ORIGINAL RESEARCH PAPER | Engineering | Volume : 6 | Issue : 8 | August 2016 | ISSN - 2249-555X | IF : 3.919 | IC Value : 74.50

Behavior of Self Compaction Concrete Filled Steel Tubes (SCC FST) Columns Under Cyclic Loading

KEYWORDS: SCC- self compaction concrete, CFST- concrete filled steel tubes, cyclic loading, Ultimate load

Noorain khanum	E.Ramesh Babu	Dr N S kumar
Post Graduate Student-Structural Engineering, Department of Civil Engineering, Ghousia College of Engineering, Ramanagaram, Karnataka, India	Associate Professor, Department of Civil engineering, Ghousia College of Engineering, Ramanagaram, Karnataka, India	Professor and Director of R&D,Department of Civilengineering, Ghousia College of Engineering, Ramanagaram, Karnataka, India

ABSTRACT *In the present research, behavior of self-compacting Concrete Filled Steel Tube (CFST) under cyclic loading is investigated. The parameters chosen for the study are geometry of the specimen – circular section, different L/D ratios, and different grades of self-compaction concrete infill. The study includes experimental investigation on a total of 36 specimens that includes nine hollow and twenty seven specimens filled with SCC of grades M20, M30, and M40. The specimens include three L/D ratios [6, 12 and 16] and three diameters [33.7, 42.4 and 48.3mm] having a common thickness of 3.2mm. The experimental results indicate that the load carrying capacity of the hollow steel tubes is less than those filled with SCC, with increase in L/D ratio the load carrying capacity of the steel tube decreases, load carrying capacity increases with increase in the diameter of the steel tubes and for higher grade of concrete, the load carrying capacity of the CSFT is high. The experimental column strengths are compared with values predicted by AIJ (2011) and with the analytical results obtained by conducting linear analysis using Abaqus6.10-1 software.*

1. INTRODUCTION

Concrete filled steel tubes (CFST) are widely used in modern structural systems and have turned the most successful ones with excellent performance results. CFST columns are a composite material system which employs the various advantages of different materials; combing them together, thus have distinct advantages over equivalent steel, reinforcement concrete, or steel-reinforced concrete columns. The CFST members consist of steel at the outer perimeter confining the concrete core. The outer steel shell performs efficiently under tension and in resisting bending moment. The concrete core confined increases the compressive strength of the steel tube. The modulus of elasticity of steel is greater than that of concrete, increasing the stiffness of CFST greatly, making greater contribution to the moment of inertia. The external steel tubes is elastic-plastic material and internal solid concrete cores is brittle, the contribution of this composite material gives an effective structural performance.[1]

The steel shell acts as longitudinal and transverse reinforcement. The steel shell also provides confining pressure to the concrete, which puts the concrete under a triaxial state of stress. Due to the stiffening of steel tubes by the concrete inward bucking of the steel tube is prevented, thereby increasing the strength and stability of the concrete column. The steel tubes provide a protective covering by reinforcing the concrete to resist the tensile forces, shear forcing and bending moments and confinement to concrete. [2] Steel tube acts as a permanent form work hence labor cost and time consumption is reduced. During the construction process, the steel columns that forms steel skeleton can be erect first; this can support the construction loads and the dead loads. Subsequent concreting increases the capacity, and the composite columns, which develop when concrete hardens, efficiently resist additional loads and dead loads. [1]

Circular tubular columns perform very well and more advantageous over other types of sections such as rectangular and square shapes when used as compression members mainly because, they have a large uniform flexural stiffness in all directions for a given cross sectional area. [1]

Instead of using empty steel tubes, infilling steel tubes with concrete increases the ultimate strength of the structural member, with not much increase in construction cost. CFST has a main advantage that it delays the occurrence of local buckling of the member. Thus CFST's serves as a most economic form of structural member, mainly as columns for bridges and buildings.

Objectives of present study

- To study the behavior self-compaction concrete filled steel tubes (SCC FST) under cyclic loading.
- To understand the strength gain in steel tubes for different L/D ratios, D/T ratios and for different grades of SCC infill.
- To understand the variation of ultimate load for different lengths.
- To know the failure mechanism of composite steel and hollow steel.

2. MATERIAL PROPERTIES

Self-Compaction Concrete: Self-compacting concrete [SCC] is a flowing concrete mixture that is able to consolidate under its own weight, suitable for structures with congested reinforcement ensuring a good balance between deformability and stability. The concrete remains homogeneous in a form during and after the placing process.

Superplasticizer: Conplast SP 430 is used as super plasticizer, conformed by IS: 9103:1999 and IS2645:1975 .The specific gravity of Conplast SP 430 is 1.222.

Steel: The Tata steel tubes are available in different cross

Volume : 6 | Issue : 8 | August 2016 | ISSN - 2249-555X | IF : 3.919 | IC Value : 74.50

sections of length 6m. Steel tubes of circular cross-sections are used, have tensile strength of 500MPa, yield strength of 310MPa, elastic modulus of 210GPa and a Poisson's ratio of 0.3. The steel tubes are cut down to specimens of required dimensions shown in table 1.

Table.1 Geometrical properties of hollow steel specimens

Dia (mm)	Thickness [T] (mm)	D/T	L/D	Length [L] (mm)
33.7	3.2	10.5	6	202.2
			12	404.4
			16	539.2
42.4	3.2	13.3	6	254.4
			12	508.8
			16	678.4
48.3	3.2	15.1	6	289.8
			12	579.6
			16	772.8

3. EXPERIMENTAL PROGRAM

SCC of grade M20, M30 and M40 of design strength of 24.21Mpa, 36.97Mpa and 48.45Mpa respectively was produced. The SCC of three different grades is filled in the steel tubes, cured for 28days, and then tested under cyclic loading machine. Figure1 shows the cyclic loading machine setup and the SCADA software from where the results are obtained.

Fig.1Cyclic loading machine

Experimental Results and discussions

The experimental results are denoted as Pu_{exp} and are shown in the table 2. Figure 4 shows the load v/s deflection curves for specimen of dia 42.4mm under cyclic loading. Figures.5, 6 and 7 shows the Plot of Load v/s L/D ratio for the specimens of dia 33.7, 42.4 and 48.3.respectively, which show that with increase in L/D the Pu_{exp} decreases. Thus with increase in length the load bearing capacity decreases. Also the variation of Pu_{exp} with D/T is shown in Figures 8, 9, and 10, which show that with increase in D/T ratio the Pu_{exp} increases considerably. In this study the thickness remains constant; this indicates that with increase in diameter the ultimate load carrying capacity increases. From the experimental investigation it was found that the Ultimate load strength of SCC FST was about 13-20% higher than that of the hollow steel tubes. The load v/s D/T curves also indicate that with increase in grade of concrete the ultimate load increases marginally.

Local buckling:

Figure 2 shows the hollow steel specimen bulged at the end. The failure is characterized with local buckling at the centre and bulging at the ends. Figure 3 shows the SCC FST after failure. Failure is characterized with buckling at the centre and no bulging at the ends. Thus in the CSFT local bucking is delayed and sometimes prevented.

Fig.2 hollow steel tubes at failure

Fig.3 SCC infilled steel tubes at failure

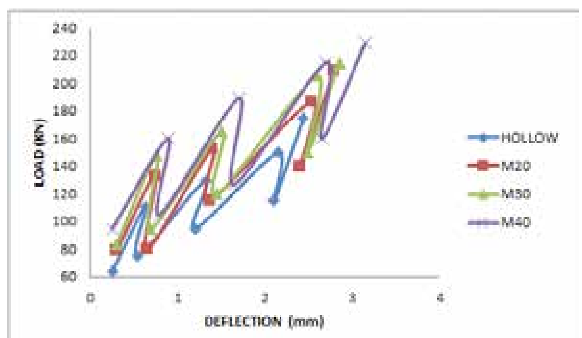

Fig.4 load v/s deflection curve for dia 42.4mm

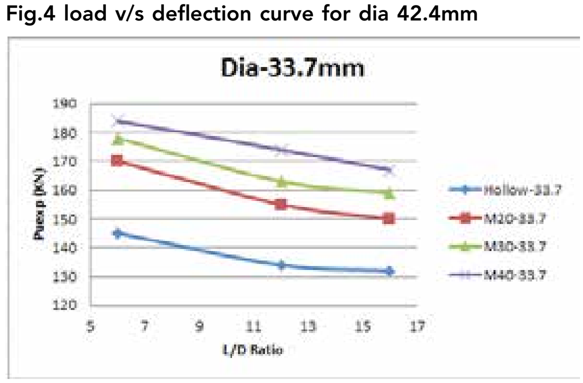

Fig.5 Pu_{exp} v/s L/D ratio for 33.7mm dia

Volume : 6 | Issue : 8 | August 2016 | ISSN - 2249-555X | IF : 3.919 | IC Value : 74.50

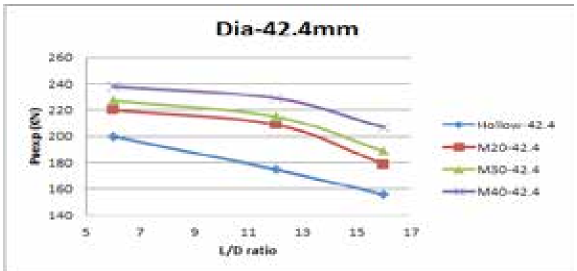

Fig.6 Pu_{exp} v/s L/D ratio for 42.4mm dia

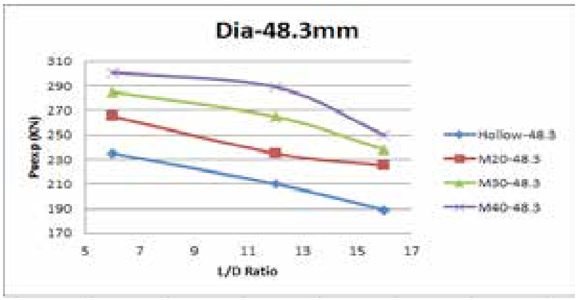

Fig.7 Pu_{exp} v/s L/D ratio for 48.3mm dia

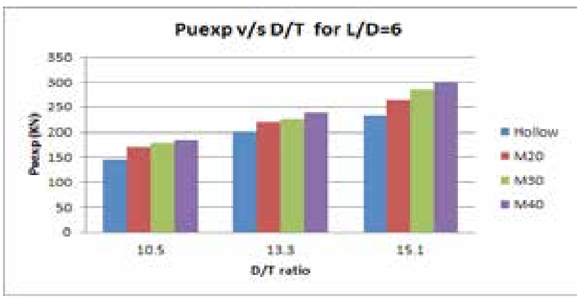

Fig.8 Pu_{exp} v/s D/T ratio for L/D=6

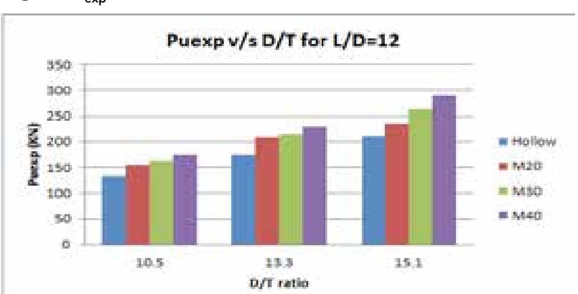

Fig.9 Pu_{exp} v/s D/T ratio for L/D=12

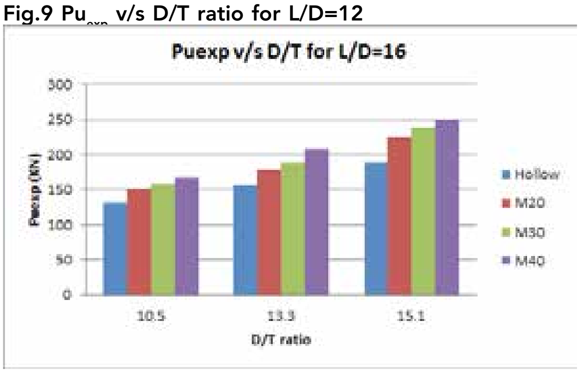

Fig.10 Pu_{exp} v/s D/T ratio for L/D=16

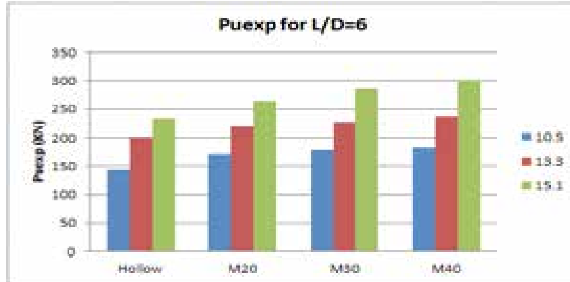

Fig.9 11Puexp v/s grade of concrete

4. COMPARISON OF EXPERIMENTAL RESULTS

COMPARISON with AIJ code:

The AIJ code volume4 deals with Design of CST [concrete filled tube] system. The newest edition of SRC standard of AIJ was published in 2011. This edition includes three types of sections namely; concrete-encased steel tube, the CFT and concrete encased and filled tubes. AIJ classifies the columns based on the l_k/D and the ultimate compressive strength is calculated as follows.

For, l_k /D ≤ 4[short column]

$N_{cu1} = {}_cN_{cu} + (1+\eta)\, {}_sN_{cu}$

For, 4< l_k /D ≤ 12[intermediate column]

$N_{cu2} = N_{cu1} - .125\{N_{cu1} - N_{cu3}\}*\{(l_k /D)-4\}$

For, l_k /D >12[slender column]

$N_{cu3} = {}_cN_{cr} + {}_sN_{cr}$

Where, D = Outer diameter of the steel tube, l_k = effective length of a CFT column, **η=0.27 for circular CSFT column**, cNcu = ultimate strength of a concrete column, ${}_sN_{cu}$ = ultimate strength of a steel column, ${}_cN_{cr}$ = buckling strength of a concrete column, ${}_sN_{cr}$ = buckling strength of a steel column and N_{cu1}, N_{cu2}, N_{cu3}: ultimate strength of a CFT column. The predicted values are denoted as Pu_{AIJ} and presented in table.2. In the table2 it can be seen that the predicted values and experimental results vary by 15-25%. Thus AIJ provides a good prediction of the ultimate load carrying capacity of the CSFT column.

Comparison with Analytical results: In this study the linear analysis is conducted using the ABQCUS6.10-1 software. The analytical values are compared with the experimental results for better understanding of the behavior of the SCC FST under the loading and as a check. The ultimate load obtained from analysis are denoted as Pu_{ABQ} and presented in table 2. The Pu_{ABQ} obtained from the linear analysis are very much closer to the $Pu_{exp,}$ validating the experimental investigation.

Table 2 shows the comparison between predicted values [Pu_{AIJ}] with Pu_{exp} and Pu_{ABQ}. The mean value of Pu_{exp}/Pu_{AIJ} is 1.25 i.e., experimental results vary by 15-25% from predicted values. Also the experimental results are higher than the predicted values, this indicate that AIJ provides good prediction of ultimate load carrying capacity of CSFT column. The mean Pu_{exp} / Pu_{ABQ} =1.015.ie experimental results and analytical results vary by 2%. Thus analytical results obtained from Abaqus software serves as good means of validation. Figure 11 shows the comparison of Pu_{AIJ}, Pu_{exp} and Pu_{ABQ} for different diameters.

Volume : 6 | Issue : 8 | August 2016 | ISSN - 2249-555X | IF : 3.919 | IC Value : 74.50

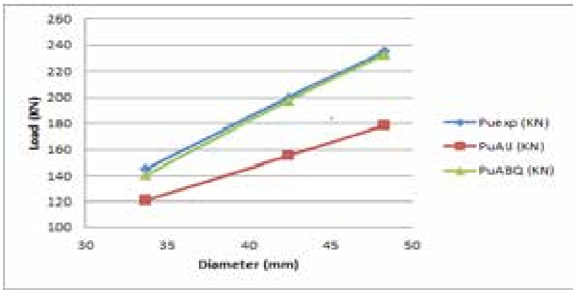

Fig.12 comparison of experimental results

Table.2 Results and comparison

SI.NO	Dia (mm)	L/D	D/T	Length (mm)	Grade	Pu_{exp} (KN)	Pu_{AIJ} (KN)	Pu_{ABQ} (KN)	Pu_{exp}/Pu_{AIJ}	Pu_{ABQ}/Pu_{AIJ}	Pu_{exp}/Pu_{ABQ}
1	33.7	6	10.5	202.2	Hollow	145	120.72	140.44	1.20	1.16	1.032
2	33.7	6	10.5	202.2	M20	170	132.76	166.54	1.28	1.25	1.021
3	33.7	6	10.5	202.2	M30	178	139.11	177.15	1.28	1.27	1.005
4	33.7	6	10.5	202.2	M40	184	144.82	179.00	1.27	1.24	1.028
5	33.7	12	10.5	404.4	Hollow	134	112.28	133.50	1.19	1.19	1.004
6	33.7	12	10.5	404.4	M20	155	124.02	151.89	1.25	1.22	1.020
7	33.7	12	10.5	404.4	M30	163	130.12	158.12	1.25	1.22	1.031
8	33.7	12	10.5	404.4	M40	174	135.58	169.11	1.28	1.25	1.029
9	33.7	16	10.5	539.2	Hollow	132	103.84	130.56	1.27	1.26	1.011
10	33.7	16	10.5	539.2	M20	150	115.27	146.98	1.30	1.28	1.021
11	33.7	16	10.5	539.2	M30	159	121.13	154.71	1.31	1.28	1.028
12	33.7	16	10.5	539.2	M40	167	126.34	161.78	1.32	1.28	1.032
13	42.4	6	13.3	254.4	Hollow	200	155.15	197.47	1.29	1.27	1.013
14	42.4	6	13.3	254.4	M20	220	176.10	217.56	1.25	1.24	1.011
15	42.4	6	13.3	254.4	M30	227	187.14	223.54	1.21	1.19	1.015
16	42.4	6	13.3	254.4	M40	238	197.07	233.45	1.21	1.18	1.019
17	42.4	12	13.3	508.8	Hollow	175	144.44	172.89	1.21	1.20	1.012
18	42.4	12	13.3	508.8	M20	209	164.94	206.75	1.27	1.25	1.011
19	42.4	12	13.3	508.8	M30	215	175.61	211.88	1.22	1.21	1.015
20	42.4	12	13.3	508.8	M40	229	185.17	224.64	1.24	1.21	1.019
21	42.4	16	13.3	678.4	Hollow	156	133.74	153.44	1.17	1.15	1.017
22	42.4	16	13.3	678.4	M20	179	153.79	176.78	1.16	1.15	1.013
23	42.4	16	13.3	678.4	M30	189	164.09	185.56	1.15	1.13	1.019
24	42.4	16	13.3	678.4	M40	207	173.26	202.77	1.19	1.17	1.021
25	48.3	6	13.3	289.8	Hollow	235	178.50	232.97	1.32	1.31	1.009
26	48.3	6	13.3	289.8	M20	265	206.87	262.35	1.28	1.27	1.010
27	48.3	6	13.3	289.8	M30	285	221.83	281.45	1.28	1.27	1.013
28	48.3	6	13.3	289.8	M40	301	235.28	296.28	1.28	1.26	1.016
29	48.3	12	13.3	579.6	Hollow	210	166.26	208.12	1.26	1.25	1.009
30	48.3	12	13.3	579.6	M20	235	194.07	231.75	1.21	1.19	1.014
31	48.3	12	13.3	579.6	M30	265	208.56	261.42	1.27	1.25	1.014
32	48.3	12	13.3	579.6	M40	289	221.53	284.15	1.30	1.28	1.017
33	48.3	16	13.3	772.8	Hollow	189	154.02	188.32	1.23	1.22	1.004
34	48.3	16	13.3	772.8	M20	225	181.26	222.15	1.24	1.23	1.013
35	48.3	16	13.3	772.8	M30	238	195.28	234.55	1.22	1.20	1.015
36	48.3	16	13.3	772.8	M40	250	207.77	245.15	1.20	1.18	1.020
Mean value									1.25	1.23	1.015

CONCLUSION

The ultimate load carrying capacity of SCC infilled steel tubes is about 13-20% higher than the hollow steel tubes. [from load verses deflection curves, load verses L/D ratio curves]

Volume : 6 | Issue : 8 | August 2016 | ISSN - 2249-555X | IF : 3.919 | IC Value : 74.50

The local buckling is delayed in CFST compared to the hollow steel tubes [shown in fig 2 and 3] and may it be prevented.

With increase in grade of concrete the ultimate load increases marginally by 4-5%. Thus the load verses deflection curve is shifted higher for higher grades of SCC.[from load v/s deflection curve, Load v/s L/T curves, Load v/s D/T curves]

As L/D ratio increases, the load carrying capacity of the composite tube decreases by 7%-12%.[from L/D ratios]

As D/T ratio increases the ultimate load carrying capacity increases by 38% and 62% for steel tubes of diameter 42.4 and 48.3mm.Thus with increase in diameter of the steel tube the ultimate bearing capacity increases.

The Pu_{AIJ} differs from Pu_{exp} by about 15-25% thus; AIJ provides a good prediction of the ultimate load carrying capacity of the CSFT column and is a conservative design method.

References

[1] Nameer A. Alwash, Hayder I. AL-Salih, "Experimental Investigation on Behavior of SCC Filled Steel Tubular Stub Columns Strengthened with CFRP" Babylon University, Iraq; July 2013.
[2] Anil Kumar Patidar "Behaviour of Concrete Filled Rectangular Steel Tube Column Department of Civil Engineering, School of Mechanical and Building Sciences (SMBS)" VIT University - Chennai Campus, Chennai – 600127, Tamil Nadu.
[3] XIONG Ruia, LU Zheana, REN Zhiganga, HE Chunguanga, "Experimental Research on the Performance of Microexpansion and Self-compacting Concrete-Filled Steel Tubular Short Column under Axial Compression" International Conference on Structural Computation and Geotechnical Mechanics 2012, Wuhan 430070, China.
[4] Xiong Rui, LU Zhean, REN Zhigang, Xu Changwu,"Experimental Study of Self-stressing of Self-compacting Concrete Filled Steel Tubular Short Columns" Wuhan University of Technology, Wuhan 430070, China.
[5] Thanuja H.P, E.ramesh Babu, Dr.N.SKumar, "A study on Behavior of circular stiffened hollow steel column filled with self-compaction concrete under monotonic loading", Ghousia college of engineering, Ramanagaram, August 2014.
[6] Architectural Institute of Japan (AIJ). (2011),"Design and Construction of Concrete-Filled Steel Tube Column System in Japan".
[7] T. Kibriya and M. Iqbal "Performance of blended cement SCC filled steel tubes for repair/rehabilitation of structural columns of buildings, bridges and deep foundations" National University of Sciences and Technology, Pakistan