

CONCRETE FILLED STEEL TUBES SUBJECTED TO AXIAL COMPRESSION

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Abstract

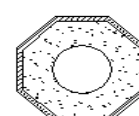
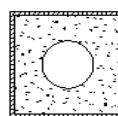
Concrete-filled steel tubular columns have excellent earth-quake resistant properties such as high strength and ductility and large energy absorption capacity. For concrete-filled steel tubes (CFST), local buckling commonly observed in bare steel columns is effectively prevented, giving a higher capacity. However if the concrete core and the steel tube are loaded simultaneously the steel tube expands more than the concrete core under moderate loads since Poisson's ratio is higher for the steel section. The objective of this paper is To evaluate the accuracy of codal design approach by comparing experimental results with the analytical results obtained using EC4, ACI-318 and AISC-LRFD, for prediction of load carrying capacity of CFST columns under axial compression. Based on this the experimental programme is conducted on concrete filled steel tubes of length 300mm, thickness 1 to 3mm for circular, square and rectangular cross section with three different grades of concrete. 200 T capacity Compression testing machine is used for experimental investigation.. The experimental results are compared with analytical results obtained by stated code of practices. From this it is concluded that EC4 gives conservative results. From which it is observed that EC4 gives conservative results with experimental results and it is concluded that EC4 provisions may be used for further analytical study to develop an expression to predict the section capacity CFST columns. As the grade of concrete increases the load carrying capacity is also increases. This paper presents the details of study carried out and the conclusions arrived.

Keywords: CFST, high strength, local buckling, analytical, ACI-318, EC4, AISC-LRFD.

1. INTRODUCTION

In the Concrete Filled Steel Tube (CFST) Structural System high-strength concrete is used for filling steel tubes. These members are ideally suited for all applications because of their effective usage of construction material. CFST structure is a type of the composite steel-concrete structures used presently in civil engineering field. In this type of composite members, the advantages of both hollow structural steel (HSS) and concrete is utilized. Due to excellent static and earthquake resistant properties of CFST, they are being used widely in real civil engineering projects. They possess properties such as high strength, high ductility and large energy absorption capacity. Concrete filled steel tubes (CFST) are also used extensively in other modern civil engineering applications. When these types of composite members are used as structural columns, especially in high-rise buildings, they may be subjected to high shearing force as well as moments due to wind or seismic actions. Therefore it is very important to study the behaviour of CFST Columns in axial compression. It may be noted here that mechanical and economic benefits can be achieved by high strength concrete infill, which contributes greater damping and stiffness to CFST columns compare to normal strength concrete. Moreover, high strength CFST columns require a smaller cross section to withstand the load, which is appreciated by architects and building engineers. Main advantages of the interaction between the steel tube and concrete are local buckling of steel tube is delayed due to concrete infill and steel tubes provided sufficient confining effect to concrete. The enhancement of CFST column in

structural system is due to composite action between constituent elements. The steel shell acts as longitudinal and transverse reinforcement. The shell also provides confining pressure to the concrete, which puts concrete under tri-axial state of stress. On the other hand, the steel tube is stiffened by the concrete core. This can prevent the inward buckling of steel tube, and increases the stability and the strength of column system, resulting in higher flexural strength. Therefore tubes with thinner walls could reach the yielding strength before local buckling. Under axial compression, the steel tube confines the concrete, therefore improves both axial load resistance and ductility of CFST members. Concrete filled steel tubes are used in many structural applications including columns supported offshore platforms, roofs of storage tanks, bridge piers, piles and columns in seismic zones. Application of the CFST concept may lead to 60% total saving of steel in comparison to conventional structural steel system. Steel tubes were also used as permanent formwork and the well distributed reinforcement located at most efficient position. Due to large shear capacity of concrete filled steel tubular members, they predominantly fail in flexure in a ductile manner. Confinement effectiveness may be reduced to bit if rectangular or square tubes are filled up with high strength concrete but it provides advantage against flexure.



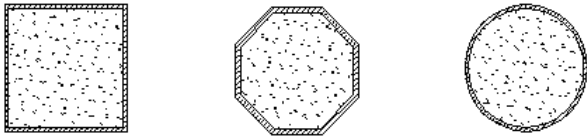


Fig. 1: Various cross-sections of CFST composite columns

2. EXPERIMENTAL WORK

For experimental investigation axial load is applied on CFST specimen. While testing care taken that the end surfaces on which concrete filled steel tubes keeping for testing should be plane.

All specimens were tested in Compression Testing Machine and are simply supported at both ends.

2.1 Experimental Test Setup

The concrete filled steel tube specimens of different cross sections are tested for their load carrying capacity under axial compression on the compression testing machine. The actual test setup is as shown in following figure. The specimen of CFST is placed centrally on plates of compression testing machine and load is applied gradually. The capacity of compression testing machine in our college is 200 ton. The readings were taken on dial gauge and tabulated.



Fig-2: Photograph of Test setup for CFST on compression testing machine.

2.2 Grade of Concrete

The concrete infill used for CFST are of M20, M30 and M40 grades. The proportions obtained by mix design of concrete by using IS 10262:1982. The concrete blocks of size 150mm x150mm x 150mm are prepared by obtained proportions. Three blocks are casted by each proportion and tests were carried out under compression testing machine. The average test results are tabulated in table 1

Table 1: 28 day’s strength for M20, M30 and M40 grade of concrete block

Grade of concrete	Load in kN	Avg. strength in N/mm ²
M20	627.37	27.88
M30	793.90	35.15
M40	962.83	42.75

2.2 Steel Tube Specimen Details

For experimental investigation three different cross sectional steel tubes were used viz. circular, square and rectangular section. All specimens are prepared from mild steel grade steel pipes. For each cross sections three specimens were tested and the average value of load carrying capacity is taken for further studies. The details of steel tubes are tabulated in table 2

Table 2: Steel tube Specimen details

Cross Section	Inner dimensions in mm	Length in mm	Thk.	D/t	L/t	Marked as
Circular	Dia = 55.8	300	1.3	44.92	5.14	C1
	Dia =72.1	300	2	38.05	5.14	C2
Square	48.3x 48.3	300	1.2	42.25	5.91	S1
	69 x 69	300	1.7	42.59	5.91	S2
Rectangular	38 x 77.4	300	1.3	31.23	7.39	R1
	43.3 x93.3	300	2	23.65	6.34	R2



Fig-3: Steel tubes for casting of CFST specimens



Fig-4: CFST Specimens immediate after casting.



Fig-5: CFST Specimens after 28 days curing, before testing.

3. RESULTS AND DISCUSSION

3.1 ACI-318 Code of Practice

According ACI-318: Building Code Requirements for Structural Concrete and Commentary, American Concrete Institute, the theoretical load carrying capacity of steel encased concrete column that is CFST is calculated by equation 6.1. The load carrying capacity of CFST specimens used for experimental analysis is calculated using same equation and compare the results with experimental results.

$$P_n = 0.85A_c F_c + A_s F_y$$

3.2 EC4 Code of Practice

According EC4: Design of Composite Steel and Concrete Structures Part 1-1: General rules and rules for buildings, the theoretical load carrying capacity of steel encased concrete column that is CFST is calculated by equation 6.2. The load carrying capacity of CFST specimens used for experimental analysis is calculated using same equation and compare the results with experimental results.

$$P_n = A_c F_c + A_s F_y$$

3.3 AISC- LRFD Code of Practice

According AISC-LRFD: Load and Resistance Factor Design Specifications for Structural Steel Building, American Institute of Steel Construction, the theoretical load carrying capacity of concrete filled steel column is calculated by equation 6.3 or 6.4 according to condition mentioned with respect to equation. The load carrying capacity of CFST specimens used for experimental analysis is calculated using same equation and compare the results with experimental results.

$$\text{When, } P_e \geq 0.44P_0$$

$$P_n = P_0 [0.658^{\left(\frac{P_0}{P_e}\right)}]$$

$$\text{When, } P_e < 0.44P_0$$

$$P_n = 0.877P_0$$

$$P_0 = C_2 A_c F_c + A_s F_y$$

The value C_2 is 0.85 for rectangular sections and 0.95 for circular sections

$$P_e = \frac{\pi^2 (EI_{eff})}{(KL)^2}$$

In Above Equation value $K = 1$, For Steel Encased concrete sections according to AISC: LRFD code of practice

$$EI_{eff} = E_s I_s + C_1 E_c I_c$$

$$C_1 = 0.6 + 2 \left(\frac{A_s}{A_c + A_s} \right) \leq 0.9$$

3.4 Comparison of Results

In this comparison is made with results obtained by different code of practice and experimental results, also ratio of experimental load carrying capacity to analytical results are calculated for comparison on the basis of size and shape.

Table 3: Comparison between experimental test results and ACI-318

Specimen marked	Concrete grade	Expt. L.C.C. in kN (N_e)	L.C.C. by ACI-318 in kN (N_a)	Ratio N_e/N_a
C1	M20	153.69	99.85	1.54
C2	M20	268.14	185.71	1.44
S1	M20	134.07	99.06	1.35
S2	M20	264.87	201.13	1.32
R1	M20	153.69	126.70	1.21
R2	M20	238.71	209.28	1.14
C1	M30	182.12	120.63	1.51
C2	M30	310.65	220.40	1.41
S1	M30	166.77	118.39	1.41
S2	M30	313.52	241.60	1.30
R1	M30	183.12	151.70	1.21
R2	M30	264.87	243.62	1.09
C1	M40	209.28	141.40	1.48
C2	M40	340.08	255.08	1.33
S1	M40	179.85	138.72	1.30
S2	M40	346.62	282.06	1.23
R1	M40	209.28	176.70	1.18
R2	M40	304.11	277.95	1.09

Table 4: Comparison between experimental test results and EC4

Specimen marked	Concrete grade	Expt. L.C.C. in kN (N_e)	L.C.C. by ACI-318 in kN (N_a)	Ratio N_e/N_a
C1	M20	153.69	107.18	1.43
C2	M20	268.14	197.95	1.35
S1	M20	134.07	106.05	1.26
S2	M20	264.87	215.41	1.23
R1	M20	153.69	135.52	1.13
R2	M20	238.71	221.39	1.08

C1	M30	182.12	131.62	1.38
C2	M30	310.65	238.76	1.30
S1	M30	166.77	129.39	1.29
S2	M30	313.52	263.02	1.19
R1	M30	183.12	164.93	1.11
R2	M30	264.87	261.80	1.01
C1	M40	209.28	156.07	1.34
C2	M40	340.08	273.56	1.24
S1	M40	179.85	152.71	1.18
S2	M40	346.62	310.63	1.12
R1	M40	209.28	194.35	1.08
R2	M40	304.11	302.20	1.01

Table 5: Comparison between experimental test results and AISC-LRFD

Specimen marked	Concrete grade	Expt. L.C.C. in kN (N _e)	L.C.C. by ACI-318 in kN (N _a)	Ratio Ne/Na
C1	M20	153.69	103.26	1.49
C2	M20	268.14	192.33	1.39
S1	M20	134.07	97.74	1.37
S2	M20	264.87	199.78	1.33
R1	M20	153.69	124.34	1.24
R2	M20	238.71	206.66	1.16
C1	M30	182.12	125.88	1.45
C2	M30	310.65	230.50	1.35
S1	M30	166.77	117.11	1.42
S2	M30	313.52	239.79	1.31
R1	M30	183.12	148.50	1.23
R2	M30	264.87	240.27	1.10
C1	M40	209.28	148.48	1.41
C2	M40	340.08	268.69	1.27
S1	M40	179.85	136.41	1.32
S2	M40	346.62	279.70	1.24
R1	M40	209.28	172.53	1.21
R2	M40	304.11	273.80	1.11

Comparative Graphical Presentation

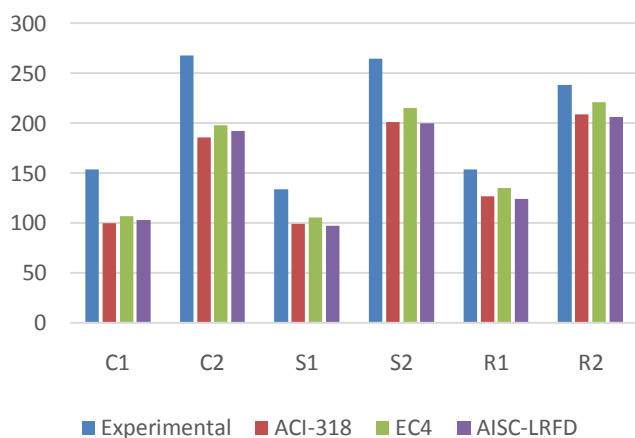


Fig 6: Comparative graphical presentation for test results and different code of practices with M20 concrete

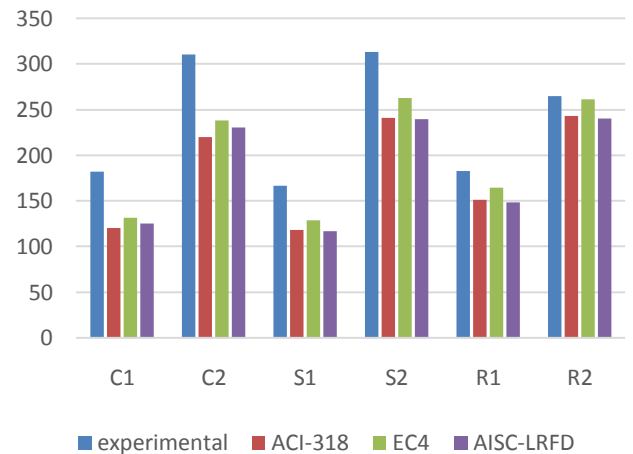


Fig 7: Comparative graphical presentation for test results and different code of practices with M30 concrete

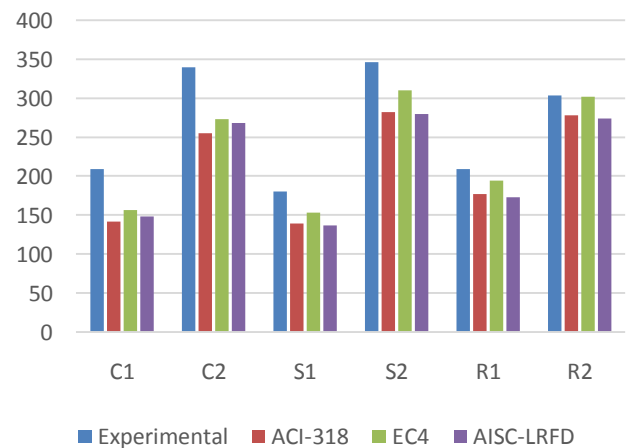


Fig 8: Comparative graphical presentation for test results and different code of practices with M40 concrete

3.5 Effect of High Strength Concrete Infill

High strength concrete infill increases the strength of concrete filled steel tubes. Graphs are plotted individually for all six specimen types with all grades of concrete, from which we can get clear idea. The effect is also studied from graphs plotted for shape, from which it is observed that the ratio of experimental results to the analytical results are slightly varying with increase in concrete grade. As the grade of concrete increases the strength is also increases, therefore use of high infill concrete whenever there is restriction on size of column to get desired strength.

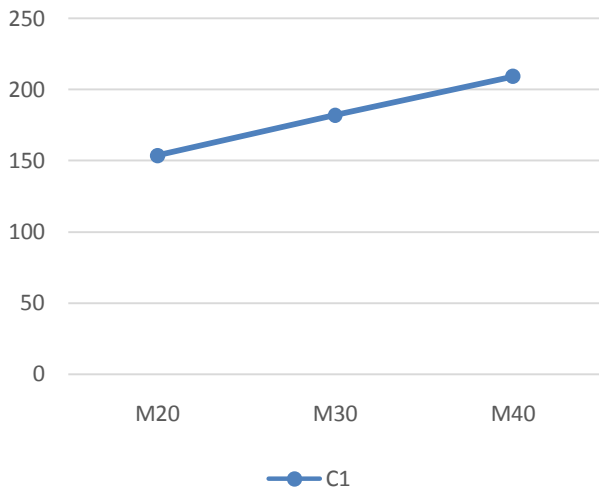


Fig 9: Effect of high strength concrete infill on load carrying capacity with C1 type of CFST specimen

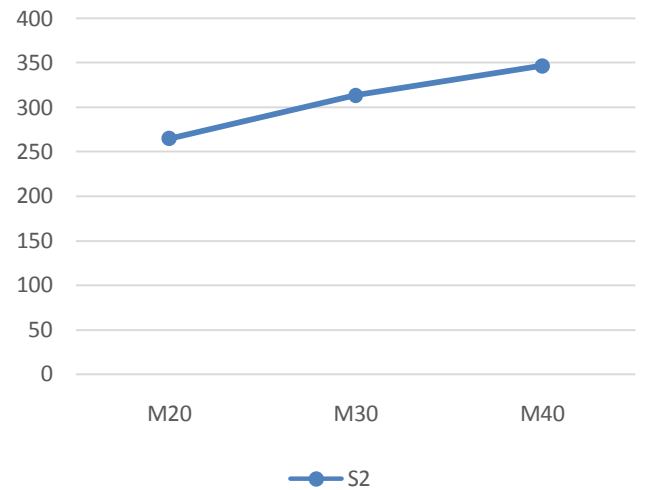


Fig 10: Effect of high strength concrete infill on load carrying capacity with C1 type of CFST specimen

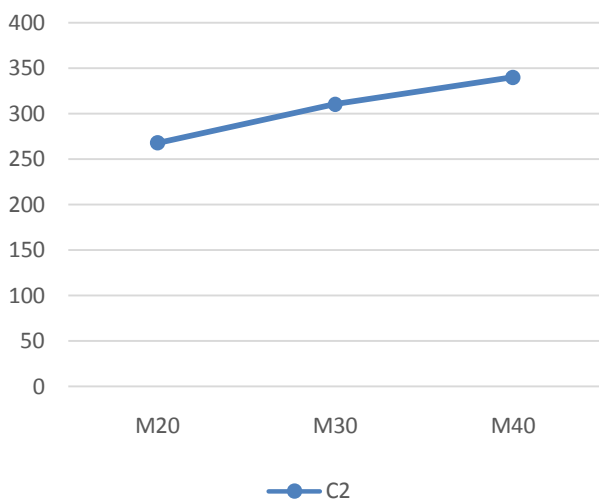


Fig 10: Effect of high strength concrete infill on load carrying capacity with C1 type of CFST specimen

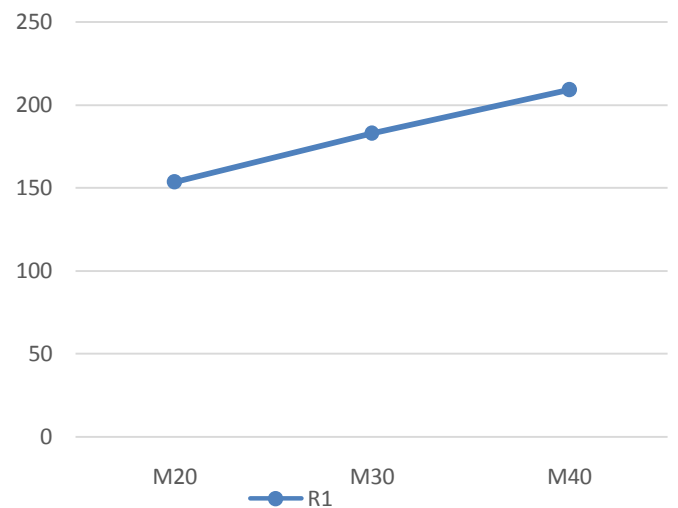


Fig 10: Effect of high strength concrete infill on load carrying capacity with C1 type of CFST specimen

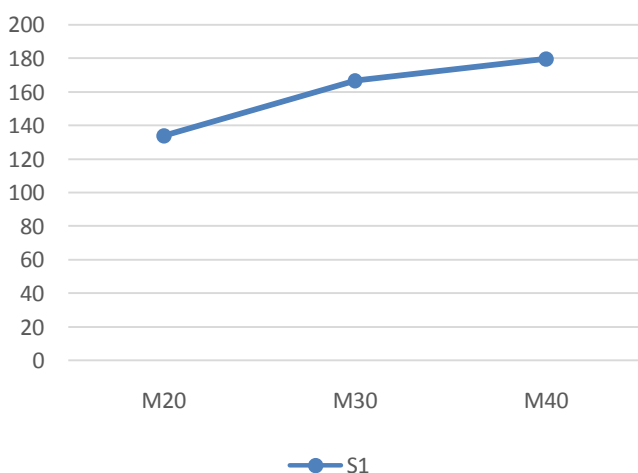


Fig 10: Effect of high strength concrete infill on load carrying capacity with C1 type of CFST specimen

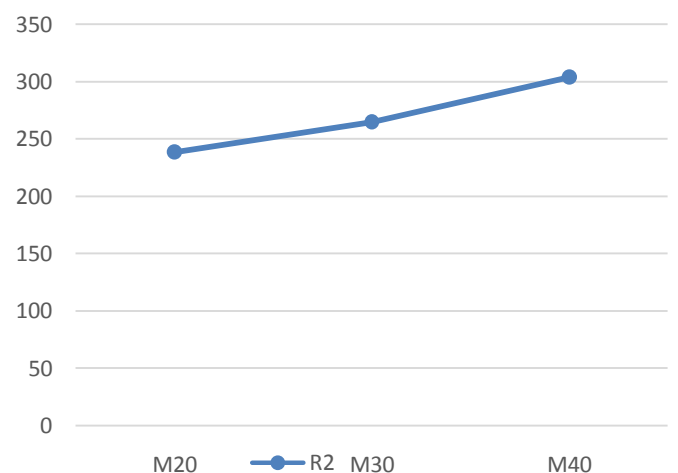


Fig 10: Effect of high strength concrete infill on load carrying capacity with C1 type of CFST specimen

4. CONCLUSION

1. The Experimental results compared with all stated code of practices which shows that the results from ACI-318 and AISC-LRFD are in good agreement with each other while EC4 results are more than other two code of practices. From which it is observed that EC4 gives conservative results with experimental results and it is concluded that EC4 provisions may be used for further analytical study to develop an expression to predict the section capacity CFST columns.
2. As the size of CFST specimen increases, strength increases but the ratio of experimental load carrying capacity to the analytical load carrying capacity decreases. From which it is concluded that as the size increases the effectiveness of CFST reduces because analytical formula used for calculation of load carrying capacity is same.
3. Circular cross sections proved much stronger than square and square section proved quite stronger than rectangular sections. The confinement effect increases the concrete resistance in circular section while confinement effect is reduces in rectangular sections due to stress concentration at corners.
4. As the high strength concrete infill is used strength is also increases. The ratio of Experimental results to analytical results for high strength concrete infill is decreases with small amount therefore it is concluded that use high strength infill concrete is much more effective to get extra strength with same size CFST column.

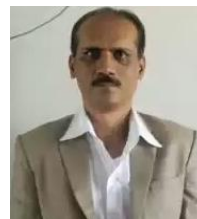
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