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Performance Evaluation of Short Circular Concrete Filled Steel Tube Columns under Axial Compression

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ABSTRACT

This paper aims to develop a suitable constitutive model addressing the behavior of short concrete Filled Steel Tubular (CFST) column on the compressive response under axial loads. The nonlinear finite element program is carried out to study the force transfer between steel tube and concrete core. Parametric study is conducted using nine circular CFST columns to investigate the load carrying capacities and confinement of CFST columns. The parameters such as yield stress of steel, diameter of the column and thickness of the steel tube are studied. 120-137% of load carrying increment is observed for concrete filled steel tubes by addition of concrete in the hollow steel tube. 95% of load increment by varying the diameter of the column and keeping other parameters constant. 8-16% of load increment is recorded by changing the steel yield strength and keeping remaining parameters as constant. 5.27% increase of load carrying capacity is observed by changing L/D from 3 to 5 and a decrease in the load carrying capacity is observed with an increase of L/D ratios from 5 to 7.

Keywords : Concreter filled steel column- Axial load capacity-grade of steel-hollow core section.

I. INTRODUCTION

CONCRETE FILLED STEEL TUBES (CFST)

Cold-formed steel tubular members have become popular in seismic regions, especially, for high rise structures (Liu Z. & Goel S., 1988). Tests have been performed by WalpoleW,(1995), Jain et al. (1980), Sherman & Sully (1994) and Grzebieta et al. (1997) on coldformed hollow section members. The results showed that the capacity of cold-formed tubular members reduced significantly due to local buckling in the sections and the magnitude of the local buckles became tremendous under different loading. Recently many different types of composite material systems have been widely applied to concrete column design to provide better performance in terms of high strength, stiffness, ductility and seismic resistance. Some of these composite columns are fully encased steel sections, partially encased steel sections and concrete filled steel tube. Among them, the concrete-filled steel tube (CFST) column system has turned out to be one of the most successful composite concrete column systems. The CFST column is a composite material system which employs the various advantages of different materials and combines them together in a steel tube column which is filled-in with concrete. CFST columns have anumber of distinct advantages over equivalent steel, reinforced concrete, or steel- reinforced concrete columns. Steel columns have the advantages of high tensile strength and ductility, while concrete columns have the advantages of high compressive strength and stiffness.

Composite columns combine steel and concrete, resulting in a column that has the beneficial qualities of both materials. The steel tube serves as a form work of casting the concrete, which reduces construction cost.

II. LITERATURE REVIEW

In CFST columns the steel lies at the outer perimeter where it performs most effectively in tension and in resisting bending moment. Similarly, the stiffness of the concrete-filled column is greatly enhanced because the steel is situated farthest from the centroid, where it makes the greatest contribution to the moment of inertia. The continuous confinement provided to the concrete core by the steel tube enhances the core's strength and ductility. The concrete core delays the local buckling of the steel tube by preventing inward buckling, while steel tube prevents the concrete from spalling (Lu and Zhao, 2010; Zeghiche & Chaoui, 2005).

CFST columns have been used widely in construction industry over the past half century in many parts of world primarily for low to medium rise buildings. It has been well documented that for short, circular CFST columns, there exists an enhancement in strength of the composite section relative to its uniaxial capacity and has good ductility. This effect is attributed to the lateral confinement concrete infill provided by the steel encasement. Despite the advantages and benefits this form of construction, its application in the Indian building industry has been poor, possibly due to the lack of a suitable design code and local technical data and shortage of understanding about CFST columns.

Lu & Zhao (2010), Yamamoto et al. (2000), Chen et al. (2011),andTian (2014) all found experimentally that the axial bearing capacity of circular CFT changed slightly with increasing size. EL-Heweity M. M., (2012), found the increase in yield stress of steel tube has a minimal effect but pronounced effect on concrete ductility. Since the experimental investigation of axial load carrying capacity of CFST columns extensively attracts the interests of researchers.

Due to their excellent structural performance, high strength and ductility, concrete filled steel tubular columns are extremely suitable as structural members for buildings, bridges, trussed structures and deep foundations. When they are used as structural columns, especially in high-rise buildings, the composite members may be subjected to high shearing force as well as moments under wind or seismic actions. It may be noted here that mechanical and economic benefits can be achieved if CFST columns are constructed taking advantages of high-strength materials. For example, high strength concrete infill contributes greater damping and stiffness to CFST columns compare to normal strength concrete. Moreover, high-strength CFST columns require a smaller cross-section to withstand the load, which is appreciated by architects and building engineers.

III. METHODOLOGY

An analytical model for the simulating short concrete filled steel tubular columns loaded in axial compression using the finite element software is done.The simulation procedure attempts to use nine models of varying diameters 100mm,140mm and 200mm each element of different steel grades such as 235,275 and 355 Mpa. The proposed model isused to study the variation of steel yield strength, and diameter ofthe tube on the overall performance (capacity aspect and confinement aspect) of the concretefilled steel tube columns, as well, the load bearing enhancement of filled tubes than thehollow tubes in terms of axial load carrying capacity is studied.

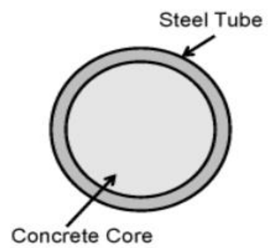

Figure 1: Concrete Filled Steel Tubes

IV. RESULTS AND DISCUSSION

A. Performance of column by varying different grade of steel

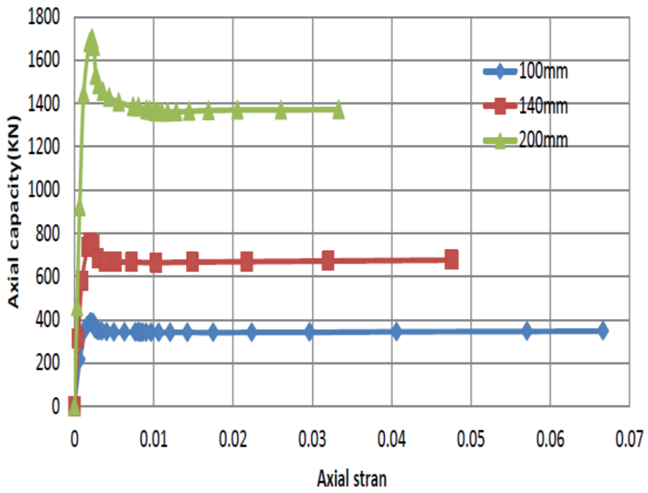

Figure 2 Load–strain response of CFST columns with different diameter size-fy =235 MPa

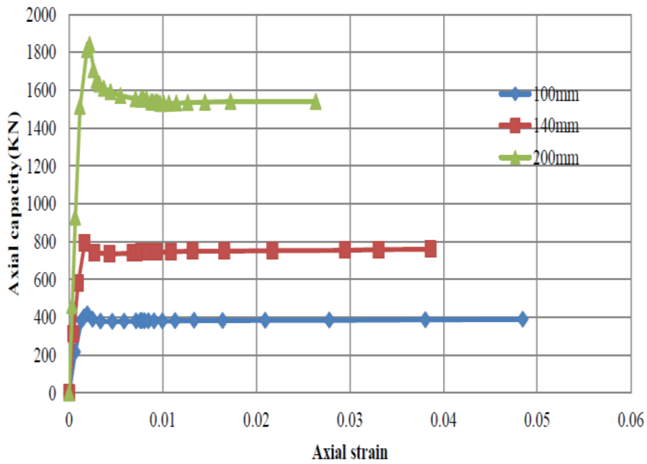

Figure 3 Load–strain response of CFST columns with different diameter sizes -fy =275 MPa

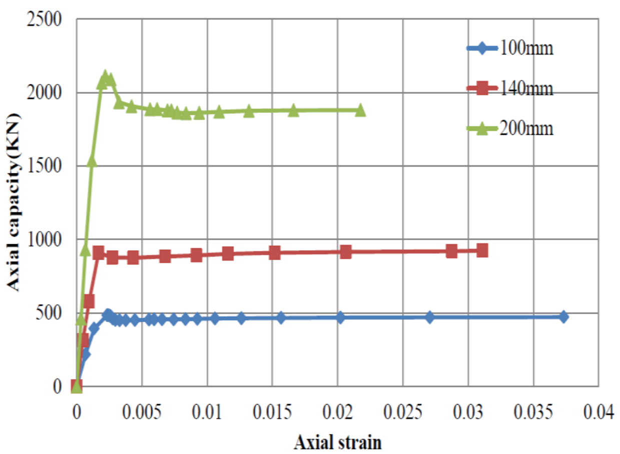

Figure 4 Load–strain response of CFST columns with different diameter sizes -fy=355MPa

B. CapacityAspect

The failure mode of the analyzed columns was identified as fully material plasticity of thesteel tube. It was noticeable herein that the mode of failure of CFST columns was notchanged by changing both studied parameters. theaxial load decreased slowly in the post-peak region, indicating reasonable ductilityperformance for CFT columns. Large columns with diameter 200 mm could not undergorelatively large axial strain (0.032) as compared to a strain of 0.046 achieved by smallercolumns (140 mm in diameter) and a strain of 0.067(100mm).

It should be pointed out that the maximum axial carrying capacity in CFST column increaseswith increasing the column diameter. Generally, increasing the diameter much increases both stiffness and capacity. For example, when thediameter increases from 100 mm to 140 mm (40%), the axial capacity of the columnimproves by up to 95%. Actually, this improvement may be due to increasing the yield stress of steel case which leads to much confinement to the concrete core. Besides, increasing theyield stress of the steel case increases its vertical contribution to the axial ultimate capacity of CFT column. Furthermore, the results show that for the same column diameter that the axialcapacity, axial force increases by 8% and 16% as the steel yield stress increases from 235 MPa to275 MPa and 355 MPa, respectively.

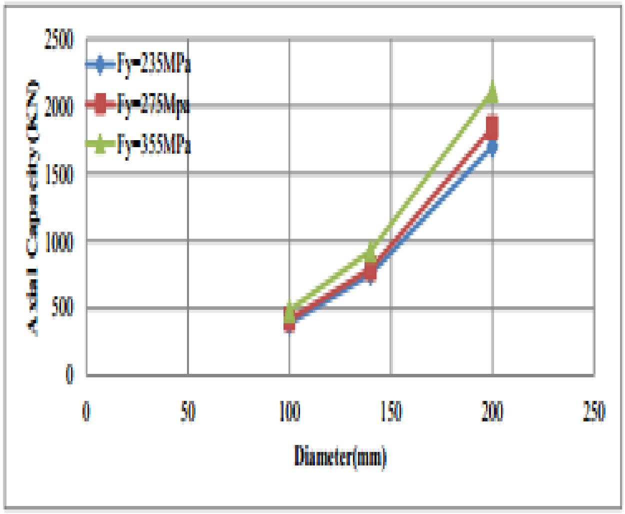

Figure 5 Effect of column diameter and steel yield stress on axial capacities of CFSTcolumns

The length to diameter ratio (L/D) represents the slenderness of the column. The failuremodes of concrete-filled columns arecharacterized by yielding of steel followed by crushingof concrete. The strength increase will occur only for columns of smaller slenderness ratio (orL/D ratio). Columns with greater slenderness ratio fail by overall buckling. Hence it can beobserved from the analytical results that the decrease in L/D ratio increases the sectioncapacity of the CFST column.

C. Confinement Aspect

For concrete filled circular sections, the confinement effect of concrete increases the concreteresistance, but at the same time reduces the axial resistance of the steel section. In EC4, thereduction of concrete strength by 0.85 may be omitted for concrete filled composite columnssince the development of concrete strength is better achieved due to the protection against theenvironment and against splitting of concrete.

The effect of confinement is considered whenthe relative slenderness λ is less than 0.5. Due toconfinement on concrete, the stress bearingcapacity of concrete increased to almost twice that of the ordinary circular column.

From another point of view, the confinement contribution on the axial carrying capacity ofCFT columns is calculated by subtracting the contribution of steel case and concrete corecolumn from the total axial capacity determined by the developed model. Hence, theconfinement contribution, ψ, may be written as

$$\psi = (P_{FE} - (f_y * A_s + f_c * A_c)) * 100 / P_{FE}$$

Increasing the yield stress of the steel casesincreases the confinement contribution of CFT column. The increase in confinement depends upon As, if we keep fy and fc constant.

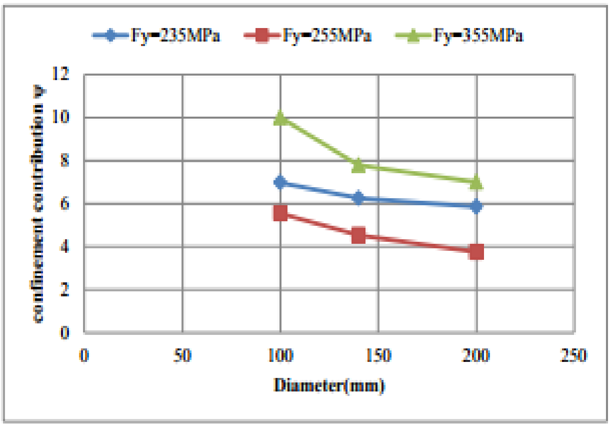

Figure 6 Effect of column diameter and steel yield stress on confinementcontributionforaxial capacities of CFT columns.

D. Comparison of CFST columns with HST columns

The axial load carrying capacity of hollow steel tubes (HST) is greatly affected by addition ofconcrete infill since local buckling of the steel tube is the failure mechanism for short tubularcolumns and buckling is for slender columns. After addition of concrete in the hollow tubesfor constant diameter and tube thickness up to 120%-137% of load carrying capacity isimproved. And also the failure mechanism is changed due to the confinement effect.

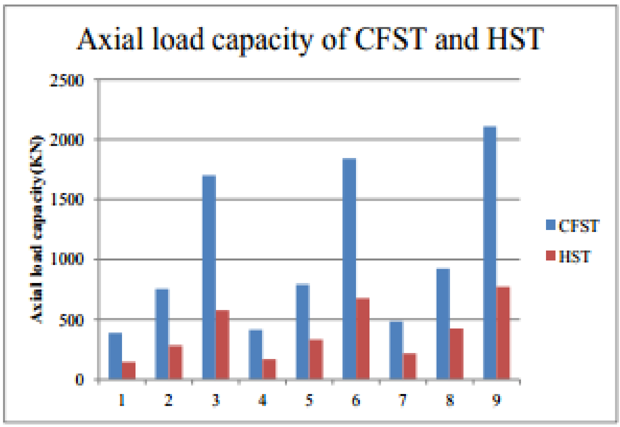

Figure 7Comparisons of axial load capacity between CFST and HST columns

the failure mode of hollow steel tube is due tobucklingand these kinds of failure is improved by the addition of concrete inside the tube and the steeltube will confine the concrete as well the concrete will restrict the steel from buckling which is the composite action will take place.

V. CONCLUSION

This investigation concluded that:

I. The confinement effects increased with the quality of the steel and the tube thickness.

II. Concrete filled steel columns with relatively higher concrete area proportionatelyincreased the ultimate strength but decrease the confinement effect.

III. Behavior of concrete is significantly modified due to confinement provided by thepresence of external steel tube.

IV. Hollow steel columns can perform considerably better with infill material. Significantimprovements in performance and load carrying capacity were demonstrated in the studydue to addition of concrete in the hollow tube. The ultimate axial compressive load of theCFST composite columns is 120 to137 % more when compared with the ultimate axialcompressive load of the hollow reference columns of the same size and shape.

V. The confinement effect increase with the increase in the yield stress of the steel tube butdecrease with an increase in diameter of the column.

VI. Increase in L/D ratio will increase the load carrying capacity up to some extent and aftersome ratios it will start reduction of load carrying capacity

VI. REFERENCES

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