

STUDY ON THE PERFORMANCE OF CFRP STRENGTHENED CIRCULAR HOLLOW STEEL SECTIONS

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Abstract

Compared to conventional steel sections, the Steel Hollow Sections have better structural performance due to excellent properties of the tubular shape with regard to loading in compression, torsion and bending in all directions. In many structural engineering applications Hollow Sections are widely used such as airport terminal buildings, railway stations, industrial structures, etc. Carbon Fibre Reinforced Polymer (CFRP) strengthening of structures has been with success applied to concrete structures, and additionally it applied to steel structures recently. In hollow section, Steel-CFRP composite combine the benefits of the high strength to weight ratio and more ductile. This paper presents an experimental investigation carried out with two different matrix layouts of carbon fibres on the axial capacity and crushing behaviour of CFRP strengthened Circular Hollow Section (CHS). With and without CFRP wrapping the experiments were conducted on short steel columns. From the experimental studies It has been inferred that the application of CFRP to short column sections increases ductility of the section and also increases axial load carrying capacity of the section. To improve the performance of existing structures, Carbon fibre could also be with success externally bonded to metal CHS, and such application could also be provided.

Keywords: Steel Hollow Sections, Carbon Fibre Reinforced Polymer, axial capacity, short steel columns, ductility

1. INTRODUCTION

In the steel construction industry, Tubular structures became typically used due to of their structural efficiency and economical values. Compared to conventional steel sections, the surface and profile of hollow steel section are attractive and structural performance. A tubular member is used either as flexure members like rectangular floor beams and circular utility telecommunication monopoles, or as axial members like columns and truss members in structures and bridges. Both transverse and longitudinal directions, FRP sheets could be bonded in tubular cross sections.

Related to strengthening of steel hollow section with FRP there have been a number of studies in recent years. FRP jacketing is a technique for the enhance and strengthening of circular hollow steel tubes [1]. On further Studies it clarifies that the capability of applying external CFRP Steel Rectangular hollow section delaying local buckling [2]. A short circular CFRP- reinforced steel tubular column is tested by Jimmy Haedir* and Xiao-Ling Zhao [3]. The study presented valuable experimental results showed that the CFRP wraps provided better confinement of the circular steel hollow section and also CFRP sheet can restraint to delay buckling of steel hollow section. Bambach and Elchalakani [4] study about the Plastic mechanism analysis of Steel Square hollow steel tubes strengthened using externally bonded CFRP .Xiao-Ling Zhao and Lei Zhang [5] wrote an excellent state-of-the review article on FRP strong steel structures. It had in-depth coverage on the subsequent aspects: bond between steel and CFRP and Failure modes in CFRP bonded steel system.

With CFRP the Strengthening of concrete have been studied by Marc Quiertant and Jean-Luc Clement [6], Yuliarti and Hadi [7], Oral Buyukozturk et al., [8], Maalej et al., [9], this paper deals about the systematic study about the performance of CFRP strengthened circular hollow steel sections. The test programme comprising tests on full-scale circular steel hollow columns, which wrapped with longitudinal CFRP (CF-1L) shown in Figure.1, and also wrapped with transversal CFRP (CF-1H) shown in Figure.2.

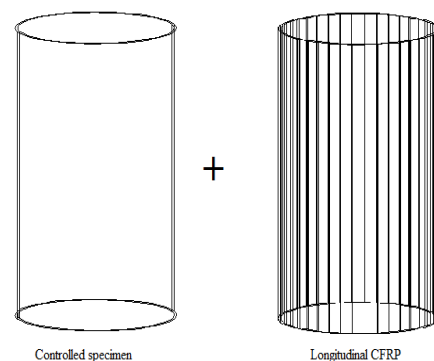


Fig -1: Composite metal CFRP - CF-1L

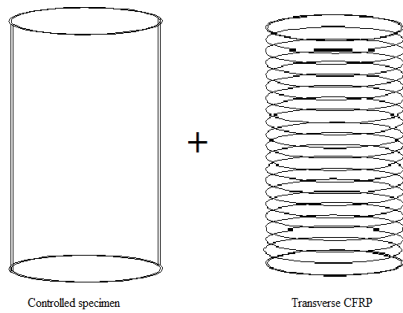


Fig -2: Composite metal CFRP - CF-1H.

2. TEST SPECIMEN AND EXPERIMENTAL SET-UP

The section dimensions of the commercially offered steel CHS with wall thicknesses 3.4mm. High strength uni-directional CFRP was used and applied to the outside of the CHS with epoxy. The high strength CFRP (termed MBrace CF 240) is nominally 3800 MPa and elastic modulus fibre is 240 GPa. The sheets were overlapped by 20 mm such that the overlaps at premature failure were avoided. To roughen the surface before laying the CFRP, the surface of the CHS was prepared by sandblasting, and then cleaned with acetone. The specimen setup is shown in Fig-



Fig-3: CFRP Surface preparation **Fig-4:** Surface preparation



Fig-5: CFRP Wrapping (CF-3H).

Fig-6: Rolling of Ribbed Roller

At room temperature, all specimens were cured for 10 days as per the manufacturer’s instructions. In a standard hydraulically actuated testing machine, the composite columns were tested in pure axial compression. Images of testing circular steel hollow columns, steel hollow columns wrapped with longitudinal CFRP (CF-1L), and also with transverse CFRP (CF-1H) are shown in Figure. 7.



Fig-7: Photos of prepared steel hollow columns – C-3, CF-3H & CF-3L

The slenderness values and dimensions of the specimen are shown in Table 1., Set 1 serve as control unstrengthen columns in order to provide a reliable test results. Sets 2 and set 3 are the CFRP-strengthened counterparts for Sets 1. Specimens in Sets 2 and 3 of each of CF-3L and CF-3H in CFRP strengthened scheme.

Table -1: Specimen Dimension

Set no	Specimen No.	Outer Dia. (mm)	Inner Dia. (mm)	Wall Thick (mm)	Length (mm)	kL/r mm	Fibre Configuration
1	C-3	88.24	81.44	3.40	300	10	-
2	CF-3L	88.24	81.44	3.40	300	10	1L
3	CF-3L	88.24	81.44	3.40	300	10	1H

The instrumentation consists of dial gauges and linear electric resistance strain gauges are given in Figure.8. A 16-channel data acquisition system such as strain and deflections was used to store the data. To provide a uniform distribution of bearing stresses the end conditions were designed to the column. to measure the variation of axial and circumferential strain distributions, an array of six strain gauges was used and they were blend every 120° around the outer circumference at the mid-height of each specimen.



Fig -8: Experimental set-up and instrumentation

3. EXPERIMENTAL RESULTS

3.1 Failure Pattern of Column

The specimens were kept at the supports and loaded up to failure to grasp the influence of CFRP on their axial behaviour and also centred to confirm symmetric loading. A smooth load–deflection curve is exhibited from the control specimen. Failure mode observed at the end of the test and is shown in Figure 9. In both the wrapping schemes, all the columns exhibited the smooth load–deflection curve throughout the entire test. Before the peak load there was no symptom of CFRP delamination or rupture of CFRP observed during the test. However, CFRP Delamination and enormous displacements occurred at a rapid rate beyond the peak load as a result of overall buckling. in CF-3L specimen the fibre was shred off beyond the peak load within the perpendicular direction to its length and it concluded eventually with the delamination towards the loading point and in CF-3H specimen, on the sides of the loading point the delamination of fibre was only observed and therefore the composite action was confirmed between CFRP and steel composites.



Fig-9: Failure pattern of column

3.2 Force – Displacement Results

Test results of force – displacement are summarized from the compression tests in Table 2, where P_u is the ultimate load obtained. At peak load Δ_{ul} is the axial shortening of CFRP confined steel tube. The confinement effectiveness of the CFRP jacket are often gauged by examining the degrees of enhancement at peak load within the ultimate load and also the axial shortening

Table -2: Summary of test results

Specimen	C-3	CF-3L	CF-3H
P_u (kN)	360.05	370.55	391.35
Δ_{ul} (mm)	7.38	8.21	8.94

When compared to the controlled Specimen from Table 2 , the ultimate load of the steel tube of CF-3L specimen was enhanced by 2.92% and also the axial shortening at peak load by 11.24%, the ultimate load of the steel tube in CF-3H

specimen was enhanced by 8.69% and the axial shortening by 21.13% at peak load . The axial force–axial displacement results responses are presented in Figure. 10.

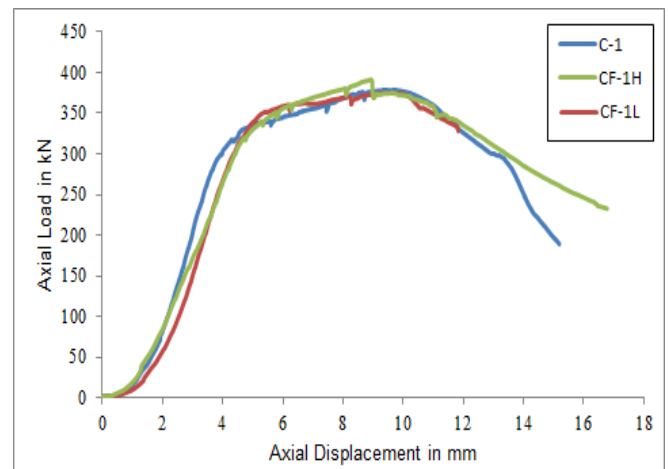


Chart -1: Axial load–axial shortening curves

3.3 Stress–Strain Behaviour

The steel tube expands laterally as a result of Poisson’s effect this enlargement is resisted by the CFRP and the normal pressure comes from the axial compression. For each specimen, the axial stress (axial load divided by the surface area of the tube) versus axial strain are shown in Figure 11

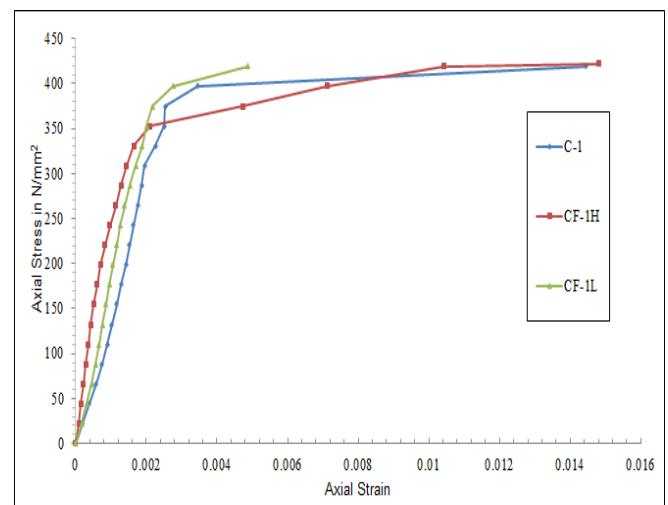


Chart -2: Stress–axial strain Behaviour

4. CONCLUSION

In the longitudinal and transverse directions the effect of CFRP sheet orientation was analysed. In order to provide compression strength for existing structures, the external bonding technique could also be applied. To demonstrate the effectiveness of CFRP confinement of steel tubes a set of axial compression tests has been conferred. CFRP confinement of circular hollow steel tubes leads to great increase in ductility with limited increases in strength, a feature that’s extremely desirable within the seismic enhance of structures. Therefore, for the seismic enhance of circular steel tubular columns, FRP jacketing seems to be a very promising technique. From the results, it’s determined

that strength and ductility aspect behaviour of specimen CF-3H was outperformed in comparison to the columns strengthened by CF-3L and strength aspect

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REFERENCES

- [1]. Teng, J.G , Hu,. Y.M., (2007). *Behaviour of FRP-jacketed circular steel tubes and cylindrical shells under axial compression*. Construction and Building Materials 21 pp. 827-838
- [2]. Bambach, M.R , Jama, H.H, Elchalakani, M (2009). *Axial capacity and design of thin-walled steel SHS strengthened with CFRP*. Thin-Walled Structures 47 pp.1112–1121
- [3]. Jimmy Haedir, Xiao-Ling Zhao (2011). Design of short CFRP-reinforced steel tubular columns. Journal of Constructional Steel Research 67 pp.497–509.
- [4]. Bambacha M.R., Elchalakani M,. (2007). Plastic mechanism analysis of steel SHS strengthened with CFRP under large axial deformation. Thin-Walled Structures 45 pp.159–170.
- [5]. Xiao-Ling Zhaoa, Lei Zhang, (2007) State-of-the-art review on FRP strengthened steel. Engineering Structures 29 pp. 1808–1823
- [6]. Marc Quiertant , Jean-Luc Clement, (2011) Behavior of RC columns strengthened with different CFRP systems under eccentric loading. Construction and Building Materials 25 pp. 452–460
- [7]. Yuliarti Kusumawardaningsih, Hadi M.N.S. , (2010) Comparative behaviour of hollow columns confined with FRP composites. Composite Structures 93 pp.198–205
- [8]. Oral Buyukozturk, et al., (2004) Progress on understanding debonding problems in reinforced concrete and steel members strengthened using FRP composites. Construction and Building Materials 18 pp.9–19
- [9]. Maalej., et al., (2003) Modelling of rectangular RC columns strengthened with FRP. Cement & Concrete Composites 25 pp. 263–276

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