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The load bearing capability of admixed Concrete Filled Steel Tube(CFST) Columns with and without shear connectors

M. Giridharan* and Dr. K. Ramakrishnan

School of Civil Engineering, SASTRA University, Thanjavur – 613401- India

Abstract: Concrete Filled Steel Tube (CFST) columns were taken in to an account because of its greater strength and malleability recital contributed by the composite action. At early elastic stage this composite action cannot be absolutely developed as the expansion of steel was quite more than that of concrete. This in turn, creates deficient interface bonding between the composites. Thus, it cut down the elastic stiffness and strength of the CFST columns. To overcome this lacuna in the initial elastic stage, provision of shear connectors was carried out to reduce the lateral dilation of the concrete core and steel. In this experimental work, CFST columns of assorted proportions, with shear connectors were tested for push out tests and axial compression. A mix design for M40 grade of concrete was adopted, in order to increase the workability of concrete. A chemical admixture, High Range Water Reducing Admixture (HRWRA) was used in the mixes which showed better compressive strength. The behavior of the admixed CFST columns with and without shear connectors was analyzed. From this experimental investigation, it had been observed that: (1) the provision of shear connectors increased the bonding of interface by about 17%, which in turn helped to achieve higher axial load-carrying capability (ranging from 17.5% to 18.3%) and reduction in axial shortening of CFST columns. (2) The ductility of CFST columns were improved by shear connectors. (3)The lateral deformation of the steel tube and the core concrete at the placement of shear connectors were limited effectively.

Keywords: Concrete Filled Steel Tubular Columns (CFST); Super Plasticizer; Interface bonding; HRWRA; shear connectors; bond strength.

Introduction

Use of composite tubular segments was getting to be very well known because of its better structural performance contrasted with that of bare hollow steel tubes and nominal reinforced column. Circular tube sections have a benefit among the different sections when they used as a compression members. For a provided cross sectional region, they have a large uniform elastic firmness (stiffness) in overall directions. By filling the bare steel tubes with concrete builds a definitive strength of the part with no noteworthy increment of expense. The principle preference of the concrete in CFST was because it can postpones the local buckling of wall of the tube and concrete core itself, in the controlled manner, and it has the capacity to support higher stress and strains than when the segment was uncontrolled. The presence of concrete inside the hollow tube was subjected to triaxial state which brings about increment in strength. Research on CFST segment has been continuing worldwide for a long time, with huge commitments has been made. Nonetheless, there was a real weakness of receiving CFST segments, which was the defective interface bonding of cement and steel tube at the time of initial elastic stage because steel expands more than concrete. As this imperfect bonding would result in the decrement of the confining pressure which was provided by the steel tube and hence there will be reduction in the initial stiffness and elastic strength of columns. This circumstance was surprisingly more terrible for High Strength CFST (HSCFST) sections as High Strength Concrete (HSC) was more fragile than normal strength concrete and may cause untimely disappointment of segments

The thickness of wall in the steel tube and the measure of shear resistance connectors utilized as a part of the CFST sections incredibly impacted the shear resistance[1].The absence of interface bonding would bring about tube buckling in the early elastic stage (premature failure) for CFST sections loaded with HSC[2].A few outline systems which can be utilized to conventionally gauge the strength of thin walled circular concrete filled steel tubes under distinctive load conditions, for example, (i) concentric loading on the steel tube alone, (ii) concentric loading on the concrete alone, and (iii) concentric and eccentrically loading on both concrete and steel[3]. A technique utilizing a successful width guideline to anticipate the conduct and load bearing capability of concrete in-filled steel tubes[4] .Because of the absence of confinement provided by the steel tube, the solid center would squash like the devastating of HSC, indicating exceptionally weak brittle conduct[5].The dedication of headed stud shear connectors and edges to upgrade the shear resistance of the steel and solid interface using push out test[6].The conduct of unusual segment and the most widely recognized utilized areas of CFST segments under concentric and cyclic loading[7].With the test parameters as the section thinness, the loading covering concentric and eccentric with unior biaxial bending and the compressive strength of the composite segment was observed[8]. In order to fully make use of the CFST columns, internal stiffeners and binding bars were proposed before concrete starts crushing[9]

A number of above literary works were for CFST segments. On the other hand, the greater part of these investigations were on sections utilizing typical and HSC, subjected to axially or eccentrically loaded conditions and limited number of literatures were available on axially loaded CFST segments with the presence of shear connectors for its bond stress. This paper exhibits the push out test for bond stress with and without shear connectors so that, how the increment of bonding in the interface influences the axial load bearing capability. To ascertain the comprehensive behavior of such section segments, an experimental investigation was carried out using fifteen specimens. The specimens were pin ended and tested under axial load. The D/t ratio as 69 with slenderness proportions of 1.7was considered as test parameter.

Details of Test Specimens

In the present study, a total of 15 specimens were made for two separate tests viz, Test I and Test II. Test I was for finding the maximum axial load bearing capability by axial compression test and the test II for finding the bond stress of the specimen by performing push out test. All the specimens were chosen according to Euro Standards provided for the selection of CFST column dimensions. $\frac{D}{t} \leq \frac{90 * 235}{fy}$ (EuroCode-4(2004)[10].Themodels having diameter 172 mm and of wall thickness of 2.5 mm (i.e. D/t proportion with 68.8)were utilized. For performing axial compression three empty steel tubes (H), three (CFST) and three Concrete Filled Steel Tubes with Shear Connectors (CFSTC) were examined. In case of push out test three Concrete Filled Steel Tubes and three Concrete Filled Steel Tubes with shear connectors were considered.

Material Specifications

Steel

The coupon samples complying with ASTM A370:2003[11]were considered for every steel material was subjected to coupon test. The measurement of coupon test example was given in Figure 1. The Yield strength (F_y) and Ultimate strength (F_u) were found to be 280N/mm^{2}and 319N/mm^2. From the stress - strain curve the modulus of elasticity was ascertained to be 2 x 10^5 N/mm^2.

Concrete

In the current study, mix design for M40 grade of concrete were done by using the guidelines of IS:10262 [12]as the concrete mix was a dry mix, in order to increase the workability A High Range Water Reducing Admixture (HRWRA)was used in the mixes which showed better compressive strength than the mixes without admixture.

Admixture

Super plasticizer CONPLAST SP430 (G) complies with IS: 9103:1999[13] and BS: 5075 (Part 3) and ASTM-C-494[14] type 'F' having a specific gravity of 1.220 to1.225 with a pH > 6 which is in Light Brown color was used as a high range water reducing agent.Air entrainment of Approx. 1% additional (As per Manufacturers manual) .The mean estimation of compressive strength of concrete at 7 days IS 50.26 N/mm^2.

Also at an age of 28 days was 60.25 N/mm^2. The test outcomes were according to IS 456 (2000)[15].

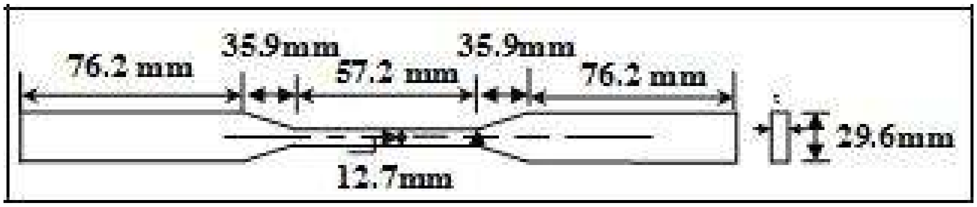

Figure 1: Dimension of tensile coupon test specimen.

Preparation of the Test Specimens

The steel specimens were cut for the obliged L/D ratio, and the edges were flattened well to obtain a level surface for uniform loading. Bolts of High strength with Grade8.8 according to IS 1364-Part 1 (2002)[16] of length 60mm was placed as demonstrated in Figure2 and utilized as a "shear connector". The bolt shear connector was embedded inside and welded to the external steel surface as shown in Figure 2.The connectors placing and position were adopted as per the particulars given for steel concrete composite bars in EuroCode-4 (2004).In the course of preparation of the test specimens, the specimens were kept in upright position and the compaction was carried out in layers for maintaining a strategic distance from air voids in concrete. And also for performing push out test for finding bond stress, before the casting of specimens a gap of 50mm left not filled at the top for enabling the movement of concrete within the outer shell at load shown in figure 3.

Figure 2: CFST with shear connector.

Figure 3: Specimen left 50mm left unfilled

Experimental Investigation

Test Setup and Procedure

The tests were carried out through a recently raised 3000 kN limit compression testing machine as indicated in Figure 4a and the universal testing machine as indicated in Figure 4b.in order to perform axial compression test, steel plates were made for required dimensions with a small groove exactly at the middle of the plate and steel ball of required dimensions were placed at the center point of the two plates.

Testing of specimen

Figure 4a demonstrated the testing set up of an axially loaded CFST segment. These sections were pin ended at the closures and the load applied exactly on the C.G of the section. A circular steel collar plates were given at the closures of specimens to exchange the concentric action with no slip. The entire setup was mounted on the compression testing machine of capacity 3000 kN. The specimens mounted with dial gauge at the compression side of the tube in order to record the amount of axial shortening for the given load at regular intervals of deflection .The peak load and its corresponding shortening was noted and compared and tabulated in Table 1. For push out test, a steel circular solid of diameter less than the diameter of the specimen was placed over the specimen in order to provide compression only on the concrete. All the specimens were mounted on universal testing machine of 1000 kN capacity. While performing the test, the specimens were kept inverted and load was applied on the concrete alone using a circular steel solid less than the diameter of the specimen as shown in Figure 4b and the 50mm gap at the bottom got collapsed and the slip were noted up to the failure load after it attains the peak load. The variation between load and slip was compared and tabulated in Table 1.

Figure 4a: Experimental setup for Axial compressions

Figure 4b:Experimental setup for push out test

Results and discussion

Push out test

While performing this, it was observed that the welded shear connector influences the failure mode. For all specimens the failure load and its corresponding axial displacement was observed, The bond strength of the specimens with and without shear connectors was shown in the Table 1.For determining the bond stress of the specimens from the failure load equation (1)was used

$$F_b = \frac{P}{\pi D L} \qquad (1)$$

Where P was the failure load, D was the inside diameter of the steel tube and L was the length of the concrete steel interface. Figure5 shows the load vs slip relationships of CFST and CFST with shear connectors. According to the test results, it can be noticed that the strength of the concrete and load conveying limit of the specimen increases with the provision of shear connector in CFST up to 17%.A sound can be perceptible once the failure load reaches. Then solid body motion of the concrete in relation with steel tube starts with increasing displacements. The failure load of the segments was shown in the Figure6.The bond failure was shown in Figure7.

Table 1: Details of tests specimens and results

Specimen type	Diameter D(mm)	Length L(mm)	Thickness t(mm)	L/D	Average ultimate compression load $f_{u\,(kN)}$	Average axial shortening (mm)	Average bond stress f_b (N/mm^2)	Percentage of increment in bonding
CFST	172	300	2.5	1.76	197.5	9	1.218	17
CFST With shear connectors	172	300	2.5	1.76	234.5	4.5	1.447	

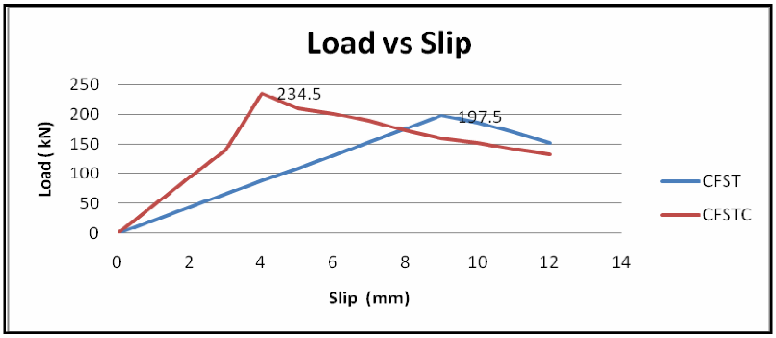

Figure 5:Load vs Slip curves

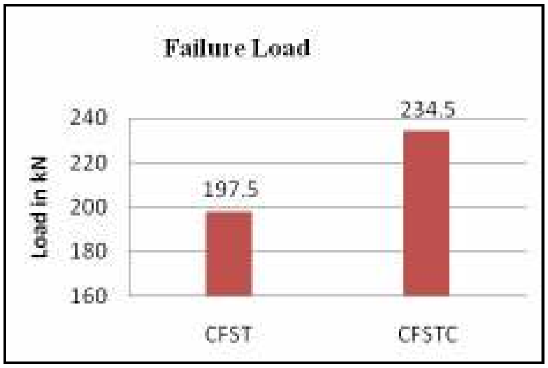

Figure 6: Failure load

Figure 7:Failure in bond

Axial compression test

Graph was plotted between axially applied load and the axial deformation for the CFST segments in Figure 8. The axial load was noted from the compression testing machine while the axial shortening was noted from dial gauge, from the Figure8a, Figure8b,Figure8c, it was observed that for the specimens with no shear connectors, at first, the axial load increase as the axial shortening increases. As the shortening increased further, the micro-cracks in the central solid concrete grew quickly and consequently the Poisson's ratio of concrete increased alarmingly and its value was more than that of steel tube. Subsequently, it actuated the confining pressure, shaping the elasto-plastic branch. For the CFST segments confined with shear connector, the shear connectors induced confining pressure in the beginning and at the absolute starting point, i.e., the starting elastic stage, which could increase the elastic strength of the segments. Figure 9 demonstrated the correlation between Ultimate loads for specimens.

The load bearing capability of CFSTC with that of CFST was increased from 17.5%to 18.3%, the test results were given in Table 2. Additionally the axial shortening significantly diminished in CFSTC and its value was 10 mm as against the value of 24mmfor CFS Tat failure loading.

Table 2:Details of tests specimens and results

Sl.no	Specimen detail	ultimate load in hollow tube(kN)	ultimate load in CFST(kN)	ultimate load in CFSTC (kN)	Increment in ultimate load %	Deflection at failure point in CFST(mm)	Deflection at failure point in CFSTC(mm)
1	CFST 1	370	1258.66	1535.2	18	23	11
2	CFST2	367	1262.25	1530.5	17.5	22	10
3	CFST3	372	1258.18	1540.2	18.3	24	11.5

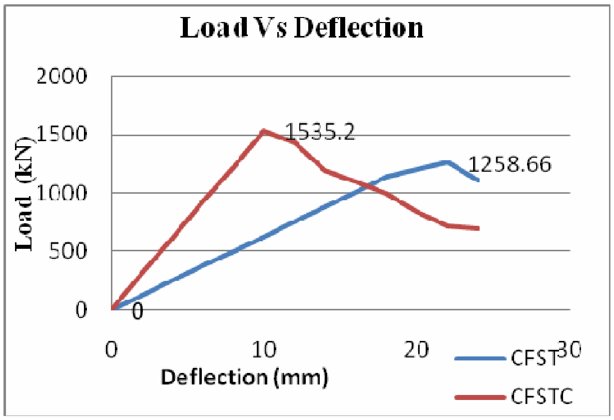

Figure 8a: Trail 1

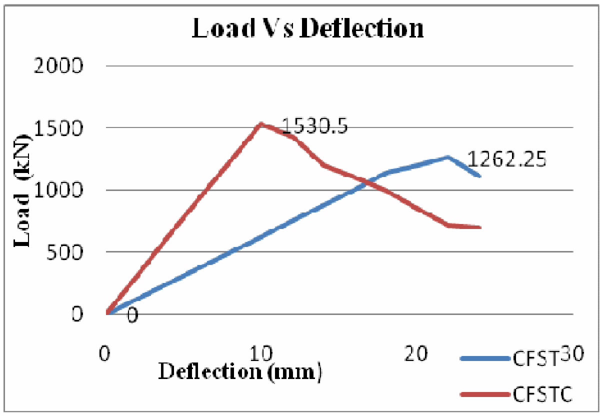

Figure 8b: Trail 2

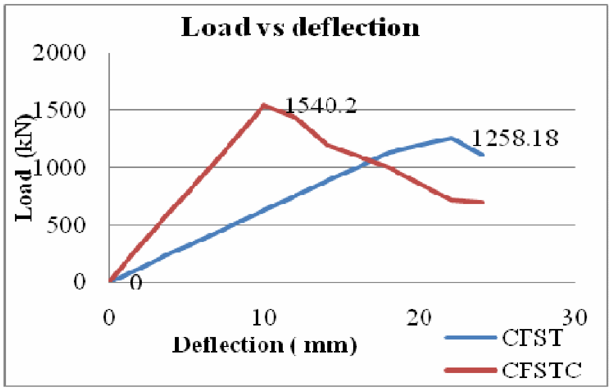

Figure 8c: Trail 3

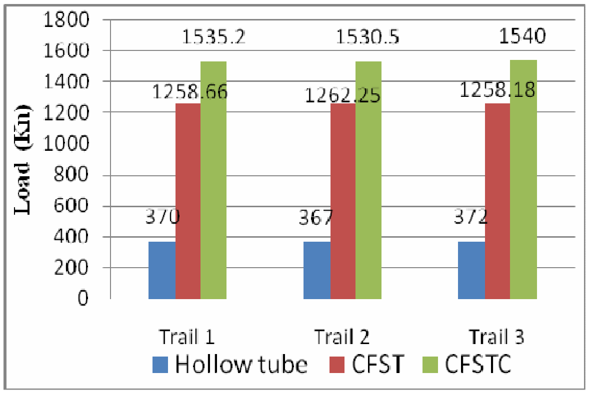

Figure 9:Comparison of loads

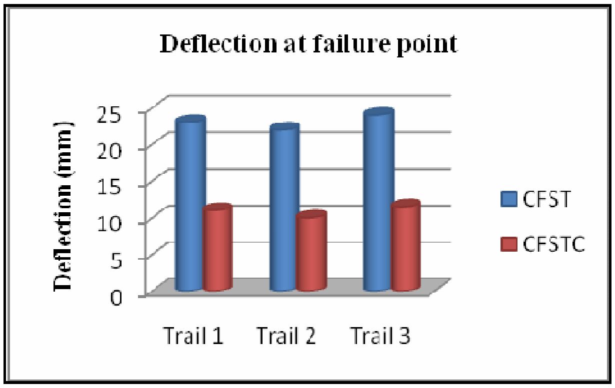

Figure 10: Deflection at failure point

Buckling patterns

The buckling patterns and the failure patterns seen during the test were given in Figure 12 and Figure 13. Figure11 demonstrated the buckling behavior of all specimens. For the CFST segments without shear connectors, it could be seen from Figure 12 that nearby buckling happened at the base and top of the segment, which was due to the end impact. For the segments with shear connectors, in addition toend impact, the shear connectors prevented the strain development along the height of the specimen which in turns restricted the outward buckling as shown in Figure13

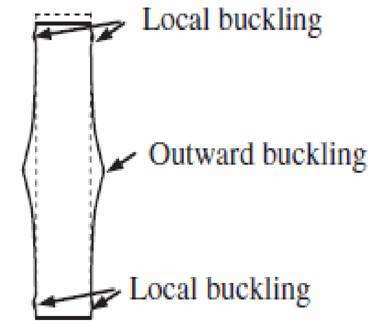

Figure 11: Failure Pattern Figure 12: CFST Figure 13: CFSTC

Conclusion

On the basis of the results,

- By the addition of chemical admixture which is High Range Water Reducing Admixture (HRWRA) resulted in increase in workability of the mixes which showed better compressive strength.
- There were significant enhancements in the physical performance of CFSTC(columns with shear connectors) inreference to ultimate load bearing capacity, stiffness and ductility.
- The consequences from push out tests specified that bond strength of CFSTC(with shear connector) specimens were found to be superior to the CFSTs specimens. It was obtained from results that the bonding capability enhanced to 17%.
- From load versus deflection curve, the proportional increase in load carrying capability of CFSTC(with shear connectors)increased in the range of 17.5% to 18.3%., when compared with CFST columns.
- Though, there was no drastic improvement in load carrying capacity of the axial loaded CFSTC columns, it offers more ductility than the CFST columns.
- Hence, CFSTC (with shear connectors) can be used in seismic areas for better physical behavior.

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