

Concrete Filled Column in High Rise Buildings: A Review

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Abstract: *In the concrete-filled steel tube (CFT) columns, the interaction between the steel tube and concrete: local buckling of the steel tube is delayed by the restraint of the concrete, and the strength of concrete is increased by the confining effect of the steel tube. Extensive research work has been done throughout the world. In this paper the available literature for the use of Concrete Filled Columns in high rise building construction has been reviewed. Shear connectors are important for the CFT column and comparative study with different type of specimen have been reported in this work. The use of ultra high strength material modifies the behaviour of CFT column and such study is also presented in this work. Behaviour of CFT column under flexural loading and eccentric loadings has been also reviewed in this work. It has been shown that CFT columns have better performance as compared to normal columns to sustain load during fire. Further, it has been reported that CFT columns with ultra high strength concrete are capable of resisting high static loaded at elevated temperature. It has been also indicated that use of shear connectors with circular column has resulted in improvement in behaviour of composite column subjected to the eccentric loading.*

Keywords: Concrete filled column, shear connectors, elevated temperature, eccentric loading, and ultra high strength concrete

1. Introduction

In present scenario reinforced cement concrete, RCC construction is mostly widely used and this construction has various limitations like rate of construction, necessity of form work and concrete crushing behaviour etc. Composite construction is combination structural steel and concrete and has many distinct advantages as compared to RCC construction. In composite construction, concrete provides economy, durability, fire resistance and structural steel provides high strength, ductility, easy to assemble and fast to erect. In RCC construction brittleness may be a problem for the structural members whereas in steel construction, local buckling may be another problem for the structural members. To overcome these problems, composite structural members can provide one of the solutions. Concrete filled tubes, CFT (Fig. 1) is one such type of composite member, where local buckling of the steel tube is delayed by the restraint of the concrete, and the strength of concrete is increased by the confining effect of the steel tube. In addition, the steel tube may also serve as permanent formwork for concrete casting and eliminate the need for formwork and lead to fast track construction and economical design. Concrete filled tubes, CFT columns prove to be promising for the construction of multi storey buildings and therefore CFT columns have recently undergone increased usage throughout the world.

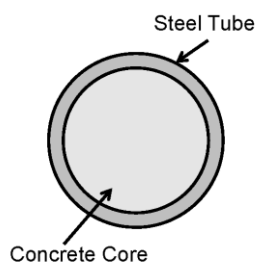


Figure 1: Schematic view of concrete filled tube column

(http://www.northeastern.edu/compositesystems/wiki/Concrete-Filled_Steel_Tubes)

This increased usage has been influenced by the improvement of high strength concrete enabling these columns to be considerably economized. Columns are designed now to resist the majority of axial force by concrete alone and can be further economized by the use of thin walled steel tube.

Concrete filled tubes, CFT columns have following advantages as compared with reinforced concrete columns:

- In CFT columns the strength of the concrete is increased due to the confining effect provided by the steel tube, and the strength deterioration is not very severe, because concrete spalling is prevented by the steel tube. Also, drying shrinkage and creep of the concrete are much smaller than in reinforced concrete columns,
- Construction efficiency is also improved as labour for forms and reinforcing bars is omitted, and concrete casting is done by Tremie tube or the pump-up method. This improved efficiency also leads to a cleaner construction site and a reduction in manpower, construction cost, and project length.
- Fire resistance of CFT columns is improved and requirement of the fire proof material can be reduced or omitted.

In this paper the available literature for CFT column for a tall building has been reviewed in the form of case studies. The various case studies have been reported to highlight the importance of concrete filled column and these studies focus on the research activities done on the CFT column over the last few years. The present compilations results in certain meaningful remarks and are also presented at the end.

2. Case Studies

In a high rise building construction CFT columns have many advantages which have been already discussed. Salient case studies are discussed below to evaluate the effect of CFT column in the construction of high rise buildings. First brief studies are presented and subsequently detailed studies are reported.

2.1 Brief Case Studies

Romero *et al.* (2011) carried out fire tests on slender circular hollow section columns filled with normal and high strength concrete. These columns were subjected to concentric axial loads in a fire situation. Test specimen columns of 3180 mm long and had a diameter of 159 mm and with a steel tube wall thickness of 6 mm. Column of 1m (short column) length are also used for fire test. The test parameters for this study were the nominal strength of concrete (30 and 80 MPa), the infilling type (plain concrete, reinforced concrete and steel fibre reinforced concrete). The columns were tested under fixed-pinned boundary conditions and the relative slenderness at room temperature was higher than the failure mode of such columns. It has been shown for slender columns subjected to high temperatures that the behaviour of high strength concrete was different than for short columns. Furthermore, the addition of steel fibres was not found very advantageous for slender columns as no increment in terms of fire resistance was obtained for these columns. However, the addition of reinforcing bars seems to be one of the solutions in some cases, where the use of external fire protection is avoided in the design of Hollow Steel section structures. It is also shown that the spalling does not appear in slender hollow steel section columns filled with high strength concrete. It was also shown that concrete filled column have better performance than normal column to sustain loads during fire.

Charles *et al.* (2011) performed a study to determine the best models for predicting the stiffness and resistance of circular CFT. In this work, 122 test specimens were evaluated and four basic types test (eccentrically loaded column tests, column foundation tests, beam-column tests, and flexural tests) were evaluated. The eccentrically loaded tests had significantly greater scatter and smaller average resistance than the other test types. Evaluation of data showed that eccentrically loaded tests were susceptible to damage from variations in load application, and these tests were excluded from the data. The results indicate that the plastic stress method is a simple yet effective method to predict the resistance of circular CFT components under combined loading. These obtained data show that current specifications provide inaccurate predictions of the flexural stiffness, and a new stiffness expression was proposed in this work. The proposed models permit simple yet accurate predictions of stiffness and resistance and will allow engineers to use CFT components routinely to design a structural member.

Lehman *et al.* (2014) have undertaken study on two large-scale (508 mm diameter) CFT column-to-footing connection specimens (one with portland cement and the other with a

high volume of supplementary cementitious materials as replacement of portland cement). Response of CFTs with conventional and high-volume supplementary cementitious materials concretes was evaluated for instant compressive, sustained, and cyclic loadings on specimens. Shrinkage and creep were evaluated for the both the large scale CFT and companion cylinders. The total creep strain in the both, conventional concretes and the supplementary cementitious materials was found to be much larger in the unsealed cylinders than the CFT specimens. The CFT specimens were also subjected to cyclic lateral loading to evaluate their response to extreme loads and it has been observed that the effect of creep loading on the performance of the supplementary cementitious materials concrete was negligible.

3. Detailed Case Studies

Case Study-1 (Richard *et al.*, 2012)

In this experimental investigation behaviour of concrete filled steel tubes by using high-strength materials was observed. The material properties of behaviour of different ultra high strength concrete (compressive strength of 180 Mpa) are obtained at curing age of 3, 7, 28 and 91 days. The residual ultra high strength of concrete after being exposed to elevated temperature was determined for residual compressive strength of cylinder and this behaviour was compared with normal compressive strength of concrete cylinder. Circular and square specimens with mild steel were used with the single tube and double tube. Both single tube and double tube, were filled with normal strength concrete and ultra high strength concrete. The specimens were tested as short column, beam and cylinder column section at elevated temperature (Fig. 2).

At elevated temperature, the reduction in high tensile strength is much more than normal tensile strength steel. Due to the brittleness of the ultra high strength concrete core, very loud cracking/crushing noise was heard during the testing for most of the ultra high strength concrete filled steel tube specimens. A steep drop in the load-displacement curves was observed right after the peak load (Fig 3).

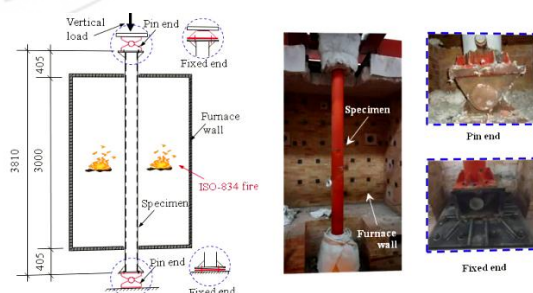


Figure 2: Fire Test setup for Column Specimen (Richard *et al.*, 2012)

Visual inspection was carried out on the specimens soon after the load drop and no visible deformation was observed. Ductile behaviour was observed from beam specimen tests as opposed to the brittle behaviour observed from short column tests. The load deflection curves after reaching the peak load were also recorded and the results indicated that the strength degradation was gradual without brittle or

sudden failure as observed from short column tests.

The overall buckling behaviour of slender ultra high strength concrete filled steel tube columns is quite ductile with smooth unloading from the peak load. No sudden failure due to the brittle failure of ultra high strength concrete was seen as observed in the short column tests.

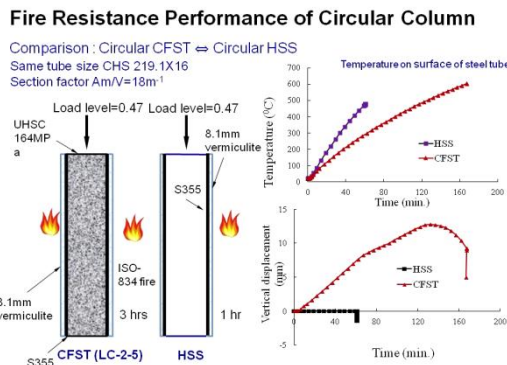


Figure 3: Fire Resistance Performance of Circular Column under fire test (Richard *et al.*, 2012)

It was shown in this study that Concrete filled tubes columns with ultra-high-strength concrete and steel are capable of resisting high compression static loads at elevated temperature. Hence, concrete filled columns are feasible for the multi-storey buildings and especially in high-rise construction, with reduced column size.

Case Study-2 (Probst, 2010)

In this study, the composite flexural behaviour of full-scale concrete filled tubes with application of shear connectors was evaluated. Full scale concrete filled tubes, beams (6 meter long simply-supported) were tested under four-point loads. Two beams of rectangular and the other two columns of circular were used in this study. These specimens were taken with and without shear connectors. Strain gauges were mounted at the mid span of each CFT flexural member to locate the neutral axis throughout the test. Load, deflection, steel strain, and concrete movement were digitally recorded.

Test results shows that in rectangular section without shear connectors and with shear connectors, longitudinal delamination between the concrete and the steel occurred by the end of the loading in the first direction. Composite action was improved by shear connectors particularly for circular CFT beams. Circular section with shear connectors, was loaded in the first direction, in two areas the steel around the shear connectors on the bottom side of the section had yielded. The crack patterns in the cut concrete section parallel to the longitudinal axis of the CFT beam were also seen. The high number of cracks in the cut concrete section indicates that the concrete cracked throughout the entire positive moment region at both the top and bottom of the section.

It was shown that the concrete in each section did not turn to rubble, but showed fine cracking at regular intervals, or slices, transverse to the length of the tube. This failure mode obtained suggests that a fairly high degree of composite action was achieved for the specimens with shear connector.

CFT beams exhibited excellent ductility and energy dissipation. The composite action became ineffective for both rectangular and circular CFT beams without shear connectors. The use of shear connectors was effective particularly for the circular shape.

Case Study-3 Chithira and Bhasker (2012)

In this work experimental study on concrete filled circular steel tubular columns under eccentric load condition with and without shear connectors was carried out. Bare steel tubes (as reference specimens), CFT columns without shear connectors and CFT columns with shear connectors, were tested under eccentrically loading condition in this study. Load Moment Interaction Curves are generated for all the test specimens and critical eccentricities are evaluated to apply the eccentric load. Different Diameter/thickness ratios and Length/Diameter ratios are considered for experiment. The columns were hinged at the ends and the load was applied through designed eccentricity. The eccentricities were equal at both ends and columns were subjected to single curvature bending. The Load Moment Interaction Curves values at the ultimate failure load of experimental study were found to be well agreed with the results of the proposed load moment interaction curves interaction model.

Experimental results show the percentage increase (6% to 13%) in load carrying capacity of CFT columns with shear connectors as compared to the ordinary CFT columns. However, the ductility factor of columns with shear connector's exhibit higher values than that of the CFT columns without shear connectors.

The use of shear connectors has resulted in considerable improvement in the structural behaviour of composite columns subjected to eccentric loading with respect to ultimate load carrying capacity, stiffness and ductility. Hence, CFT column can be used in seismic areas for improved structural behaviour.

4. Concluding Remarks

The concrete filled column has been applied rapidly to structure in last few years and this trends is continued with more and more structures. The concrete-filled steel tube (CFT) column system has many advantages compared with the reinforced concrete system. The steel tube can serve as permanent formwork for concrete casting and thus eliminate the need for formwork and lead to fast track construction as resulting clean site environment and economical design. Salient observations have been noted from the reported case studies and are given below:

- a) CFT columns can be used in multi-storey buildings and especially in high-rise construction, with reduced column size. Reduction in column size also increases the usable floor area.
- b) The environmental burden is reduced by omitting the formwork and by reusing steel tubes and using high-quality concrete.
- c) CFT Columns are quite ductile with smooth unloading from the peak load and no sudden failure has been observed. Also, these columns have better performance under the eccentric loadings.

- d) CFT column are found to be more effective to resist flexural loading with the application of shear connectors.
- e) At elevated temperature CFT column are found more reliable as comparative to conventional columns.

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