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ijirset@gmail.com

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Experimental of Short GFRP-Reinforced Steel Tubular Compression Member

P. Sarala¹, L. Sakthivel²

Associate Professor, Department of Civil Engineering, Prathyusha Engineering College, Thiruvallur, India¹

M.E (Structural Engineering), Prathyusha Engineering College, Thiruvallur, India²

ABSTRACT: This thesis presents the experimental and analytical modeling of externally bonded glass fiber-reinforced polymer (GFRP) sheets for strengthening circular steel tubular short columns. The GFRP sheets are easy to handle due to the light weight property and the high-strength can provide a degree of restraint to delay buckling of the thin steel wall. Four short columns of cold-formed steel circular hollow section (CHS) were modeled and analyzed. One column is conventional (without GFRP wrap) and other 3 columns are externally bonded unidirectional (hoop) GFRP sheets which are varying with numbers of layers (1, 2, 3 layers) were experimentally modeled and analyzed. The modeling of steel tubular column with and without CFRP wraps are done by the simulated FEM software. The experimental and analytical result shows that the steel tube is strengthened by the fiber reinforced GFRP sheets and enhances the axial section capacity. The analytical results have been found to be in good correlation with the experimented results.

KEYWORDS: GFRP Sheets, Steel Tubular Columns, Axial Compression, Local Buckling, Strengthening, Section Capacity.

I. INTRODUCTION

Current designing practice utilizes customary materials, for example, steel and concrete as basic constructional material. Amidst the most recent decades, the costs identified with fortifying and support of structural designing structures which is made of steel or concrete reinforcement has been growing significantly. In addition, present has been a much more noteworthy interest for lighter and faster construction. The corrosion is major problem involved in steel. Because of their minimum self-weight, maximum durability and reduced maintenance requirements, Glass Fiber Reinforced Polymer (GFRP) is turning into a focused alternative as structural materials. The selection for choice of GFRP column depends mainly upon the following parameters are Column length, Area of cross-section, End condition, Shape of the column, Functional requirement, Economy aspects. The choice of column systems when choose by a structural designer accounts for satisfying the needs of safety and serviceability conditions. The area of cross-section and the sectional shape are merged into a geometric property of column, known as the span of gyration. This alludes to the appropriation of an item's segments around the axis.

II. LITERATURE REVIEW

The main focus of this study was to examine the suitability of FRP for on the exterior bonded reinforcement of concrete constitution subjected to flexural loading. A part of adhesive connection skill, composite material and algebraic modeling were used and practical to plate connecting skill. From this research it was concluded that the stiffness and strength of the beams strengthened with multiple plate was significantly maximized (Dipen Kumar Rajak 2019). In this journal, GFRP composites are used in submerged steel piles for repair and strengthening purpose. GFRP is corrode resisting material. I section encased with GFRP wrapped concrete. When the FRP wrap is higher than concrete, the FRP takes an initial axial load. Therefore, the stress transformation between FRP and concrete is same. To achieve bond strength the FRP wrap should be 2 layers along the concrete. Shear connectors are used to transfer the load between steel and concrete. In web and flange the shear transfer rod is connected (Vijay et al. (2016)). In this journal, there are 6 different circular columns which is free at one end and fixed at other end were experimentally tested. They are ordinary reinforcement concrete, RC enclosed with carbon fiber, RC enclosed with glass fiber, RC enclosed with steel, and 2 steel tube filled with RC column is enclosed with GFRP. The buckling is reduced with the help of wrapped FRP. These specimens are exanimating under axial load along with later cyclic displacement. The hysteretic behavior is poor in OPC. The GFRP wrap improving the energy dissipation. When

compared to GFRP wrap in concrete, the GST with confined RC is much efficient Zhongkui (2016)³. In this paper, the buckling behavior is restraint by using GFRP steel braces. It also used to resist seismic performance and corrosion. It classified as 2 component such as, core energy dissipates and external restraining. These braces are heavy, costly and not suitable for wide application. Transportation, lifting and installation process are easy. Core steel focus on middle braces. Paper has set A and set B variation. Set A is deformation and set B is failure mode. Maximum deformation occurs when GFRP layers is thick. The layer is mixed in transverse direction. It can give adequate stiffness and strength in longitudinal direction. Set B has 3 specimens based on set a result. Local buckling mainly occurs on end of brace. The result has been concluded as, in practical engineering, GFRP steel BRB is recommended. Manufacturing process is effortless and fit for wide applications. Brace has enhanced local stability in core steel brace. Crack will present if the GFRP wrapped on outer side Kailai et al. (2015)⁴. In this journal, the flexural strength of unfilled GFRP was performed in both experimentally tested and analytically modeled. By using vacuum bagging and hand layup method, there are eight layers, (0/90/±45/±45/0/90/0/90/±45/±45/0/90) of glass fiber/ epoxy is laminated. The specimen has length of 10mm and width of 30mm. Until 1st failure, the load is applied at middle by transverse direction. Eight layers were tested and average value has been taken. Analytical study is done by using ANSYS software. The author concluded has both the experimental and analysis values are similar. Using field emission scanning electron microscope, the nano and micro fracture have also been found (Chaudhary et al. 2018)⁵. In this journal, glass jute fibers and glass fibers are studied and compared by experimental test. The mechanical properties, viz, hardness, yield strength, flexural strength and tensile strength of both fibers are observed. The thickness of fiber is 1mm and it is molded by using hardener and resin until the thickness of 3mm. The roller is used throughout the surface to distribute the resins. For a week, mould is cured in sunlight and it has been tested. The result showed that jute fiber has less tensile strength than glass fiber. Hardness is same in both materials. Toughness improvement doesn't exist in jute fiber (Magarajan et al. 2018)⁶.

III. METHODOLOGY

Experimental studies combined with parametric studies are done by researchers on this subject widely based on presence of Hollow column used in the buildings. Here, experimental works on the aforementioned aspects and devoted the same for the comparison with finite element modeling to reinforce the results and findings obtained from the experimental modeling. The present intention of the study is to maximize load carrying capacity by using GFRP layers in Hollow steel section. There are 4 columns used for experimental as well as analytical work. Each column as different thickness due to GFRP layers present on it. The columns considered for the study is circular hollow section.

IV. EXPERIMENTAL PROGRAM

A. Material Properties

STEEL

As per the recommendations of IS-800-2007, the minimum grade of steel to be used for hollow column is to be kept as 310 Grade, so the steel grade used is 328 N/mm². The steel hollow column as in circular shape with modulus of elasticity is 2×10^5 N/mm², Poisson's ratio 0.3, Inner diameter 105.8mm, Outer diameter 114mm, Height of column 780mm, and Thickness of steel 4.5mm.

GFRP

GFRP can be used as bars, laminated sheets and chopped powder which is used in concrete for strengthening. Each longitudinal fiber sheet has width of 300 mm and length 780 mm. The material properties of GFRP are Poisson's Ratio 0.35, Shape is circular, young's modulus 35000N/mm², Thickness of 1 layer of GFRP 1.4mm, Thickness of 2 layers of GFRP 3.3mm, Thickness of 3 layers of GFRP 4.03mm, and strain 0 to 0.015.

EPOXY RESIN

Epoxy is the primary fluid response result of bisphenol-A with abundance of epichlorohydrin and this gum is called as diglycidylether of bisphenol A (DGEBA). The property of Epoxy resin is Density 1.2g/cm³, Tensile strength of 50MPa, and Hardener-Resin Ratio 1:5.

B. SHORT COLUMN

The behaviour of hollow and GFRP reinforced short steel circular column have been studied in this journal. The steel columns are designed under slenderness ratio, λ_s , which is ranges from 0-50, the role of GFRP to steel, and the



direction of the fibre reinforcements are virtual to the column axis. The hollow steel column of GFRP with and without wrapping is briefly explained with their length, diameter, thickness of steel and fiber and then layers of fiber which is presented on CHS. The experiment specimens were secreted into four sets depending on their diameter-to-thickness ratios, d/t . A total of 4 columns of cold-formed CHS were experienced, of which 1 column is conventional and four were reinforced by glass fibre composite sheets is varying with numbers of layers. Each of the samples was cut from a selected tube size and then machined to precise sizes to gain the mandatory local slenderness value. The nominal length of every segment was somewhere around multiple times the external distance across to hinder any impact on the test results because of section thinness. The column specimen are shown in Figure 1.



Figure 1 (a) Conventional Column CC (b) Strengthened Column with one layer CG-1 (c) Strengthened column with two-layer CG-2 (d) Strengthened column with three layers

C. STRENGTHENING TECHINQUE

The procedure for strengthening the column by bonding FRP sheets to steel involves surface roughening, application of epoxy resin of steel surface, placing of the Firstly, the surface of steel was made rough and cleaned to uphold a best adhesion like epoxy resin. Every layer of glass fiber sheet was arranged in necessary dimensions, and diverse epoxy was tarnished equally on the surface of the sheet fiber. Sheet was then placed on external surface of hollow steel specimen and to ensure the uniform bond thickness, the fiber sheets were slowly pressed with a paddler roller. Earlier than bonding the FRP laminates onto the steel surface, special consideration has to be given for plane research prior to the application of epoxy adhesive to take away the surface grease and smoothness. The available dust spot on the surface of concrete were cleaned by using vacuum. Steel strengthening are shown in Figure 2.

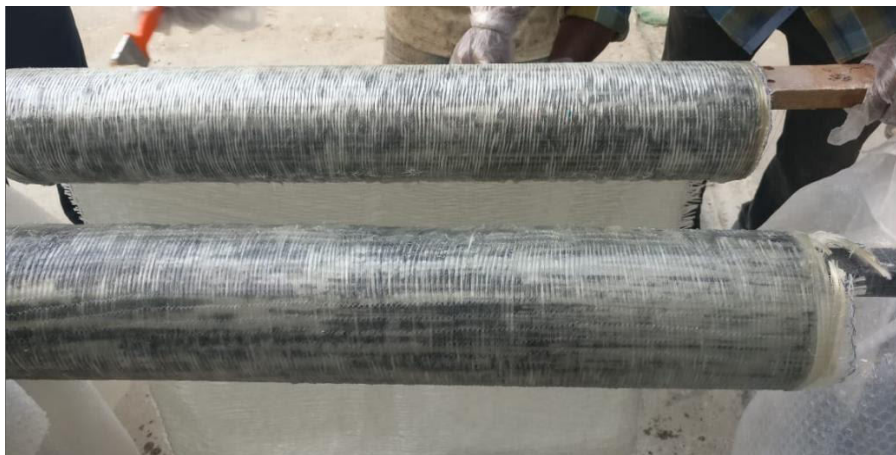


Figure 4.2 Steel Strengthening with FRP

D.SET-UP PROCEDURE

The hollow steel column is placed under testing machine. One column is conventional (without wrapping with GFRP) tested under universal testing machine. And other 3 columns were varying with numbers of layers.

Orientation of GFRP fiber was hoop which is considered in this study to examine the load carrying capacity. The length of column is 780mm. The experimental setup image are shown in Figure 3.



Figure 3 Experimental Set-ups for Conventional Column

The apparatus consists of string potentiometers and linear electric resistance strain gauges. On the top of the boundary conditions, all rotations and displacements were prohibited at the bottom end section (fixed end). At the peak end part, the displacement about the longitudinal axis is set free and at the other axes is restrained. This condition is calculated to deliver a even distribution of bearing stresses to the specimen. The strain gauge position is shown in Figure 4.



Figure.4 Position of Strain Gauge

Deflection of this column was measured using the dial gauges. Total two dial gauges were fixed at two points where the loads are applied and at midpoint of the beam. Thus, dial gauges will be removed from the test setup after the formation of initial crack on the surface of column considering that column would get failed at any moment. Least count of dial gauge is found to be 0.01mm and max deflection that can be measured is about 25mm.

E. EXPERIMENTAL RESULTS

FAILURE MODE

The failure columns with load with deflection are shown in Table 1. In the unreinforced wide HSC, near the ultimate load, type of buckling was noticed whilst local failure in the form of interior wing after single or additional buckles heading for the strength of the slenderer hollow sections. General damage was marked in reinforced column with minimum fiber reinforcement. The reinforcing was hoop in direction prove inadequate restraining force in external buckling in the ending regions of the column, foremost to crack. The crack is recognized to originate the adhesive boundary. In each specimen the failure nodes are noted to check a load carrying capacity. Ultimate load value for each column are separately mentioned in Figure 5. Axially the load is applied to hollow steel column of with and without GFRP. These load help to perform in comparison manner which is equivalent to steel section. Until structure fails, load is applied to specimen. The load versus graph for experimental is shown in Figure 6.



Figure 5 (a) Failure pattern for CC (b) Failure pattern for CG-1 (c) Failure pattern for CG-2 (d) Failure pattern for CG-3

BUCKLING BEHAVIOR

The buckling history of all the columns was recorded at top and middle of the span. The buckling behavior of the strengthened columns was compared to that of conventional column. Figure 5 shows the failure mode of the column specimens. It is prominent that behavior of columns bonded with numbers of GFRP layers shows better buckling behavior values than conventional column. By increasing the layers, the load carrying capacity increases. Failure mode of 1-layer GFRP wrapped with column (CG-1) shows a color changes where the glass fibers peel off. At 2nd and 3rd layer of buckling behavior is higher than the conventional column.

COLUMN	LOAD	% OF LOAD INCREASE OVER CC	MAXIMUM DEFLECTION (mm)
CC	510.1	-	1.45
CG-1	599.2	17%	1.51
CG-2	687.6	34%	2.1
CG-3	764.3	49%	2.35

Table 1 Load and deflection values for experimental results

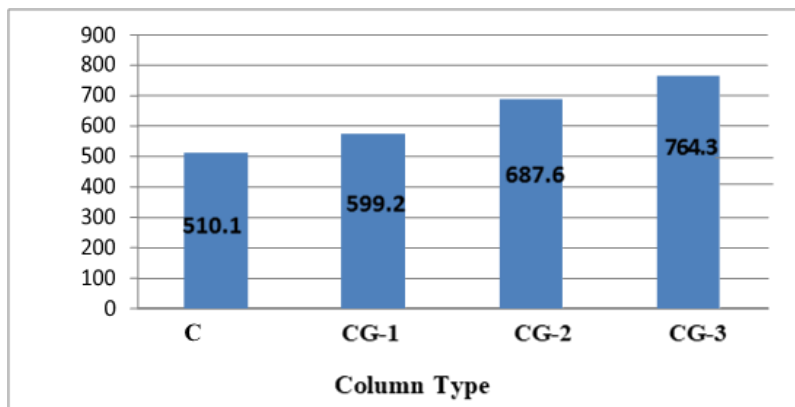


Figure 6 Ultimate Load Value for Experimental

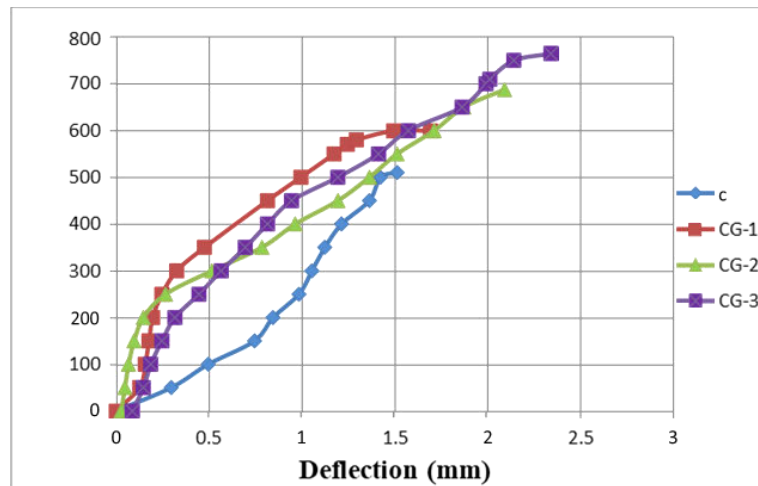


Figure 7 Load Vs Deflection Graph-Experimental

Deflection in these columns is compared with serviceability limit of the column and it is found that load carrying capacity of these columns (bonded with laminates) are higher and the crack propagation was slower when there is no chance for occurrence of sudden failure of columns, but in case of conventional column, the buckling behavior is higher which leads to a sudden failure of columns.

V. CONCLUSION

This study has presented the comparison study of GFRP wrapped and unwrapped hollow steel column by experimental and analytical modelling. A sequence of compression tests of steel columns reinforced by high-quality GFRP sheets was performed to learn the axial behavior and strength of the columns. The test outcome recommends that the utilization of a mixture of hoop GFRP in a slender tube can support the yield limit of the exposed tube. A sensible agreement was acquired. In addition, design strength curves for GFRP-reinforced steel columns have been obtained. The design normal approach for steel configurations was used to institute the design curves for GFRP reinforced steel CHS.

From the experimental results, the following conclusions have been drawn:

- The load carrying capacity of the CHS steel column 510 kN. The load carrying capacity of the column was further increased by wrapping GFRP with varying reinforcement configurations.
- The increase in buckling load of externally bonded GFRP column is about 17% - 49% on comparison with the column without confinement.
- On increasing layers of GFRP the ultimate load has been increased simultaneously. It is economical to use GFRP for strengthening steel as it is less expensive than other types of fibres.
- The bonding between GFRP laminate and steel column was intact up to the failure of column which clearly specified the composite action of GFRP laminates.
- The analytical modelling results obtained for the specification of experimented specimens were found to be similar.

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