A Study on Effect of Steel Tube in Axial Behavior of CFST Stubs

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Abstract. Concrete filled steel tubular (CFST) columns are becoming popular due to its advantages from both steel and concrete in resisting loads. CFST members are made up of steel hollow section of rectangular or circular sections filled with plain or reinforced concrete. CFST columns can be used effectively in high raised structures and in bridges. The reduced cross sections of columns can be achieved by the composite action of steel and concrete. The steel tube provides confinement to the concrete and helps to improve load carrying capacity. The concrete core offers higher resistance to axial compression. The inward buckling of steel tube will be avoided due to concrete and the out buckling resistance may be improved due to higher stiffness of the column due to higher gross moment inertia with combined effect of steel and concrete. This experimental work made an attempt to understand the effect of thickness of steel tube in behavior of CFST stubs.

In the present experimental study, a total of 24 cylindrical concrete filled steel tube specimens were prepared to evaluate the uniaxial compressive behavior and to understand the effect of thickness and aspect ratio \((h/D)\) on the compressive strength. Two different thickness of steel tubes 3 mm and 5 mm and four aspect ratios \((h/D)\) 1, 2, 3 and 4 are considered in the present study. M30 grade of concrete is used. From this study, as the aspect ratio increases the buckling loads decreases. The decrement is up to 37\% in aspect ratio 4 when compared to aspect ratio 1.

1. Introduction

Concrete-Filled Steel Tubes (CFST) members comprises of a steel tube in filled with concrete. It has the advantage of both concrete and steel. The steel tube provides confinement to the concrete core and is capable of enhancing the core strength and ductility [2]. Inward buckling of tube is restrained by the concrete, while the steel tube is provided as tensile reinforcement for the concrete [5].

The steel at the outer perimeter is most effective in resisting bending stresses. Typically, the stiffness of the CFST is improved because of steel. Since steel has a greater elastic modulus than the concrete. Steel also contributes more to the moment of inertia as it is situated farthest from the centroid.
Therefore the stiffness of the member also greatly improved. The concrete core helps in delaying and often avoids inward buckling of steel tube and sustains the compressive loading in typical applications. Local buckling takes place at higher loads than the usual. CFST columns have exceptional structural benefits for earthquake resistance of structures due to its large energy absorption capacity and high ductility [4]. With the elimination of permanent form work construction time can be considerably reduced. Steel tube of CFST provides both longitudinal and transverse reinforcement and also acts as a confinement to concrete core, which favours the introduction of tri axial stress state to core of the concrete. The concrete core stiffens steel tube. The mechanical material properties like yield strength of the steel and compressive of the concrete determines the resulting ultimate strength of CFST columns. The concrete core stiffens steel tube. CFST columns are used mainly in bridges, and high rise buildings. These composite columns however can require additional protection, in structures under fire conditions. The cross section of CFST columns is smaller in comparison to RCC columns.

1.1. Advantages of CFST columns
CFST columns have many advantages compared with RC system or steel construction. The important advantages are as follows.

1.1.1. Composite behaviour
The occurrence of inward buckling of the steel tube is avoided and outward buckling is delayed. The residual strength after the local buckling is not very severe due to the resisting effect of concrete. The axial capacity of concrete is increased because of the confinement from the steel tube. The spalling of concrete is also prevented by the steel tube.

1.1.2. Sectional properties
In the RC sections and encased column sections the ratio of reinforcement is much lesser than those in the CFST cross section. In CFST sections steel will be plasticized under bending since the steel location is outside of the section.

1.1.3. Construction efficiency
Construction efficiency will improved with time, manpower and cost as form work is not required. Concreting can be done by pumping method and reinforcement can be avoided depending upon the requirement. The CFST columns are even suitable to precast construction.

1.1.4. Fire resistance
The performance of CFST columns under the fire can improved by use of fire resistance coating material since steel is exposed to fire.

1.1.5. Cost
The cost of the structure may bit higher than RC but comparatively overall cost of the structures will be reduced due the advantages listed above.

2. Experimental investigation
In the present study, an experimental program carried out to understand the behavior of CFST short...
columns with different aspect ratios (h/D) and different thicknesses of steel tubes. As load resisting capacity of concrete short columns increases in the presence of steel tubes compared to RCC columns due to confinement of concrete and yielding of steel. A total 24 specimens are prepared for the present study. The steel tubes are of two different thicknesses of 3 mm and 5 mm and outer diameter is 100 mm. The steel tubes were cut to desired dimensions with aspect ratios of 1, 2, 3, and 4. Each aspect ratio contains three columns of each thickness. The steel tubes used are of mild steel and the grade of concrete used was M30. The grade of cement used was OPC 53 grade. The mix design was done as per IS 10269:2009. The mix proportions of different ingredients used per m3 are shown in table 1. Trial mixes were made and cube specimens were prepared. 28 days of curing was done by watering. The characteristic compressive strength was found to be 32 N/mm².

| Ingredient          | Cement (kg) | Fine Aggregate (kg) | Coarse Aggregate (kg) | Water (Liter) | Chemical admixture (kg) |
|---------------------|-------------|---------------------|-----------------------|--------------|-------------------------|
|                     | 335         | 888                 | 1095                  | 143          | 6.68                    |

For the specimen preparation, steel tubes which were cut to the desired shape by taking proper care to have plane surfaces at top and bottom. The concrete was mixed to designed proportion in pan mixer and filled in the circular cylindrical steel tubes in 4 layers. Each layer is compacted manually with a compacting rod for 25 blows as per IS 516:1959. Before placing concrete in steel tubes were cleaned off the dust and applied with oil. The care is taken for avoiding segregation and bleeding. Then the concrete filled steel tubes are finished on the top with cement paste. All prepared samples are shown in Fig.1. To these columns curing compound is applied to retain the moisture in the concrete. The prepared specimens are allowed to cure for 28 days. The cured specimens were tested for axial compression in compression testing machine of loading capacity 3000kN. A dial gauge with maximum capacity of 25mm was used to measure the longitudinal deformations of the CFST columns. The loading set up is shown in Fig.2.

**Table 1**: Ingredients of concrete per m³

![Fig 1: CFST stub specimens](image)
Compression testing is setup of axially loaded CFST segments. These sections are pin ended at the closures and the load applied exactly on the longitudinal axis of the column. A dial gauge was mounted on platen to record the amount of axial shortening for the given load at regular intervals of loading. Proper care was taken and observes the alignment of the test set up periodically to avoid the eccentricity of the loading which may lead to damage of alignment of platens of compression testing machine. Continuous monitoring was done to note the buckling load and its corresponding shortening and test was continued till the maximum piston displacement or failure of the specimen whichever is earlier. The buckling patterns and the failure patterns are also observed during the compression test.

![Compression testing machine and test setup](image)

**Fig 2**: Compression testing machine and test setup

3. **Results and discussions**

3.1. Load carrying capacity

The experiments are conducted on 3000 kN capacity semiautomatic CTM. A rate of loading 140 kg/cm²/min was maintained and the deformations were recorded using dial gauge. Continuously monitored during the testing and buckling loads and axial deformations are noted. For each thickness and aspect ratio, three specimens were tested and averages of the results were considered in results. The specimens which were failed early due to eccentricity of loading due to initial imperfection were avoided in considering results. Due to the limitation in equipment the maximum deformation measured only 25mm. The load vs axial deformation curves for 3mm thick and 5 mm thick samples are presented in Fig 3 and Fig 4.

From Fig 3 and Fig 4, It is observed that all the specimens are have initial portion ascending curve merely linear and then yielding and strain hardening portion after certain loading. This behavior indicates clearly that the concrete contributes to taking load up to certain loading and once it crushes steel start taking load. Once steel reaches to its yield strength in compression and it start buckle. In the specimens of 3 mm and 5 mm thick CFST stubs, the aspect ratio 1 i.e. 3CF100 and 5CF100 are resisting higher loads than other aspect ratio specimens. The behavior of aspect ratio 3 and 4 specimens are
almost close and it indicates the higher than aspect ratio 2, the load carrying capacity in compression is not increasing and the specimens have long column effect. Since complete failure of specimens are not observed, the loads at 15 mm axial deformations are compared for understanding capacities. At 15 mm axial deformation the load capacities in 3CF100, 3CF200, 3CF200 and 3CF400 are 1800kN, 1380kN, 1200kN and 1168kN respectively. As the aspect ratio is increasing from 1 to 2 the capacity is decreasing 23%, 1 to 3 the capacity is decreasing by 33% and from 1 to 4 the capacity is decreasing by 35%.

**Fig 3.** Load Vs Axial deformation for 3 mm thick specimens

**Fig 4.** Load Vs Axial deformation for 5 mm thick specimens
At 15 mm axial deformation the load capacities in 5CF100, 5CF200, 5CF200 and 5CF400 are 1950kN, 1710kN, 1530kN and 1480kN respectively. As the aspect ratio is increasing from 1 to 2 the capacity is decreasing 12%, 1 to 3 the capacity is decreasing by 21% and from 1 to 4 the capacity is decreasing by 24%. On comparing capacities between thickness of CFST stubs, as the thickness increases the capacity of specimen increases. the capacity is increasing by 8% in aspect ratio 1, 23% in aspect ratio 2, 27% in aspect ratio 3 and 26% in aspect ratio 4. The aspect ratio 1 specimen behaves more stiffer than other aspect ratios. It can be observed that as the thickness increases the stiffness of the member also increasing.

3.2. Buckling behavior

The failure specimens are shown in Fig 5. The mode of failure of CFST is concrete crushing followed by steel tube buckling. The buckling effect is more in higher aspect ratio specimens which buckles at lower loads due to slender effect. Some specimens were buckled at end locations.

![Tested specimens- failure modes](image)

The buckling load results are presented in Fig 6. It is clearly shows that as the h/D ratio increases the buckling load decreases. For a particular h/D ratio, as the thickness increases the buckling load increases. In 3 mm thick specimens, the buckling loads in aspect ratio 1,2,3 and 4 are 1624 kN,1223kN,
1122 kN and 1062 kN respectively. As the aspect ratio is increasing from 1 to 2 the capacity is decreasing 24%, 1 to 3 the capacity is decreasing by 30% and from 1 to 4 the capacity is decreasing by 34%. In 5 mm thick specimens, the buckling loads in aspect ratio 1,2,3 and 4 are 1802 kN, 1590 kN, 1500 kN and 1133 kN respectively. As the aspect ratio is increasing from 1 to 2 the capacity is decreasing 11% , 1 to 3 the capacity is decreasing by 16% and from 1 to 4 the capacity is decreasing by 37%.

![Buckling load Vs Aspect ratio](image)

**Fig 6.** Buckling load Vs Aspect ratio

4. **Conclusions**
   - As the aspect ratio increases the buckling load capacity is decreasing. In 3 mm thick CFST short columns of aspect ratio 2, the buckling load capacity decreased by 24%, for aspect ratio 3, is decreased by 30% and for aspect ratio 4, is decreased by 34% when compared to aspect ratio 1.
   - In 5 mm thick CFST short columns for aspect ratio 2, the buckling load capacity decreased by 11% and for aspect ratio, is decreased by 16% and for aspect ratio 4, is decreased by 37% when compared to aspect ratio 1.
   - The aspect ratio 4 and more the percentage decrement in buckling load is almost is same irrespective of thickness of the CFST column.
   - The aspect ratio 1 specimens behave more stiffer than other aspect ratios. It can be observed that as the thickness increases the stiffness of the member also increasing.

**References**

[1] Abdelmaseeh Bakos Keryou and Gailan Jibrael Ibrahim 2014 Axial load carrying capacity of thin walled HSS stub columns filled with waste glass concrete International Journal of Enhanced Research vol 3 issue 5.
[2] An Heou Zha 2019 Experimental and numerical investigations of concrete-filled stainless steel tube stub columns under axial partial compression Journal of Constructional Steel Research 158 405-416.
[3] Arivalagan and Kandasamy 2009 Energy absorption capacity of composite beams Journal of Engineering and Science and Technology vol 2 issue 1.
[4] D R Panchal, V P Sheta 2016 Experimental study on circular and square concrete filled steel tube columns subjected to axial compression loads vol 5 issue 5.
[5] Fa-xing Ding et.al. 2015 Mechanical behavior of circular and square concrete filled steel tube stub columns under local compression Thin Walled Structures 94 155-166.

[6] Farid Abed, Mohammad AlHamaydeh, Suliman Abdalla 2013 Experimental and numerical investigations of the compressive behavior of concrete filled steel tubes (CFSTs) Journal of Constructional Steel Research 80

[7] IS 516:1959 Indian standard Methods of Tests for Strength of Concrete Bureau of Indian standards (New Delhi).

[8] IS 10262:2009 Guidelines for concrete mix design proportioning Bureau of Indian standards (New Delhi) 110020.