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Experimental Investigation on Concrete Filled Steel Tubular Columns Using FRP Composites

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Abstract: This paper is aimed at investigating the improvements of hollow steel tubes filled with concrete and externally bonded with fibre reinforced polymers. CFST members is an innovative idea in which steel element acts together with concrete element, so that both elements resist the axial and flexural loads. Experiments were carried out until failure and the influence of FRP composites on the behavior of CFST sections including their failure modes, axial behavior and enhancement in load carrying capacity were discussed. This paper introduces the structural system and discusses advantages, research findings and recent construction trends of CFST column system.
Keywords: CFST members, FRP composites, Strengthening

I. INTRODUCTION

Composite construction may be considered as a reliable choice of attaining proper balance between the advantages it offers and the cost. An extensive variety of composite columns and beams are available nowadays, but the concrete filled steel tubular (CFST) sections are most commonly used one. CFST member is an innovative idea a hollow tubular member is filled with concrete, used as beams or columns that are appropriate replacement for hot-rolled steel (or) reinforced concrete (RC) members in structural systems of tall buildings and bridges. This composite system utilizes the compressive strength of the concrete and the steel tube lies in the outer limits contributes a large portion of the stiffness and tensile strength, in addition, it provides required confinement to the concrete core, which increases the compressive strength of the column member. In compression, CFST short column reaches their ultimate capacity when both the steel and the concrete reach their strength limit point, i.e. yielding of the steel and crushing of the concrete and the CFST slender columns are governed by stability and failed by either elastic or inelastic column buckling.

The CFST structural member has a number of distinct advantages over a steel and reinforced concrete member. Owing to their structural benefits such as reduced cross section, high strength, improved fire resistance, greater apparent stiffness and excellent seismic resistant structural properties like high ductility and energy absorption, the use of CFST beams and columns has become increasingly popular in construction of building structures. Furthermore, the steel tube of CFST member can serve as formwork during infilling of concrete. The inward local buckling commonly observed in bare steel tubes, is effectively prevented and eliminated in CFST member. The CFST member also has variety of applications such as columns supporting platforms in offshore structures, roofs of oil storage tanks, large industrial workshops and tall structures, bridges and open-air overhead traveling cranes and also used as a piles in foundation. During the application of loads, the steel tube provides equal and uniform continuous pressure on the concrete core. So the concrete is subjected to tri-axial state of stress results in the enhancement of ultimate carrying capacity and stiffness of the member (Liu Dalin, Gho Wie-Min and Yuan Jie). On the other hand, the concrete prevents the inward local buckling of steel tube by increasing its local buckling strength. Circular cross sections are used over other sections due to the confinement of concrete. The size of CFST column is smaller than that required for RC columns to support same loads. Because of its high resistance for a small cross sectional area, it maximizes the useable floor area. The need of longitudinal reinforcement, transverse reinforcement and formwork are satisfied with the structural behavior of steel tube and it tends to rapid construction. FRP is becoming a popular material for rehabilitation due to its superior material properties like: corrosion and weather resistance, high mechanical strength, less weight, ease of handling, good fatigue resistance and ductility. However, research related to FRP applications to steel structures has started quite recently and there are still few applications in practice due to uncertainties concerning the long term behavior of these applications and the bonding between the composite materials and steel. From the journal "Experimental Investigation of FRP jacketed CFST under axial compression" M. Saranya, T. Karthigaipriya, G. Sathya, V. Muthukumar and Dr.M.C. Sundar raja by : Horizontal wrapping style of narrow strip is proposed by them to increase the strength was effective. They used Carbon FRP and the strength was increased.From the journal "Strengthening of Concrete Filled Steel Tubular columns using FRP composites" by P.Kiruthika, S.Balasubramanian, M.C sundarraja, J.Jegan: In unwrapped CFST column the outward buckling is noticed and the inward buckling is prevented by filled concrete. After CFRP is added the overall buckling of steel at mid height is delayed and the crushing and rupture of CFRP strips takes place at ultimate load.From the journal "Behaviour of FRP-Confined Concrete-Filled Steel Tube columns" by Yiyan Lu , Na Li and Shan Li :The experimental results indicated that the FRP wrap can effectively confine the concrete expansion and delay the local buckling of the steel tube. Both the load capacity and the axial deformation capacity of concrete-filled steel tube columns can be substantiaaly enhanced with FRP confinement. From the journal "Steel Tubed Columns to FRP tubed column" by Yan Xiao, Ph.d,P.E :Proved to be very effective in preventing column shear failure & developing significant ductility.Concrete filled steel tubular columns using FRP under axial compression as a part of larger study has been undertaken at HONG KONG POLYTHECHNIC UNIVERSITY. The main aim of this study is to analyze the performance of FRP strengthened CFST column in the structural aspects thereby controlling the width of FRP.

II. MATERIALS PROPERTIES

A. Steel

The hollow steel tube of circular cross section with the size of 50mmdiameter, 3mm thickness and 450mm height. Its yield strength is given as 415MPa in the manufacturer specification details.

B. FRP

FRP used is polypropylene.The properties are low density, high stiffness, heat resistance, good transparency, stretch ability.

C. Adhesive

The most suitable adhesive material with FRP fabrics is synthetic rubber adhesive supplied by FEVICOL PVT LTD. The adhesive type consists of two compounds, a resin and a hardener.

D. Concrete Mix Proportion

The designed mix proportion of 1:1:2 was used to attain strength of 25N/mm^2. The compressive strength attained at the end of 28 days curing.

Polypropylene

III. EXPERIMENTAL PROGRAM

A. General

For this research work, the HYSD steel tube of 0.45m height was cut out from 6m length steel tube with the circular cross section of 50mm diameter and 3mm thickness. Here the FRP were used to complement the strength of steel tubes and the tubes were filled with normal strength concrete. Three specimens were tested without FRP and Three specimens were tested with FRP under axial loads.

B. Fabrication of Specimens

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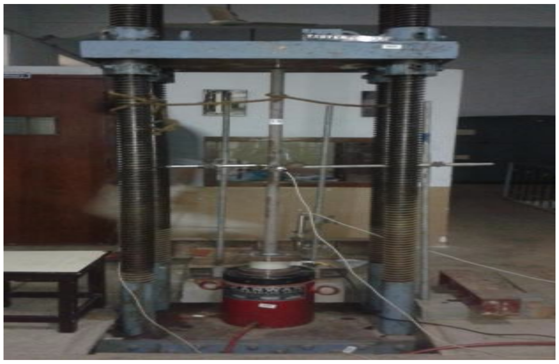
1) Casting and Curing of CFST Specimens: The steel tube of circular cross section with 50mm diameter, 3mm thickness and 450mm height was made from the 3000mm length of steel tube. The linear surface-grinding machine was used to smoothen the end portion of the steel tube. Rust and loose debris presented inside the steel tube were cleaned completely using steel wire brush. Concrete was filled inside the steel tube, with bottom end closed with the polythene sheet, so as to prevent the leakage of slurry and thoroughly compacted, to keep it free from air gaps. Then the specimens were kept under the process of wet curing.

Steel tube

2) Application Of FRP Composites: The adhesive was prepared, by mixing the base and hardener proportionately and a single coat was applied over the surface. Before getting dried, the surface was wrapped with a layer of fiber to avoid the direct contact between polypropylene and steel so as to prevent galvanic corrosion . During wrapping, air may get entrapped and so it was cleared in the fibre direction, by ribbed roller. Finally the specimens were allowed to cure .

3) Test Procedure: All the specimens were tested under axial compression in a column tester of 2000KN capacity . The columns were placed, centered and levelled using spirit level and plumb bob. Lateral deformations were observed. To begin with the test, a 20kN load was applied and removed to make the column rest on their base. Then the experimentation was begun with the increment of loads at regular intervals. The failure modes, lateral deformation and failure load were recorded up to its ultimate load.



IV. EXPERIMENTALRESULTSAND DISCUSSION

The parameters considered for the investigation of FRP bonded CFST columns included the width, spacing and the number of layers in order to optimize its usage. Experimentations results were reviewed, in the aspect of above said parameters. The lateral deformation behavior and load carrying capacity were observed and discussed.

A. Effect of Fiber-Reinforced Polymer (FRP) Confinement

The comparison of axial behavior for the FRP specimens and the corresponding CFST specimens. The CFST specimen and the FRP specimens behaved similarly till the steel tube yielded. When the steel tube yielded, the axial load of the FRP specimens increased in an approximately linear way. This is because the FRP wrap provided confinement to the steel tube and the concrete when the steel tube yielded; thereafter, the decrease of the rigidity of the CFST columns was delayed.

The CFST specimen experienced continuous dilation in the mid-height region in the later stage of loading. The local buckling of all FCCFST specimens was not so obvious, due to the external confinement from the FRP Wrap.

B. Failure Modes

In general, overall buckling, resin crushing and fibre rupture were the common failure modes observed. Besides, delamination of fibres was not observed in any of the specimens, which showed that there was a proper bonding action found between steel tube and fibre. After the rupture of fibres taken place and because of the absence of confinement pressure by FRP strips, there was no increment in the load capacity of CFST specimens.

From the above observations, it was understood that the FRP s helped in enhancing the behavior of CFST columns, by delaying the overall buckling under its peak load. The failure of FRP wrapped CFST specimens of 300 mm thickness were occurred due to the reduced confinement area provided by increased spacing of FRP fibre wraps. On the other side, the deflection was delayed due to the increased wrapped zone width.

C. Load Carrying Capacity

The main aim of this research work is to improve the load carrying capacity of CFST specimens by bonding them externally using FRP wraps. It was also achieved, as there was considerable increment in the strength of CFST specimens when compared with unwrapped specimen.

V. CONCLUSIONS

This paper presents an experimental study aimed at gaining a further understanding of the compressive behavior of FRP-confined concrete-filled steel tube columns. The external FRP wrap is provided to constrain outward local buckling deformation of the steel tube and to better confine the concrete core. The examined parameters were the FRP layer number, the thickness of the steel tube and the concrete strength. On the basis of experimental results, the following conclusions can be drawn:

The load capacity and the axial deformation capacity of concrete-filled steel tube columns can be effectively improved by the FRP wrap. All specimens failed by the explosive rupture of the FRP in the mid-height region because of the lateral expansion of the concrete.

The FRP wrap can delay the outward local buckling deformation of the steel tube and suppress the lateral expansion of the concrete in the CFST column. The strength and the strain capacity of the concrete can be enhanced by the additional confinement from the FRP wrap.

The axial compressive behavior of CFRP strengthened CFST columns was enhanced both in terms of strength and stiffness, by reducing the lateral deformation and increasing the load carrying capacity when compared to unstrengthen CFST column.

From the results, it was clear that the number of layers of FRP wraps 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.

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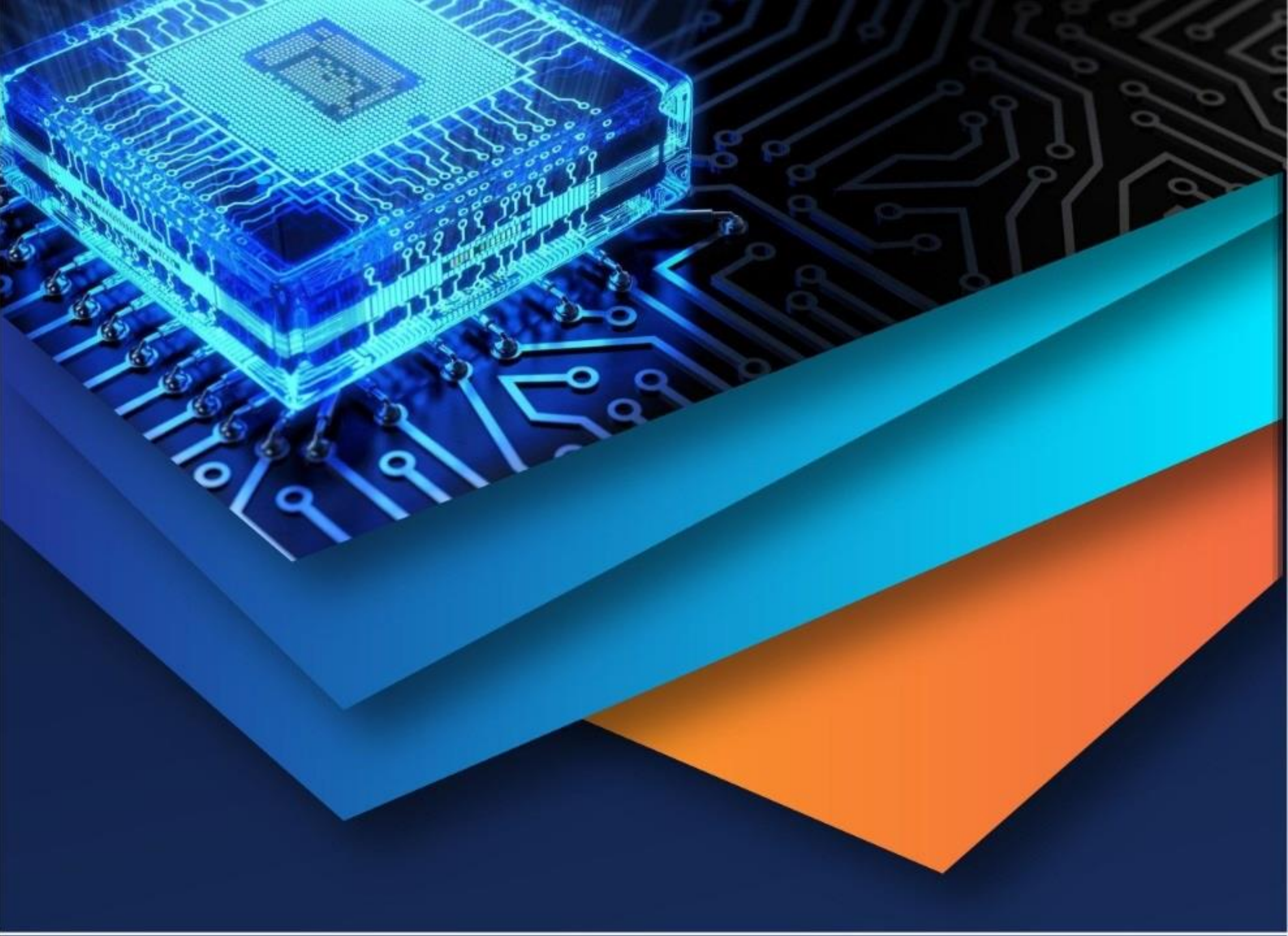

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