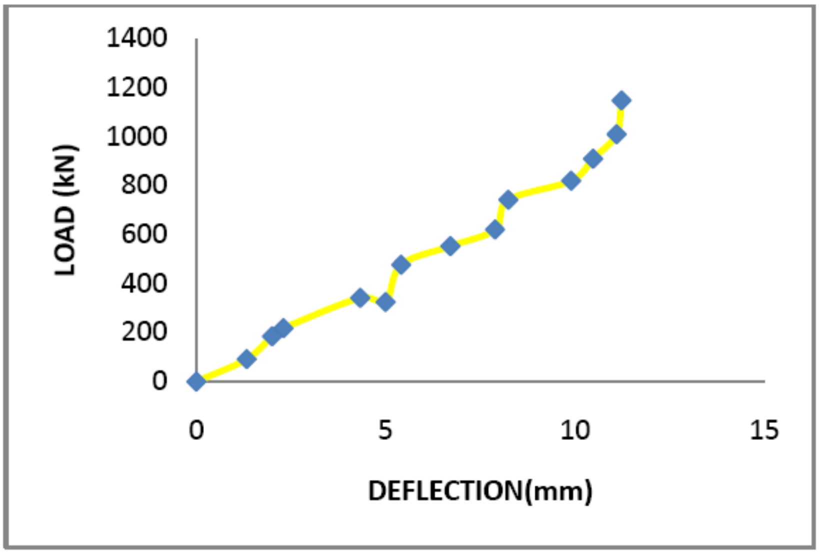

Figure20. *Load Vs Deflection for Third Layer CFCT –II*

4. CONCLUSION

Based on the experimental investigations, the following conclusions were drawn.

1. Experimental investigation is done successfully and their results are compared.
2. From the investigation it is clearly identified that Ultimate load carrying capacity increases with increase in thickness (fiber) of the specimen.
3. The compressive strength gradually increases from C0, C1, C2, and C3 Layers with CHS tube content and increases for above average 5%-15% in each layer.
4. The 28 days average compressive strength obtained for C0, C1, C2, and C3 Layers with CHS tube content shows 10% to 45% increase in compressive strength when compared to control mix concrete.
5. Load carrying capacity of CFCT 3rd LAYER & CFCT 2ndLAYER section is increased up to 20%-50% when compared to CONTROL & CFCT 1st LAYER sections.
6. So it is verified that CFRP will increase the strength of the sections in normal condition and also in damaged condition.

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