EXPERIMENTAL INVESTIGATION OF CONCRETE FILLED STEEL TUBULAR COLUMN UNDER AXIAL LOAD

Vinod Balmiki,
M.Tech Student, Department of Civil Engineering, Faculty of Technology, Uttarakhand Technical University Dehradun, India
Sangeeta Dhyani,
Head of the Department (HOD), Department of Civil Engineering Faculty of Technology, Uttarakhand Technical University Dehradun, India

ABSTRACT

In a CFST column steel tube surrounds the concrete. Thus the steel tube acts as both longitudinal and transverse reinforcement hence it is subjected to biaxial stresses. In addition to this the steel tube also acts as confinement for the concrete. The main advantage of CFST column is that the steel tube in it acts as a permanent confinement for the concrete and also prevents spalling of concrete. Similarly, the concrete inside the steel tube prevents local buckling of tube inside, hence adds to the strength of the column.

In this research, an experimental study is conducted on the CFST columns subjected to failure under axial load. The results obtained were compared with the codal provisions. In this study total 48 specimens were made of CFST column out of which 36 were made of steel tubes filled completely with concrete, 3 were kept hollow, and 9 were conventional concrete columns. All the specimens were tested for load carrying capacity. These specimens are of various cross-sections and load carrying capacities were studied depending on the section of the specimen.

The main aim of this research is to experimental study of CFST columns under the influence of axial loads till failure and to verify the experimental results by codal provisions hence check the accuracy of codal formulas.

Keywords: CFST, axial loading, local buckling, failure.

I. INTRODUCTION

The basic concept of Concrete Filled Steel tube (CFST) is that when the tube made of steel is provided as a casing outside the concrete filling, its properties are modified by to combined effect steel as well as concrete. In CFST concrete core of high as it contains goodness of both high strength steel as well as strength of high strength concrete. The most common CFST column.

It possesses both static plus the earthquake resistant properties. It is more ductile and absorbs larger energy thus making it perfect for earthquake resistant buildings.

CFST members are mostly used as supports in high buildings. Due to their earthquake resistant properties it is perfect for structural columns, where they are subjected to high shear stresses along with wind and seismic forces. In past numerous studies are done to study the behaviour of CFST columns under axial loads and bending stresses but still the research done is not satisfying all the areas of CFST. Still some gap is left in the researches. If high strength materials are used, the properties of the columns and the economy of the high buildings are greatly affected in a good way. If high strength concrete is used in CFST column, it attains high damping as well as stiffness is increased. Similarly if we use high strength steel for steel tube, smaller sections is used to carry the same load thus improving economy which is important in projects. The important aspect of CFST column is that due to interaction between steel casing and infill concrete, the concrete prevents and postpones local buckling in the steel and the steel surrounding the concrete prevents it from spalling providing confinement to the concrete and increasing its compressive strength. Mainly Concrete Filled Steel Tubes are used in seismic designs, roofs of storage tanks, and piers in bridges and many other structures. CFST have been used in a bridge in Quebec. This bridge having a span of sixty metres contains steel tubes as diagonal truss members in which high strength concrete in form of powder is compressed in steel tubes.

II. EXPERIMENTAL SETUP

This research is a work consisting of observations based on experiment that were conducted on steel tubes filled with concrete and they were loaded axially till failure occurred. Total 48 specimens were used. The specimen had length-diameter ratio between 5.0 to 6.0 and their diameter - thickness ratio between 16.5 to 54. The tubes that were used were of steel having grade 250 Mpa. Only axial compression was used in this test over the specimens. We calculate the load capacity and then compare it analytically with the codal procedure designs, and also with some of the previous results that published. To study the bond between the concrete in filled and the face of steel tube, some of the tubes were kept rough. The codes used were EC4, ACI & LFRD. The results obtained were compared to the values obtained by tests. The test specimen details are given Table below tables.

Detail of specimen:

- Circular :
  Diameter = 50 mm.
  Length = 300 mm.
  Thickness = 3 mm.
- Rectangular:
  Dimension = 35*72 mm.
  Length = 300 mm.
  Thickness = 3 mm.
- Square:
  Dimension = 50*50 mm.
  Length = 300 mm.
  Thickness = 3 mm.

Ratios of the specimen:

- Circular:
  Length/Diameter ratio = 6
  Diameter/thickness ratio = 16.66
- Rectangular:
  Length/Diameter ratio = 53
  Diameter/thickness ratio = 17.88
- Square:
  Length/Diameter ratio = 6
  Diameter/thickness ratio = 16.66

Material used:

Concrete: The grade of concrete used in the specimen is M25 with varies % of water.

- M1-water used 40% of weight of cement.
- M2-water used 30% of weight of cement.
- M3-water used 20% of weight of cement.

Steel: The grade of steel used in tube is fe 250.

Fig.2.1 Experimental Setup

Table 2.1: Results for M1, M2 and M3 concrete using Circular tube

CIRCULAR SECTION	ULTIMATE LAOD USING M1-CONCRETE	ULTIMATE LAOD USING M2-CONCRETE	ULTIMATE LAOD USING M3-CONCRETE
C–M	195	200	210
C–M	200	210	210
C–M	210	210	220
C(T)-M	200	210	225
CIR (H)	100	100	100
C(S) M	50	90	110

Table 2.2: Results for M1, M2 and M3 concrete using Square tube

SQUARE SECTION	ULTIMATE LAOD USING M1-CONCRETE	ULTIMATE LAOD USING M2-CONCRETE	ULTIMATE LAOD USING M3-CONCRETE
S–M	300	340	360
S–M	310	340	360
S–M	315	340	350
S(T)-M	340	360	370
SQ (H)	110	110	110
S(S) M	80	100	130

Table 2.1: Results for M1, M2 and M3 concrete using Rectangular tube

SQUARE SECTION	ULTIMATE LAOD USING M1-CONCRETE	ULTIMATE LAOD USING M2-CONCRETE	ULTIMATE LAOD USING M3-CONCRETE
R–M	180	200	210
R–M	190	180	230
R–M	180	210	220
R(T)-M	210	220	220
R (H)	90	90	90
R(S) M	80	70	90

III. COMPARISON OF RESULTS

In this section depicts comparison of the results obtained by tests. The results are also compared to the results that are predicted using codes.

3.1 Comparison with codes of design:

Following formula is given by codal provisions of American Concrete Institute (ACI) and Australian institute (AS):

$$N_u = 0.85A_c\ f_c + A_s\ f_y$$

AISC/LRFD gives no special formulas for treatment of CFST columns. Therefore, design formula for steel columns having contribution of concrete is used.

$$Nc = As \times f_{cr}$$

$$f_{cr} = (0.658\lambda\ c^2)f_{my}$$

$$f_{my} = f_y + 0.85fcA_c/a_s$$

Euro code 4 uses following formula:

$$N_u = A_c\ f_c + A_s\ f_y$$

Table 3.1 - Comparison with ACI Code using M1 concrete

	ULTIMATE LAOD	Ultimate load	RATIO

SECTIONS	USING M1-CONCRETE (EXP. VALUE) (KN)	corresponding to ACI(KN)	N_{EXP}/N_{ACI}
C–M	195	142.9	1.36
C–M	200	142.9	1.39
C–M	210	142.9	1.46
C(T)-M	200	142.9	1.39
CIR (H)	100	110.6	0.90
C(S) M	50	32.29	1.54
S–M	300	182.1	1.64
S–M	310	182.1	1.70
S–M	315	182.1	1.72
S(T)-M	340	182.1	1.86
SQ (H)	110	141.0	0.78
S(S) M	80	41.1	1.94
R–M	180	192.1	0.93
R–M	190	192.1	0.98
R–M	180	192.1	0.93
R(T)-M	210	192.1	1.09
R (H)	90	151.5	0.59
R(S) M	80	41.1	1.94

Table 3.2 - Comparison with ACI Code using M2 concrete

SECTIONS	ULTIMATE LAOD USING M2-CONCRETE (EXP. VALUE) (KN)	Ultimate load corresponding to ACI(KN)	RATIO N_{EXP}/N_{ACI}
C–M	200	142.9	1.39
C–M	210	142.9	1.46
C–M	210	142.9	1.46
C(T)-M	210	142.9	1.46
CIR (H)	100	110.6	0.90
C(S) M	90	32.29	2.78
S–M	340	182.1	1.86
S–M	340	182.1	1.86
S–M	340	182.1	1.86
S(T)-M	360	182.1	1.97
SQ (H)	110	141.0	0.78
S(S) M	100	41.1	2.43
R–M	200	192.1	1.04
R–M	180	192.1	0.93
R–M	210	192.1	1.09
R(T)-M	220	192.1	1.14
R (H)	90	151.5	0.59
R(S) M	70	41.1	1.70

Table 3.3 - Comparison with ACI Code using M3 concrete

SECTIONS	ULTIMATE LAOD USING M3-CONCRETE (EXP. VALUE) (KN)	Ultimate load corresponding to ACI(KN)	RATIO N_{EXP}/N_{ACI}
C–M	210	142.9	1.46
C–M	210	142.9	1.46
C–M	220	142.9	1.53
C(T)-M	225	142.9	1.57
CIR (H)	100	110.6	0.90
C(S) M	110	32.29	3.40
S–M	360	182.1	1.97
S–M	360	182.1	1.97
S–M	350	182.1	1.92
S(T)-M	370	182.1	2.03
SQ (H)	110	141.0	0.78
S(S) M	130	41.1	3.16
R–M	210	192.1	1.09
R–M	230	192.1	1.19
R–M	220	192.1	1.14
R(T)-M	220	192.1	1.14
R (H)	90	151.5	0.59
R(S) M	90	41.1	2.18

Table 3.4 - Comparison with EURO Code 4 using M1 concrete

SECTIONS	ULTIMATE LAOD USING M1-CONCRETE (EXP. VALUE) (KN)	Ultimate load corresponding to EC 4 (KN)	RATIO $N_{EXP}/N_{EC\ 4}$
C–M	195	148.6	1.31
C–M	200	148.6	1.34
C–M	210	148.6	1.41
C(T)-M	200	148.6	1.34
CIR (H)	100	110.6	0.90
C(S) M	50	37.9	1.31
S–M	300	189.4	1.58
S–M	310	189.4	1.63
S–M	315	189.4	1.66

S(T)-M	340	189.4	2.41
SQ (H)	110	141.0	0.78
S(S) M	80	48.4	1.65
R–M	180	199.3	0.90
R–M	190	199.3	0.95
R–M	180	199.3	0.90
R(T)-M	210	199.3	1.05
R (H)	90	151.5	0.59
R(S) M	80	47.8	1.67

Table 3.5 - Comparison with EURO Code 4 using M2 concrete

SECTIONS	ULTIMATE LAOD USING M2-CONCRETE (EXP. VALUE) (KN)	Ultimate load corresponding to EC 4(KN)	RATIO $N_{EXP}/N_{EC\,4}$
C–M	200	148.6	1.34
C–M	210	148.6	1.41
C–M	210	148.6	1.41
C(T)-M	210	148.6	1.41
CIR (H)	100	110.6	0.90
C(S) M	90	37.9	2.37
S–M	340	189.4	1.79
S–M	340	189.4	1.79
S–M	340	189.4	1.79
S(T)-M	360	189.4	1.90
SQ (H)	110	141.0	0.70
S(S) M	100	48.4	2.06
R–M	200	199.3	1.00
R–M	180	199.3	0.90
R–M	210	199.3	1.05
R(T)-M	220	199.3	1.10
R (H)	90	151.5	0.59
R(S) M	70	47.8	1.46

Table 3.6 - Comparison with EURO Code 4 using M3 concrete

SECTIONS	ULTIMATE LAOD USING M3-CONCRETE (EXP. VALUE) (KN)	Ultimate load corresponding to EC 4(KN)	RATIO $N_{EXP}/N_{EC\,4}$
C–M	210	148.6	1.41
C–M	210	148.6	1.41
C–M	220	148.6	1.48
C(T)-M	225	148.6	1.51
CIR (H)	100	110.6	0.90
C(S) M	110	37.9	2.90
S–M	360	189.4	1.90
S–M	360	189.4	1.90
S–M	350	189.4	1.84
S(T)-M	370	189.4	1.95
SQ (H)	110	141.0	0.78
S(S) M	130	48.4	2.68
R–M	210	199.3	1.05
R–M	230	199.3	1.15
R–M	220	199.3	1.10
R(T)-M	220	199.3	1.10
R (H)	90	151.5	0.59
R(S) M	90	47.8	1.88

Comparing my results with some of the results that have been already published:

Table 3.7 - Comparison table

According to	Mean N_{EXP}/N_{ACI}	Mean N_{EXP}/N_{EC4}
Dalin	1.27	1.29
Furlong	1.44	----
S. De. Nardin	-----	1.20
My Results	1.48	1.40

IV. CONCLUSION

An investigation was carried out to determine the behaviour in CFST columns and then compare them with the codal procedures for designing in axial loading. Along with concrete filled in tubes, plain concrete specimens were also tested which had same dimension as the steel tube.

The results obtained are compared to codes, namely, ACI, EC4 and LRFD. The codes gave the values for the experiment. Using the results in my thesis some conclusions are drawn for axial loading of CFST columns:

1. The tube has confining effect on concrete and that too is visible in my investigations.
2. In case of axial loading, slippage in concrete and tube is negligible hence; bond strength is of little importance in axial loading.
3. Unlike RCC columns, strain hardening doesn't occur in CFST column under axial loading.

4. Strength is more for square column than circular columns.
5. As earlier discussed, square column are stronger and show larger deformations after yielding.
6. Rectangular results are much agreed to codal design methods.

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