BEHAVIOR OF COMPOSITE STEEL COLUMNS IN-FILLED WITH SELF-COMPACTION CONCRETE UNDER CYCLIC LOADING

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***Abstract:** In the present study, the behavior of self-compacting Concrete Filled Steel Tube (CFST) columns under cyclic loading has been tested. The experimental investigations are carried out for 72 specimens that includes eighteen hollow steel specimens and fifty four specimens filled with Self compacting concrete (SCC) of grade M20, M30 and M40 with different L/D ratios. The parameters such as the geometric properties of the column section specimens with different L/D ratios, diameters with constant thickness and different grades of self-compacting infill concrete have been considered during the test. It is found that the capacity of buckling load and deformations are obtained from testing under cyclic loading, the buckling or ultimate load for CFST columns are higher compare to hollow columns, also the confinement of infill concrete increases the load carrying capacity these results are verified and validated using Finite element software ABAQUS6.10.1*

IndexTerms - SCC-self compacting concrete, CFST- concrete filled steel tube, cyclic loading.

I. INTRODUCTION

Self-compaction concrete (SCC) is preferable for replacement of conventional concrete in the highly congested reinforced structures because it is difficult to compact. SCC is a special type of concrete which is flowable and non-segregating concrete and placed easily and compacted under its own self weight, so no need of any mechanical vibrator for placing and filling the CFST columns [1, 2].

CFST columns have high strength, ductility and are good in earth quake resistance with good energy absorption capacity [3]. Concrete-filled steel tubular (CFST) columns have gained pleasant appearance for buildings, bridges and other types of structures. CFST columns become trendy with designers also structural engineers. CFST columns come together the structural property and compensation together steel and concrete resources [4]. They assist to increase the speed of construction while the steel tube acts like a shoring through the solid pour, subsequently this leads toward economy in the concrete pouring method by eliminating the require for formwork [5]. Further reward is the elevated strength and raise of the structural firmness [6, 7].

CFST columns contain high load bearing capability and high seismic fighting [8, 9]. Steel tube provide captivity to the solid infill, which here acts like a bear to the steel pipe and limited inmost buckling of the section and CFST columns contain an smart appearance and compact section. Due to application of cyclic loading on columns or structural components, subjected to repeated or fluctuating stresses and strains on structural components [10, 11].

II. OBJECTIVES

1. To know the behavior self-compaction concrete filled steel tubes under cyclic loading.
2. To understand the variation of ultimate load or buckling load at different lengths and at different diameters.
3. To know the failure mechanism of composite steel and hollow steel when subjected to cyclic loading.

III. MATERIALS

Self-Compacting Concrete

Self-compacting concrete (SCC) is a fresh construction material among enhanced properties like higher strength, longer durability and higher workability than normal concrete [12]. As per IS 10262; 2009 mix proportion for SCC are listed in table 1 [13].

Table 1 Mix proportions of SCC concrete

Material	M20	M30	M40
Cement	323.63kg/m^3	400kg/m^3	445kg/m^3
Fine aggregate	1090.89 kg/m^3	1074.49 kg/m^3	1015.72 kg/m^3
Coarse aggregate	879.13 kg/m^3	857.18 kg/m^3	831.04 kg/m^3
W/C ratio	0.55	0.45	0.40
Super plasticizer	0.00611 kg/m^3	0.006 kg/m^3	0.0070 kg/m^3
Mix proportion C:FA:CA	1:3.320: 2.716	1:2.727:2.142	1:2.282:1.867

Super Plasticizer

Super plasticizer is a chemical complex used to enhance the workability lacking addition extra water. Conplast SP 430 is added by 2% of cement weight.

Structural steel

Steel is the material used in the current work where hot rolled steel tube These steel tubes are having a tensile strength 500MPa, yield strength 310MPa, elastic modulus 210GPa and a Poisson's ratio 0.3 [14]. The dimensions of specimens shown in table 2.

Diameter (mm) D	D/T	L/D	Thickness (mm) T	Length(mm) L
33.7	10.5	6	3.2	202.2
		8	3.2	269.6
		10	3.2	337
		12	3.2	404.4
		14	3.2	471.8
		16	3.2	539.2
42.4	13.3	6	3.2	254.4
		8	3.2	339.2
		10	3.2	424
		12	3.2	508.8
		14	3.2	594.6
		16	3.2	678.4
48.3	15.1	6	3.2	289.8
		8	3.2	386.4
		10	3.2	483
		12	3.2	579.6
		14	3.2	676.2
		16	3.2	772.8

Table 2 Geometrical properties of hollow steel column

IV. EXPERIMENTAL PROGRAMME

Figure 1: Cyclic loading machine

The SCC of three different grades is filled in the steel tubes, cured for 28days, and one set of hollow steel specimens tested other specimens infill with different grades of SCC concrete with different L/D ratios tested under cyclic loading machine. Figure 1 shows the cyclic loading machine setup and using the SCADA software the results were obtained.

V. MODELING ABAQUS6.10-1

ABAQUS is universally useful programming software, used in a various fields engineering. In civil engineering it is used to determine the behavior of a composite material may be of steel or steel concrete composite. ABAQUS software is utilized to determine the analytical load acting on concrete filled steel tubes. Figure 2 shows the buckling of typical model of the CFST column modelled using ABAQUS software.

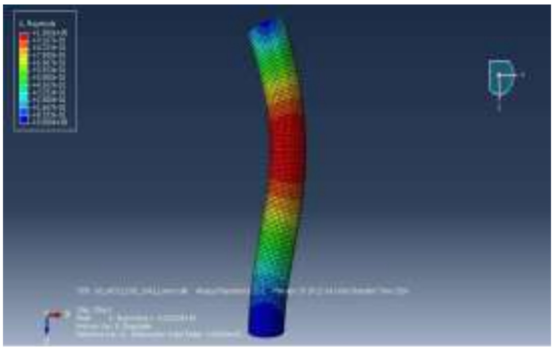


Figure 2. Buckling shape of column section

VI. EXPERIMENTAL RESULTS AND DISCUSSIONS:

The experimental results are denoted as Pu_{EX} and are presented in the Tables 3 to 7. Figures 3 to 6 represents the load v/s deflection curves for specimen of outer diameter 42.4 and thickness 3.2 mm under cyclic loading. The values show that with increase in L/D ratio the value of that Pu_{exp} decreases. Thus with increase in length the load bearing capacity decreases. From the experimental investigation it was found that the Ultimate load strength of SCC filled steel column sections was about 12-20% higher than that of the hollow steel tubes.
Figure 7 shows the variation of buckling loads for L/D ration of 12 for hollow and different grades of SCC as infill grades of M20, M30 and M40.

Table 3 Hollow steel tube of length 508.80 mm, outer dia 42.4.mm and thickness 3.2mm

Load (KN)	Deflection (mm)	Strain	Stress (N/Sq.mm)
0	0	0	0
30	0.15	0.00029	76.12667
60	0.3	0.00059	152.25335
85	0.5	0.00098	215.69225
60	0.35	0.00069	152.25335
75	0.56	0.00110	190.31669
100	0.9	0.00177	253.75558
120	1.25	0.00246	304.50670
90	1.04	0.00204	228.38002
125	1.49	0.00293	317.19448
140	1.9	0.00373	355.25782
110	1.75	0.00344	279.13114
95	1.7	0.00334	241.06780
140	2.14	0.00421	355.25782
160	2.5	0.00491	406.00893
120	2.45	0.00482	304.50670
150	2.65	0.00521	380.63337
170	3	0.00590	431.38449

Table 4 M20 steel tube of length 508.80 mm, outer dia 42.4.mm and thickness 3.2mm

Load (KN)	Deflection (mm)	Strain	Stress (N/Sq.mm)
0	0	0.00000	0.00000
33	0.15	0.00029	65.67687
67	0.31	0.00061	133.34395
80	0.42	0.00083	159.21665
55	0.3	0.00059	109.46145
100	0.62	0.00122	199.02082
120	0.8	0.00157	238.82498
80	0.7	0.00138	159.21665
100	0.78	0.00153	199.02082
145	1.2	0.00236	288.58019
90	1	0.00197	179.11874
120	1.16	0.00228	238.82498
150	1.45	0.00285	298.53123
170	1.63	0.00320	338.33539
110	1.47	0.00289	218.92290

Load (KN)	Deflection (mm)	Strain	Stress (N/Sq.mm)
135	1.56	0.00307	268.67810
160	1.7	0.00334	318.43331
180	1.98	0.00389	358.23747
150	1.75	0.00344	298.53123
125	1.65	0.00324	248.77602
185	2.2	0.00432	368.18851
200	2.45	0.00482	398.04164
150	2.4	0.00472	298.53123
190	2.8	0.00550	378.13955
206	2.95	0.00580	409.98288

Table 5 M30 steel tube of length 508.80 mm, outer dia 42.4.mm and thickness 3.2mm

Load (KN)	Deflection (mm)	Strain	stress (N/Sq.mm)
0	0	0.00000	0.00000
35	0.16	0.00031	66.43635
60	0.25	0.00049	113.89089
80	0.35	0.00069	151.85452
50	0.28	0.00055	94.90908
100	0.5	0.00098	189.81815
125	0.76	0.00149	237.27269
90	0.7	0.00138	170.83634
75	0.68	0.00134	142.36362
100	0.85	0.00167	189.81815
120	1.1	0.00216	227.78179
150	1.3	0.00256	284.72723
125	1.25	0.00246	237.27269
100	1.15	0.00226	189.81815
130	1.45	0.00285	246.76360
175	2.2	0.00432	332.18177
130	1.9	0.00373	246.76360
110	1.85	0.00364	208.79997
150	2.5	0.00491	284.72723
190	2.75	0.00540	360.65449
205	2.84	0.00558	389.12722
214	3.15	0.00619	406.21085

Table 6 M40 steel tube of length 508.80 mm, outer dia 42.4.mm and thickness 3.2mm

Load (KN)	Deflection (mm)	Strain	Stress (N/Sq.mm)
0	0	0.00000	0.00000
40	0.14	0.00028	73.07271
90	0.32	0.00063	164.41359
60	0.28	0.00055	109.60906
100	0.4	0.00079	182.68177
135	0.6	0.00118	246.62039
90	0.42	0.00083	164.41359

Load (KN)	Deflection (mm)	Strain	Stress (N/Sq.mm)
130	0.62	0.00122	237.48630
160	0.85	0.00167	292.29083
120	0.73	0.00143	219.21812
98	0.65	0.00128	179.02813
125	0.85	0.00167	228.35221
160	1.1	0.00216	292.29083
190	1.45	0.00285	347.09536
150	1.4	0.00275	274.02265
120	1.3	0.00256	219.21812
170	1.45	0.00285	310.55901
200	1.88	0.00369	365.36354
170	1.65	0.00324	310.55901
140	1.5	0.00295	255.75448
185	1.9	0.00373	337.96127
210	2.2	0.00432	383.63171
150	2	0.00393	274.02265
175	2.25	0.00442	319.69309
210	2.84	0.00558	383.63171
227	3.15	0.00619	414.68761

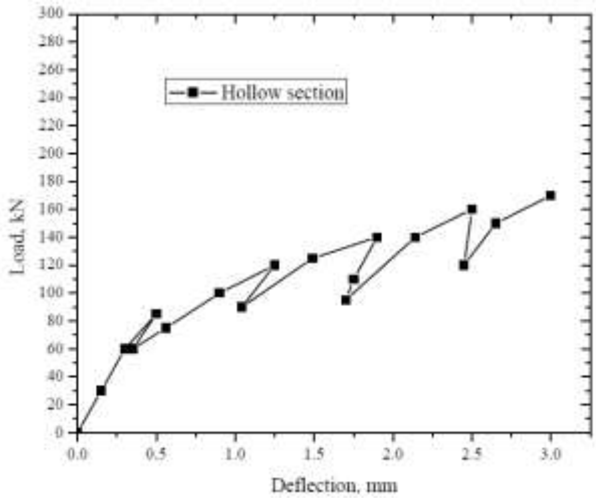


Figure 3 Load vs. deflection curve for hollow section.

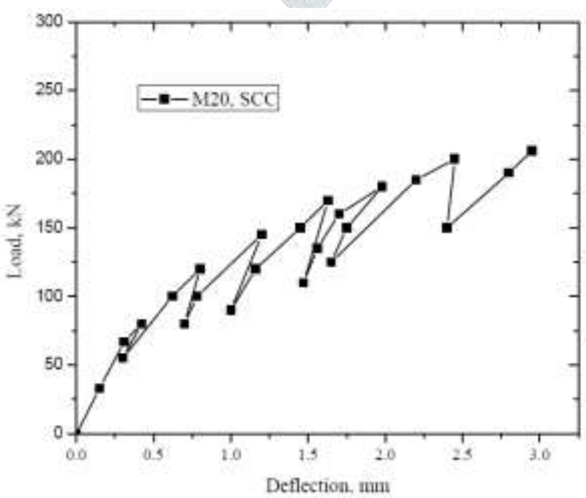
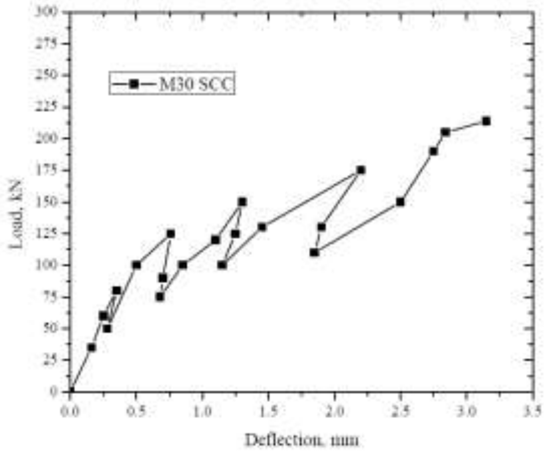


Figure 4 Load vs. deflection curve for CFST column with SCC M20 infill



.Figure 5 Load vs. deflection curve for CFST column with SCC M30 infill

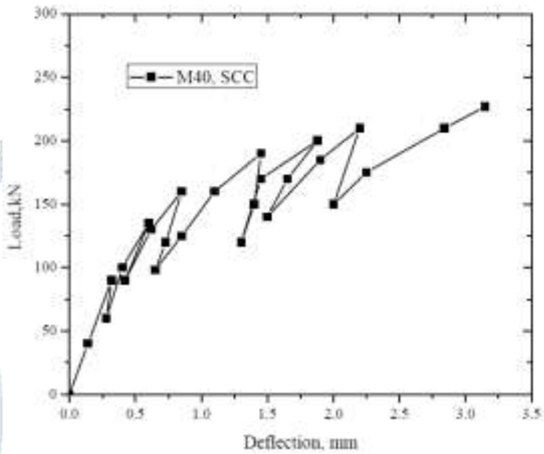


Figure 6 Load vs. deflection curve for CFST column with SCC M40 infill

Table 7 Buckling load for CFST columns with different L/D ratios and grades of SCC

Case	Outer Dia. in mm	L/D	Exp. Load (KN)	ABAQUS Load(KN) Pu_{ABQ}
HOLLOW STEEL TUBES	33.7	6	142	140
		8	140	139
		10	138	136
		12	135	133
		14	125	128
		16	112	116
	42.4	6	179	195
		8	177	190
		10	174	186
		12	170	174
		14	154	152
		16	136	140
	48.3	6	213	224
		8	211	218
		10	209	214
		12	206	208
		14	185	190
		16	170	177
M20 GRADE LWC INFILL	33.7	6	167	166
		8	164	165
		10	160	162
		12	156	154
		14	148	142
		16	124	131
	42.4	6	216	221
		8	213	219

		10	210	215
		12	206	209
		14	193	195
		16	176	178
	48.3	6	249	260
		8	246	258
		10	244	254
		12	233	237
		14	224	228
		16	208	217

Continuation of Table 7

Case	Outer Dia. in mm	L/D	Exp. Load (KN)	ABAQUS Load(KN) Pu_{ABQ}
M30 GRADE LWC INFILL	33.7	6	176	178
		8	172	174
		10	168	170
		12	163	160
		14	150	153
		16	136	145
	42.4	6	223	227
		8	220	223
		10	217	219
		12	214	212
		14	198	202
		16	184	188
	48.3	6	276	282
		8	273	279
		10	268	273
		12	260	263
		14	246	249
		16	228	235
M40 GRADE LWC INFILL	33.7	6	183	180
		8	180	178
		10	177	175
		12	173	172
		14	161	165
		16	146	160
	42.4	6	235	233
		8	233	231
		10	230	227
		12	227	224
		14	211	215
		16	198	205
	48.3	6	290	297
		8	287	295
		10	284	289
		12	280	285
		14	264	272
		16	242	245

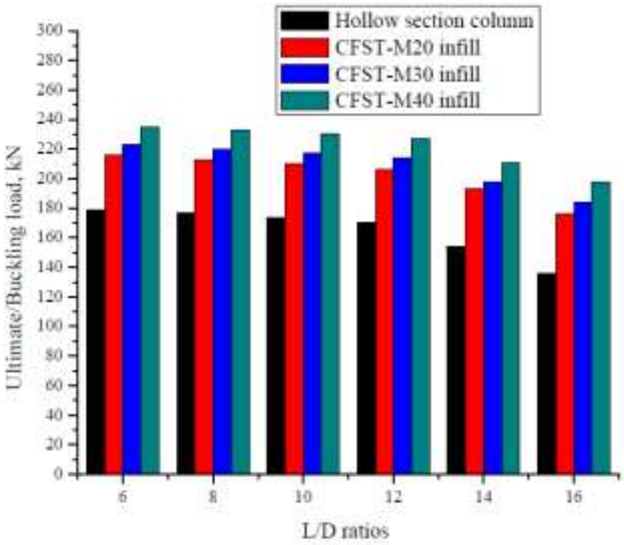


Figure 7 Buckling load for 42.3 outer dia CFST columns

CONCLUSION

- The ultimate load carrying capacity of SCC filled steel tubes is about 12-20% higher than hollow steel tubes from the figure 3, 4 ,5 and 6.
- The local buckling is delayed in CFST compared to the hollow steel columns.
- With increase in grade of concrete the ultimate load increases marginally by 3-5%. Thus the load verses deflection curve is shifted higher for higher grades of SCC.
- As L/D ratio increases, the load carrying capacity of the composite tube decreases.
- The variation of experimental results and obtained using ABAQUS software is 2- 5 percent.

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