

Experimental Investigation on the Buckling Behaviour of Steel Tubular columns using CFRP

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ABSTRACT: Recently, CFRP is being used for metallic structures. The purposes of using CFRP materials are i) High Strength to Weight ratio ii) Better durability in worst environment. It increases load carrying capacity and improves stiffness and buckling behaviour of structure. In this paper, study of behaviour of Hollow circular Section strengthened with Carbon Fibre Reinforced Polymer is carried out. Hollow sections were used as columns and CFRP as a strengthening material. The CFRP was found to significantly improve the capacity by preventing local inward buckling. Hollow columns CFRP bonded columns CFRP were tested. In comparison of intact section and CFRP bonded sections, load carrying capacity of CFRP bonded sections were increased.

KEYWORDS: Hollow column section, CFRP, inward buckling, strengthening, load carrying capacity.

I. INTRODUCTION

Many studies have been carried out to establish a reassurance over this relatively new material and new technique, RC column strengthening by FRP wrapping, over the last 20 years. However, nearly in all of them, the experimental works were carried out only on solid cross-sectioned short columns leaving hollow cross-sectioned column out of discussion, which were already left in the dark even in existing design codes for RC concrete columns. This study aims at explaining the behaviour of hollow columns wrapped with CFRP material under axial compressive loads.

In the literature, CFRP strengthening just delays buckling; it doesn't make any change in the mode shape of the buckling, CFRP strengthening improves the load carrying capacity of hollow section. Thus, it can be used as an alternative strengthening method. For Section with changing CFRP Strip, it was effective as it covers more buckling region of the section which is explained by A.P. Ghorapade 2015.

In addition, the overall buckling of the steel tube at the mid height was delayed and it was followed by crushing of resin and rupture of CFRP strips, for strengthened CFST columns under ultimate load. The reduction in lateral deformation of CFST columns corresponding failure load of CS. The lateral deformation was decreased by using three layer CFRP strip. The load carrying capacity of the CFST columns was enhanced by CS. From the results, it was clear that the spacing and number of layers of CFRP strips played a dominant role in the strengthening of CFST columns, as the former controlled the confining area and the latter improved the intensity of confinement pressure which is noted by P. Kiruthika 2015.

In this literature, unlike steel, the properties of FRP can be adapted to different directions by altering the fibre orientation and amount of fibre sheet in any specific direction. General failure modes possible in FRP strengthened are: a) Interfacial failure between steel and adhesive; b) Cohesive failure; c) Interfacial failure between adhesive and CFRP;

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d) CFRP delamination; e) CFRP laminate rupture; and f) Steel member yielding which is discussed by Ruby Freya 2012.

This paper presents an innovative approach in reinforcing the structural timber element machines graded pine (MGP10) with both U-shape steel elements and carbon fibre reinforced plastic under a three-point flexural loading. The main innovation of this work is the use of U-shape steel sections to fully strengthen both the tension and compression side of the timber. Previous studies predominantly used only plates, and only in the zone of maximum tensile stresses. It is hypothesized that the U-section reduces deboning compared with flat plates, because of shear effects between the flanges and the timber. This paper considers timber beams strengthened with steel only, CFRP only, and a combination of the two, with the aim to determine the behaviour of each case to reach the optimum arrangement. The proposed strengthening schemes can be employed to rehabilitate or repair bridge stringers, as the geometry of the present timber specimens, e.g., span length to sections' height, can be found within the applicability range of the real stringers which is presented by Tohid Ghanbari Ghazijahani 2016.

The advanced properties of FRP materials make them well promising for strengthening of steel structures. The main objective of this investigation is to assess the feasibility of strengthening circular hollow steel (CHS) tubular sections with FRP and to develop or predict the suitable wrapping scheme of FRP to enhance the structural behaviour of it. It is proposed to use mild steel tubes and carbon fibre used as external material. Experiments will be undertaken until failure to fully understand the influence of FRP characteristics on the compressive behaviour of CHS tubes which is discussed by M.C. Sundarraja 2014.

This paper was to study the behaviour of fibre composite material, more test are required to carry out to optimize the type of CFRP, sequence in applying. The main aim of this study is to discuss the performance of CFRP strengthened hollow steel columns in the structural aspects thereby controlling the CFRP

II. MATERIAL PROPERTIES

CFRP

The CFRP mesh sheet having 1mm thickness was used for experiment. These CFRP Sheets were cut into strip as per parameters. The strips were cut into 6 pieces, 300mm x 300mm strips. These strips wrapping is shown fig 1. Tensile strength and elastic modulus of CFRP is 5500MPa and 200GPa respectively.



Fig 1: CFRP Sheet and wrapped tube

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Epoxy resins

An epoxy resin was used as adhesive material is shown in fig 2. These are good bonding material between the steel and CFRP sheet. Epoxy resins having mix ratio of 1:10 by weight such as 10g resin and 100g Hardened. The elastic modulus of epoxy resin is 2.1GPa.



Fig 2: Epoxy Resin

Hollow steel tubes

The circular hollow section is chose which is conforming to IS 3601:2006. The height of the specimen fixed as 300mm. The Geometry properties are shown in table 1.

Table 1
Geometry of Hollow Steel Tubes

| Outer diameter, (D) | Inner diameter, (d) | Thickness, (t) | Length, (L) |
|---------------------|---------------------|----------------|-------------|
| 88.9mm | 86.9mm | 2mm | 300mm |

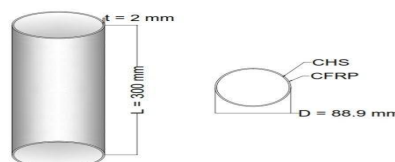


Fig 3 Geometry of CHS

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III. EXPERIMENTAL PROGRAM

Instrumentation

The overall views of the testing apparatus are shown in fig 4. This machine was an Avery Universal Hydraulic Testing machine with the maximum loading capacity of 1000 kN. As is seen, the machine consisted of two strong columns with many adjustment holes, along with two vertical shafts in order for adjustment of the top plate. The bottom plate, however, was installed to a vertically moving deck which was constructed on a rigid floor. A Linear Variable Differential Transformer (LVDT) was used to record the axial shortening of the specimens. A number of strain gages were attached to the critical spots on the specimens, the layout of which will be presented in the coming sections. All data were recorded via stand-alone measurement data acquisition; a professional tool for measurement engineers was utilized to process and record the data.



Fig 4: Test Machine

Specimen preparation

Hollow section having 6.0m length and its diameter is 88.9mm with the thickness are 2.0mm. The 6.0m long tubes are cut into 20 specimens of 300mm long. At the end of the specimen grain was found which is clear by lathe process and to get smooth edge of the specimen.

For wrapping the CFRP sheet on hollow section, it was required to prepare smooth surface of specimen and split the sheet with suitable sizes for the specimen. Sand paper used for rust free surface and to get proper bonding between steel and CFRP sheets. And CFRP sheets cut into suitable dimension and it wrapped to the specimen by using Epoxy resin, it having mix ratio of 1:10 by weight such as 1 for resin and 10 for hardener was mixed and it applied on the specimen. After 1 week the specimens were tested.

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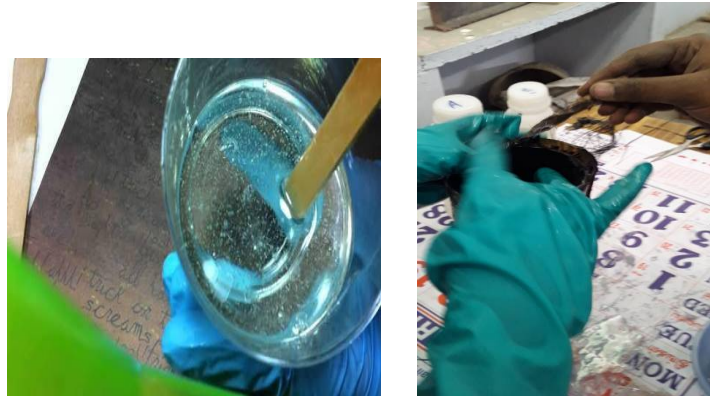


Fig 5: Epoxy resin mixing and specimen preparation

Test Specimen

Six 2mm thick CHS specimens and six CFRP wrapped specimen totally twelve specimens. The overall outer diameter and length were nominally 88.9mm and 300mm respectively for all the specimens. The specimens were nominated as 2mm thick CHS are BT1, BT2, BT3, BT4, BT5, BT6 and wrapped CHS specimen are FT1, FT2, FT3, FT4, FT5, and FT6.

IV. EXPERIMENTAL RESULTS

Failure modes

All the specimens were tested to observe under ultimate loading and displacement. The reference specimens were designated as BT1, BT2, BT3, etc... and were tested with the same loading and boundary conditions under compression. As can be seen, all strengthened control specimen exhibited a distinctive buckling failure. This failure looks like an elephant foot's buckling. This failure is proved as the past researches. Failure mode of BT1 specimen an outward buckling deformation near the mid-length of the column and near the ends of the column was observed. In the specimen BT2, local buckling deformation near the top and bottom of the specimen was noted, accompanied in BT3 specimen by a local buckling occurred at the top of the specimen was noted.



Fig 6: Failure mode of bare tubes

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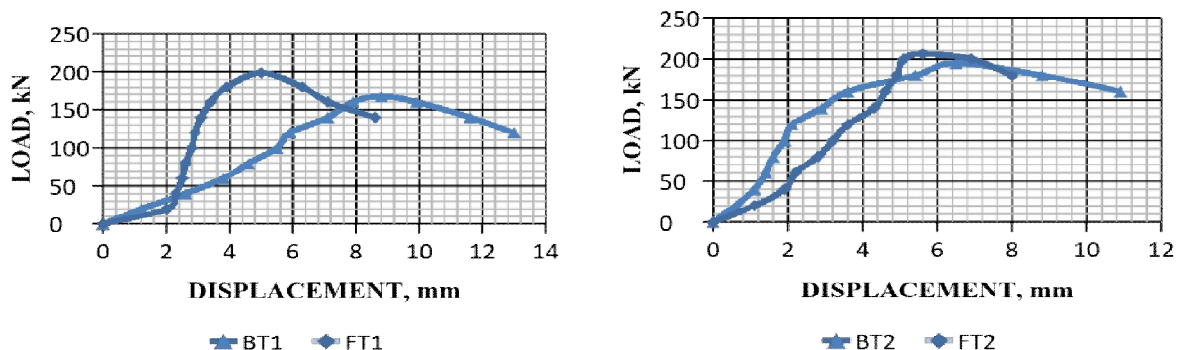
Failures modes are seen in figure 7 of the CFRP wrapped specimen were designed as FT1, FT2, FT3, etc.... and were tested with symmetrical load of the specimens. Failure mode of specimen FT1, the local buckling at the end of the specimen and slightly occurs local buckling at around 1/3 height of the specimen was noted and wrapped CFRP are crushed, accompanied in BWT2 specimen by a local buckling deformation occurred at the bottom end and bulge close to the top end of the specimen and also 1/3 height of the specimen was observed. Similarly, specimen BWT3 failed like elephant foot at the bottom of the specimens and near middle of the specimens to occur local buckling deformation was noted.



Fig 7: Failure mode of CFRP wrapped specimens

Strain response

The axial stress strain curve behaviour of bare tubes and fully wrapped specimens. When a load is applied to a specimen, deformations were occurs. The response between load and deformation of the specimens are usually determined by testing, in which the load and deformation are expressed in term of stress and strain. Figure 8 represents a typical stress-strain curve for a specimen subjected to compression test under normal condition. The specimen lateral deformation is plotted along horizontal axis and the corresponding stress is indicated by the curves. It was observed that the load is increase slowly the specimen was reaching the peak stress. When the specimen start crushing after the specimen reaches the peak value and other specimen of fibre start rupturing, there was a load return suddenly.



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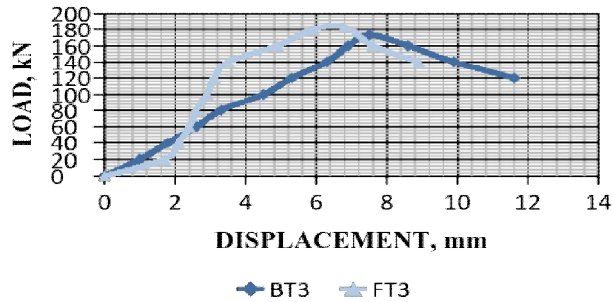


Fig 8: Comparison of Stress – strain curve for specimen

Load carrying capacity

The load carrying capacity of the entire specimen is shown in Table 2. The strengthened CFRP wrapped specimens have greater load carrying capacity when compared to control bare tube only up to a limit beyond which it decreases. Generally, the ultimate and service load carrying capacity was increased as the percentage of CFRP increased up to CFRP area of 10%. The ultimate load was increased significantly when the percentage of CFRP wrapped specimen such as FT1, FT2, FT3 was 18.52%, 5.64%, 5.83% respectively compared to the bare tubes such as BT1, BT2, BT3 respectively. The highest increment for ultimate load among these specimens was 18.52% i.e. when the beams were strengthened using 10% of CFRP. Here the CFRP wrapped specimen the increase in load bearing capacity is in one by fourth the value of bare tube load. To get a better and clearer understanding regarding this relationship, ultimate loads were plotted against percentage area of CFRP as shown in Fig 9. Here load were increased at the time deformation are controlled and to achieve the strength of the CFRP specimen over the hollow section.

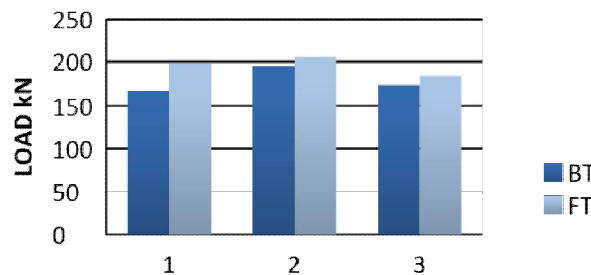


Fig 9: Comparison of Ultimate load capacity

Deformation

The deformation of the specimen was noted by the comparison of bare tubes and CFRP wrapped specimen as shown in fig 8. Here CFRP wrapped specimen delay the local buckling compared to the hollow tubes and to reduce the deformation of the hollow sections. In case of, CFRP wrapped specimen reduce the percentage of deformation compared to the hollow sections, that the range are 20% to 75%. From observe the experimental result, the value of deformation for hollow sections are 8.8@165kN, 6.5@195kN, 11.1@173.7kN, respectively and the CFRP wrapped

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specimens are 5.0@198.4kN, 5.6@206kN and 6.8@183.4kN respectively. The CFRP wrapped specimen delay the deformation at the same time the load were increase to get strength of specimen compare to the hollow sections.

Table 2

Experimental observation

| Specimen details | Ultimate load (kN) | Maximum lateral deformation (mm) | Decrement in lateral deformation (%) | Increment in load carrying capacity (%) |
|------------------|--------------------|----------------------------------|--------------------------------------|---|
| BT1 | 167.4 | 8.8 | - | - |
| FT1 | 198.4 | 5 | 76 | 18.52 |
| BT2 | 195 | 6.5 | - | - |
| FT2 | 206 | 5.6 | 16.07 | 5.64 |
| BT3 | 173.3 | 11.1 | - | - |
| FT3 | 183.4 | 6.8 | 63.23 | 5.83 |

V. CONCLUSION

From this report were concluding that the loads applied to the bare tubes and CFRP wrapped specimens which respectively gives deflection is occur which is tested by compression test. This test report says the ultimate load of CFRP wrapped specimen was increased which compared to hollow tubes and the respective deflection is occurred. we are going to test the results of strength achieved by hollow column wrapped with CFRP. And the deflection of wrapped CFRP specimen is delay to reach the load over the CHS specimens.

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