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Research Article

Behaviour of Concrete Filled Steel Tubes

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Abstract. Concrete filled steel tubular columns are preferred due to their excellent static and dynamic resistant properties such as high strength, high ductility and large energy absorption capacity. The comparison of the ultimate strength of CFST with Hollow steel tube, RCC and the bond strength between concrete and the steel was done both experimentally and analytically using ANSYS. A total of 18 specimens were cast, out of which ultimate strength was determined for 13 specimens and bond strength was observed for 5 specimens using push out test. Both experimental and analytical observations using ANSYS were carried on a cylinder of height 460 mm and a diameter of 113 mm. The grade of concrete used for infill is M30. The tests were carried on an Ultimate Testing Machine. The ultimate strength of CFST, RCC and HST were compared and CFST having the advantages of both concrete and steel is found to behave better and average bond strength ranges between 0.7 to 1.1 N/mm^2.

Keywords. CFST; Load-strain; Push out test; ANSYS

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1. Introduction

A steel-concrete composite column is a compression member, comprising either a concrete encased hot-rolled steel section or a concrete filled tubular section of hot-rolled. Steel is generally used as a load-bearing member in a composite framed structure. The main benefit of composite elements is that the properties of each material can be combined to form a single unit that performs better than its separate constituent parts. Greater stiffness, higher buckling capacity, higher ductility, smaller sections and weights, and economical benefits are some advantages of CFST columns over other columns.

The effect of the concrete strength on the concrete filled steel tubes for twenty two specimens have been studied experimentally by varying diameter of the tube, concrete grades and water cement ratio [5]. The CFST tubular columns were studied by varying steel type, concrete type and interface type and have been concluded that the use of stainless steel leads to decrease in the bond strength when compared to carbon steel tube specimens [10]. Many researchers [2–4, 6–9] have studied about the slip behaviour of CFT columns by various parameters like d/t ratio, concrete strength, l/d ratio etc. and found that slip and strength of the CFST columns better in the load bearing capacity, stiffness and deflection. In this paper, the behaviour of concrete filled steel tubes was studied and compared with normal RCC and hollow steel tube column.

2. Materials and Methods

After a detailed literature survey the materials required for experimental work is collected and it is tested according to IS2386 PART III-1963.The mix design for M30 concrete with super plasticizer and without super plasticizer were obtained according to IS 10262-2009. A total of 20 samples were prepared, and the details of the specimens were given in Table 1.

Table 1. Details of specimen

Serial Number	Description of specimen	Admixture	Diameter mm	Thickness mm	Height mm	Specimen ID	Number of specimens
1	Hollow Steel Tubular column	-	113	6	460	HST	3
2	Reinforced Cement Concrete Column	Without Super Plasticizer	113	-	460	RCC	3
		With Super Plasticizer	113	-	460	RCC-SP	3
3	Concrete Filled Steel Tubular Column	Without Super Plasticizer	113	6	460	CFST	3
		With Super Plasticizer	113	6	460	CFST-SP	3
4	CFST Push out specimen	Without Super Plasticizer	113	6	460	CFST-P	3
5	CFST Push out specimen	With Super Plasticizer	113	6	460	CFST-P-SP	2

2.1 Experimental Method

The standard cubes using design mix for M30 with and without super plasticizer was casted and cured for 28 days. The cured specimens were tested under compression testing machine, to check for its compressive strength. The *reinforced concrete columns* (RCC) and concrete filled steel tubular (CFST) columns were prepared and cured for a period of 28 days. The specimen is pasted with the strain gauge in order to measure the stain in the specimen. The axial deflection of the columns was measured using deflectometer. The strains were recorded using strain indicator. Figure 1 shows the testing of specimen in UTM having capacity of 1000kN. Push-out tests as shown in Figure 3 were also performed on concrete filled steel tubular columns to find the bond strength. Figure 2 and Figure 4 shows the specimens after failure.

Figure 1. Test in progress

Figure 2. Specimens after buckling

Figure 3. Push out test of the specimen

Figure 4. Specimens after failure

2.2 Analytical Method

All the specimens were also analyzed using finite element software ANSYS to find the maximum deflection and load carrying capacity of the column. Figure 5 shows the nodal solutions of the all specimen.

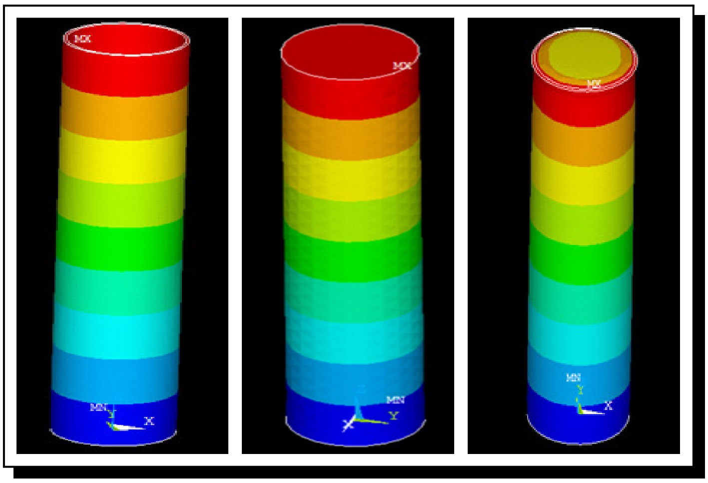

Figure 5. Nodal solutions of the HST, RCC and CFST columns

3. Results and Discussion

The behaviour of the concrete filled tubular columns were studied both by experimentally and analytically. The comparisons were also made with normal reinforced concrete and hollow steel tubular column of similar dimensions. Push out test was performed to evaluate the bond strength in CFST column. The failure mode of the column specimens were studied and it was found that HST were buckled inward, RCC columns were failed by crushing and CFST columns were by outward buckling. Figure 6 shows the schematic failure modes of the column specimens.

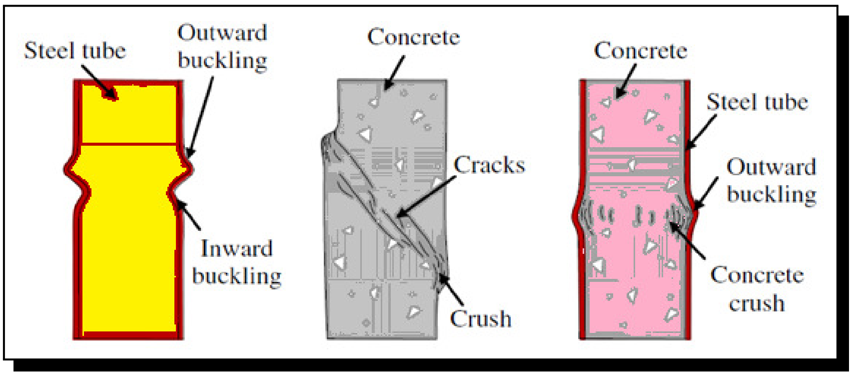

Figure 6. Schematic failure modes of the HST, RCC and CFST columns

The ultimate load carrying capacity and maximum axial deflection of all column specimens were compared and presented in the Table 2 and Figure 7.

Table 2. Compressive strength of hollow steel tubular column

Sl. No	Specimen ID	Ultimate load kN	Maximum axial deflection mm
1	HST1	285	9.52
2	HST2	275	9.96
3	HST3	282.3	9.71
4	RCC 1	183.65	4.67
5	RCC 2	188.7	4.58
6	RCC 3	185.38	5.41
7	RCC-SP1	197.7	6.14
8	RCC-SP2	190.32	5.68
9	RCC-SP3	195.40	6.01
10	CFST1	715.6	20.16
11	CFST2	740.9	19.56
12	CFST3	721.4	20.31
13	CFST-SP1	780.9	20.21
14	CFST-SP2	746.8	19.74
15	CFST-SP3	756.3	19.93

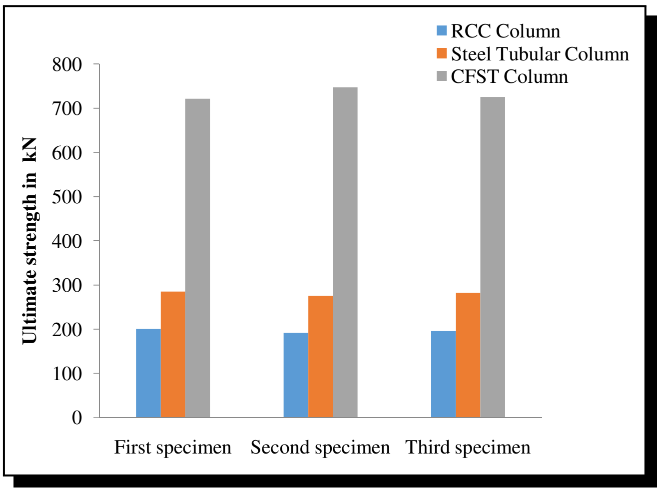

Figure 7. Comparison between the ultimate strength of the HAST, RCC and CFST columns

From Figure 7 it was found that load carrying capacity of the CFST columns increased more when compared to normal RCC and HST columns with or without the presence of Plasticizer in the concrete.

The load-strain curves were plotted after measuring strains using strain gauge for all the specimens. From Figure 8 it was observed that the initial strain was very less of 0.01 up to the load of 250 kN.

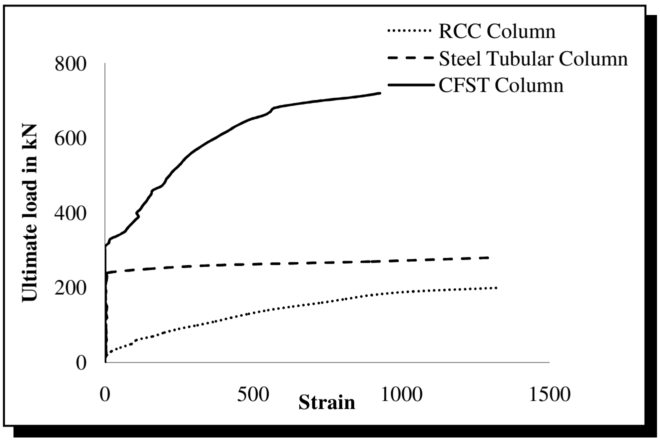

Figure 8. Load-Strain behaviour of the HST, RCC and CFST columns

4. Bond behaviour between Steel Tube and Concrete

The bond behaviour between the steel tube and concrete is evaluated by the average bond stress (ζ), which is the axial push load (P) divided by the area of the contact interface. The average surface bond stress between the steel and concrete was calculated by the equation of

$$\zeta = P/(\pi DL),$$

where P = Applied load by the testing machine; D = Inside diameter of the steel tube; L = Length of concrete core.

Using the above formula average bond strength was calculated for all push out specimens. Table 3 shows the average results of push out test specimens. The maximum bond strength ranges between 1 and 1.5 N/mm^2. A clear separation occurs at the ultimate load capacity of each specimen with 2 mm slip; increasing slip beyond 2 mm results in decreasing resistance. The clear breakaway of the initial contact between the steel and concrete and the point where sliding frictional resistance begins were observed.

Table 3. Maximum and Average bond strength of the push out specimens

Specimen ID	Peak Load (kN)	Deflection at Peak Load (mm)	Maximum Bond Stress (N/mm^2)	Average Bond Stress (N/ mm^2)
CFST-P1	191.1	2.3	1.496	1.026
CFST-P2	194.6	2.4	1.523	1.051
CFST-P3	122.5	1.9	0.959	0.702
CFST-P-SP	183.1	2.0	1.433	1.021
CFST-P-SP	153.0	2.1	1.197	0.869

The comparisons between the experimental and analytical results were listed in Table 4. From the results it was found that analytical model was stiffer than the experimental because of the rigid connection of the specimen.

Table 4. Comparison between experimental and analytical results

Serial number	Detail of specimen	Experimental results		Analytical results	
		Max load (kN)	Max deflection (mm)	Max load (kN)	Max deflection (mm)
1	HST Column	282.3	9.71	282.3	7.82
2	RCC Column	197.7	6.14	197.7	5.10
3	CFT Column	721.4	20.31	721.4	17.92

5. Conclusion

(1) The load carrying capacity of the composite column was found to be 2.5 times greater than the load carrying capacity of normal reinforced concrete column.

(2) *Concrete-filled steel tube* (CFST) columns behaves better compared to hollow steel and reinforced concrete columns in terms of higher strength, higher ductility, higher stiffness and also have larger energy-dissipation capacity.

(3) From the Push-out test, it was found that the maximum bond strength and average bond is 1.5 N/mm^2 and 1.1 N/mm^2, respectively. The bond strength between steel tube and concrete can be improved by providing shear studs or internal rings welded of the steel tube when required.

(4) The deflection found from the analytical results was less when compared to experimental results because of the stiffer analytical model.

Competing Interests

The authors declare they has no competing interests.

Authors' Contributions

The authors wrote, read and approved the final manuscript.

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