Experimental Study on Concrete Filled Steel Tubular Square Columns

Chandira Kumar D[1], Moorthi N[2]
[1]Dept of M.E-Structural Engineering
[2]Assitant Professor ,Dept of Civil Engineering
[1, 2] Paavai Engineering College Namakkal-637018, India

Abstract- *Concrete filled steel tubular columns (CFTs) are becoming widely used in engineering. The addition of granite, debris and quarry dust by replacing aggregates in concrete is to improve the compressive strength of CFTs. Concrete Filled Steel Tubes (CFST) is one of many composite elements used at present in civil engineering. Different approaches and design philosophies were adopted in different design codes for it. But for hollow CFST elements, which are more effective than ordinary CFST, any code does not provide information about how to design these elements.In this article reasons of the above-mentioned complex stress state appearance and behaviour of hollow CFST element components in different load stages of compressed stub structural member are analyzed. The test results are presented in diagrams, tables. Previous researches of other investigators are summarized. Differences and similarities in behaviour of solid concrete and composite elements and hollow members with different number of concrete core layers are discussed.*

I. INTRODUCTION

1.1. GENERAL-Behavior of composite steel-concrete elements in various loading stages is quite well analyzed by theoretical investigations and experiments. Concrete-Filled Steel Tube (CFST) is one of many composite elements used at present in civil engineering. Different approaches and design philosophies were adopted in different design codes for it. But for hollow CFST elements, of the steel tubular column.This project presents the economical comparison between five different composite columns:

1. Conventional Concrete Filled Steel Tubular Square Columns
2. Concrete Filled Steel Tubular Square Columns with partial replacement of Fine Aggregate by Quarry Dust (25%)
3. Concrete Filled Steel Tubular Square Columns with partial replacement of Coarse Aggregate by Granite (25%)
4. Concrete Filled Steel Tubular Square Columns with partial replacement of Coarse Aggregate by C&D Debris (25%)
5. Hollow Steel Tubular Square Columns

II. MATERIAL COLLECTIONS

2.1. Materials and Mix Proportions

For preparing test specimens 53 Grade Ordinary Portland Cement, Natural River sand and coarse aggregate, waste material from Granite Industry, Quarry Dust and C&D Debris were used. The maximum size of the coarse aggregate was limited to 10mm to get the maximum increase in compressive strength. A sieve analysis conforming to IS 383-1970 was carried out for both fine and coarse aggregates. The concrete mix proportions M_{20} adopted was 1.0:1.68:3.0 (cement: sand: coarse aggregate) with water cement ratio of 0.5. The concrete mix was designed so as to achieve compressive strength of concrete cube of 20 MPa after 28 days curing and also the flexural and the tensile strength of the specimen are tested.

2.2. Granite


Figure 2.1 Granite Pieces

The Granite pieces are taken from the Industry which is thrown as unwanted. They are used as a coarse aggregate with partial replacement of ordinary coarse aggregate (jelly). The size of the Granite is taken as 10mm, with uniform in angular size. The Granite is thoroughly washed before it is used and mixed with dry cement mortar.

2.3. C&D Debris

Figure 2.2 C&D Debris

The C&D debris is taken from the tested concrete cubes and cylinders which is available locally. They are broken with the help of steel hammer. They are taken as in uniform of 10mm angular size. The coarse aggregate is taken for the test purpose.

2.4. Quarry Dust

Figure 2.3 Quarry Dust

The quarry dust is taken from the quarry industry which is available locally and as a replacement of ordinary river sand this can be used as an alternative material for the construction. The quarry dust is simply taken quarry industry which is available locally.

2.5. Steel Tube Details

Steel tube dimension as below are used for composite column

Figure 2.4 Steel Tubes

III. TESTING OF MATERIALS

3.1. Determination of Specific Gravity

Apparatus used

Pyconometer, Balance, Weight box, Oven, Desiccators, Desired kerosene or any liquid with known specific gravity, Vacuum source, Thermometer.Pyconometer is a glass jar to which a brass conical cap is screwed with a rubber washer. A 6mm diameter hole is provided in the brass cap.

Procedure

1. Weigh the clean dry pyconometer with its cap.
2. Fill the pyconometer one third full with sample and determine its weight after screwing the cap.
3. Add kerosene to pyconometer after removing the cap, until the pyconometer to assist the removal of air and screw the brass cap.
4. Add the kerosene till the pyconometer is full.
5. Remove remaining air by shaking after closing the screw top with one finger. Clean the outer surface of pyconometer and then determine its weight.
6. Empty the contents of pyconometer and thoroughly wash it.
7. Fill the pyconometer with kerosene till the surface of kerosene is flush with the hold in the screw cap. Then weigh the pyconometer.
8. Note the temperature of kersen

IV. MIX DESIGN

4.1. M_{30} GRADE

DETAILS OF MIX PROPORTION

i. Grade designation : M30
ii. Type of cement : PPC cement conforming to IS: 1489 (Part 1)
iii. Maximum nominal size of aggregate : 20mm
iv. Minimum cement content : 320 kg/m^3
v. Maximum water cement ratio : 0.50
vi. Workability : 50 – 75 mm(slump)
vii. Exposure condition : Moderate
viii. Type of aggregate : Crushed angular aggregate
ix. Maximum cement content : 450 kg/m^3

TEST DATA FOR MATERIALS

1) Cement used : PPC
2) Specific gravity of cement :3.05
3) Specific gravity of
   (1) Coarse aggregate :2.68
   (2) Fine aggregate :2.66
4) Water absorption
   (1) Coarse aggregate :0.85%
   (2) Fine aggregate :1.15%
5) Sieve analysis
   (1) Coarse aggregate :conforming to Table 2 IS:383
   (2) Fine aggregate :conforming to zone II IS:383

TARGET STRENGTH FOR MIX PROPORTIONING

$$f_{ck} = f_{ck} + 1.65\ s$$

Where

f_{ck} = Target average compressive strength at 28 days
f_{ck} = characteristic compressive strength at 28 days
s= standard deviation
From table 1 standard deviation, s = 5N/mm^2
f_{ck} = 30 +1.65 x 5 = 38.25 N/mm^2

SELECTION OF WATER CEMENT RATIO

From table of IS 456-2000, maximum water cement ratio = 0.50(Moderate exposure)

Based on experience adopt water cement ratio as 0.45
0.45< or = 0.5, hence ok

SELECTION OF WATER CONTENT

From table of IS 456-2000 maximum water content = 186 liters (for 25mm-50mm slump range and for 20mm aggregates)

Reduce water by about 20% as 0.75% SP is used (Based on laboratory trail's)

Estimated water content = 152 liters

CALCULATION OF CEMENT CONTENT

Water cement ratio =0.45
Cement content = 152/0.45
=337.7 say 340 kg/m^3 >320 kg/m^3 (given)
From table 5 of IS: 456-2000,minimum cement content for moderate exposure condition=300kg/m^3
Hence OK

PROPORTION OF VOLUME OF COARSE AGGREGATE AND FINE AGGREGATE CONTENT

From table 3 of IS: 456-2000, volume of coarse aggregate corresponding to 20mm size aggregate and fine aggregate(zone II) for water cement ratio of 0.50=0.62.Modify this as w/c is 0.45. The new value is 0.63. Volume of fine aggregate is 0.37

MIX CALCULATIONS

The mix calculations per unit volume of concrete shall be as follows

a) Volume of concrete = 1m^3
b) Volume of cement =(mass of cement /specific gravity of cement)x(1/1000)
c) volume of water =(152/1)x(1/1000)
d) volume of all in aggragate =a-(b+c)
e) weight of fine aggregate = e x volume of FA x specific gravity of FA
   =724kg

MIX PROPORTIONS

Cement =340 kg/m^3
Water =152 kg/m^3
Fine aggregate =724 kg/m^3
Coarse aggregate =1242 kg/m^3
Water cement ratio=0.45
Mix proportions =340 : 724 : 1242
= 1 : 2.12 : 3.65

V. RESULTS

Table 5.1 – Compressive Strength of Concrete cubes after 28 days in N/mm^2

Replacement of Aggregate	% of Replacement	Cubes 01	Cubes 02	Cubes 03	Average
Conventional Concrete	-	27.56	28.89	29.78	28.74
by Granite (CA)	25	22.67	22.22	24.89	23.26
by C & D Debris (CA)	25	25.33	24.44	24.89	24.89
by Quarry Dust (FA)	25	22.22	23.11	23.56	22.96

Table 5.2 - Flexural Strength and Split Tensile Strength after 28 days in N/mm^2.

Concrete Filled Steel Tubular Square Column with partial replacement of Coarse Aggregate by Granite (25%) Section 72 x 72mm & 300mm		Concrete Filled Steel Tubular Square Column with partial replacement of Coarse Aggregate by Granite (25%) Section 72 x 72mm & 600mm	
Load kN	Shortening (mm)	Load kN	Deflection (mm)
0	0	0	0
20	1.40	20	0.52
40	1.80	40	1.08
60	2.14	60	1.64
80	2.55	80	2.08
100	3.00	100	2.50
120	3.50	120	2.83
140	4.09	140	3.15
160	5.70	160	3.53
180	6.00	180	3.82
200	6.30	200	4.10
220	6.70	220	4.40
240	7.20	240	4.68
260	9.60	260	4.90
266.7	9.96	280	5.20
		300	5.40
		320	5.62
		340	5.88
		360	6.15
		380	6.45
		400	7.10

The above test result shows the various strength of different types of concrete cubes with various proportion of coarse aggregate. The replacement of Aggregate by 25% by various materials like Granite, Quarry dust and (C&D) Debris to give higher performance in the results.

Table 5.3 – Load & Deflection, Load (kN) & Deflection (mm)

Hollow Steel Square Column of Section 72 x 72mm & 300mm height		Hollow Steel Square Column of Section 72 x 72mm & 600mm height	
Load kN	Shortening (mm)	Load kN	Deflection(mm)
0	0	0	0
20	0.93	20	0.9
40	1.39	40	1.95
60	1.7	60	2.96
80	2.18	80	3.65
100	2.54	100	4.3
120	3.02	120	4.85
140	3.38	140	5.44
160	3.64	160	7.2

180	4.3	180	8
200	4.75	200	8.65
220	5.2		
240	5.86		
258.25	6.45		

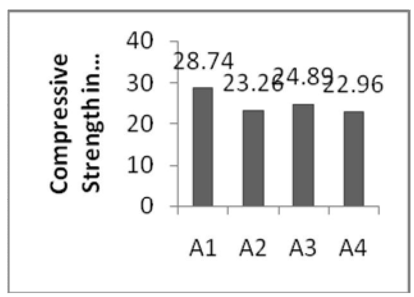
Hollow Steel Square Column of Section 100 x 100mm & 600mm height		Hollow Steel Square Column of Section 100 x 100mm & 900mm height	
Load kN	Shortening (mm)	Load kN	Deflection(mm)
0	0	0	0
20	0.82	20	0.98
40	1.86	40	2.04
60	2.76	60	2.98
80	3.65	80	3.88
100	4.06	100	4.23
120	4.65	120	4.98
140	5.24	140	5.56
160	6.88	160	7.06
180	7.88	180	8.22
200	8.4	200	8.65

Conventional Concrete Filled Steel Tubular Square Column Section 72 x 72mm & 300mm height		Conventional Concrete Filled Steel Tubular Square Column Section 72 x 72mm & 600mm height	
Load kN	Shortening (mm)	Load kN	Deflection(mm)
0	0	0	0
20	0.88	20	0.6
40	1.92	40	0.95
60	2.45	60	1.15
80	2.88	80	1.32
100	3.64	100	1.57
120	4	120	1.83
140	4.35	140	2.07
160	4.85	160	2.3
180	5.22	180	2.56
200	5.65	200	2.8
220	5.96	220	3.06
240	6.23	240	3.33
260	6.54	260	3.65
280	6.82	280	4.02
300	7.2	300	4.45
320	7.65	318.54	4.89
360	8.24		
440	9.2		

VI. YOUNGS MODULUS VALUE

Table 6.1 - Youngs Modulus in N/mm^2

Load kN	Deflection (mm)	Load kN	Deflection (mm)
0	0	0	0
20	0.8	20	0.88
40	1.65	40	1.6
60	2.98	60	2.1
80	3.75	80	2.6
100	4.1	100	3.1
120	4.8	120	3.8
140	5.34	140	4.3
160	5.65	160	4.52
180	5.85	180	4.78
200	6.05	200	5
220	6.25	220	5.18
240	6.4	240	5.25
260	6.5	260	5.42
280	6.65	280	5.62
300	6.85	300	5.94
320	7	320	6
340	7.15	340	6.2
360	7.3	360	6.45
380	7.45	380	6.65
400	7.6	400	6.92
420	7.75	420	7.18
440	7.9	440	7.45
460	8.05	460	7.8
480	8.2	480	8.2
484.6	8.4	500	9.15



Compressive Strength of Concrete Cubes
After 28 days curing in N/mm
Flexural Strength of Prisms
After 28 days curing in N/mm^2

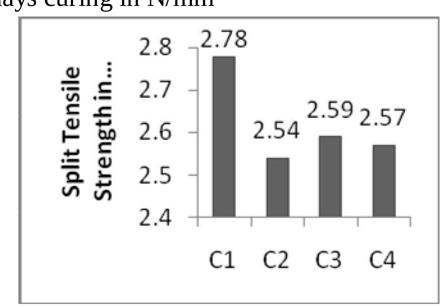


Fig 6.2 – Split Tensile Strength of Cylinders
After 28 days curing in N/mm^2

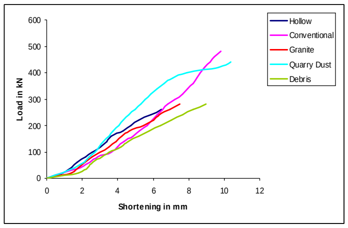


Fig 6.3 - Concrete Filled Steel Tubular Square Columns with partial replacement of Aggregate (25%), Section 72 x 72mm & 300mm

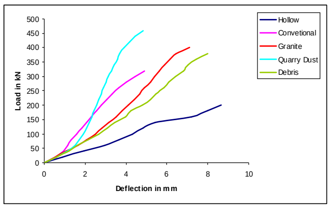


Fig 6.4 - Concrete Filled Steel Tubular Square Columns with partial replacement of Aggregate (25%), Section 72 x 72mm & 600mm

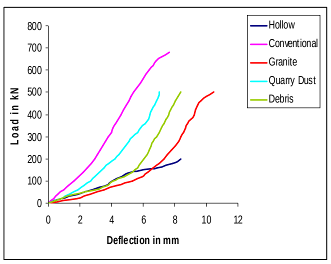


Fig 6.5 - Concrete Filled Steel Tubular Square Columns with partial replacement of Aggregate (25%), Section 100 x 100mm & 900mm

VII. CONCLUSION

From the above results it can be observed that the partial replacements are a very attractive proposition for composite columns. However, the success of the method depends on several factors.

- The Cube Strength of C&D Debris and Conventional Concrete are much more than the other mixes.
- The Youngs Modulus value of Conventional Concrete, C&D Debris and Granite is high than the other mixes.
- The test results shows that the use of waste materials from various industries (Granite and C&D Debris) gives the effective utilization of recycled aggregate and its gives an innovative and best performance.

REFERENCES

[1] shuai Jiang "Concrete Filled Steel Columns" pp 457-459,1992

[2] Hasan Hastemoglu,Suleyman Demirel University Faculty of Architecture, 32260,Sparta, Turkey,1995

[3] Varma AH, Ricles JM, Sause R et al. Behavior of High Strength Square CFT Columns In: Proceedings 6th US National Conference on Earthquake Engineering, Seattle, Washington, 31 May - 4 June 1998.

[4] Wang, Y., Wu, H. C. "Concrete reinforcement with recycled Rubbers" Journal of Materials in Civil Engineering, ASCE, 12(4), 314-319, 2000

[5] Keigo TSUDA1 , Chiaki MATSUI2 And Eiji MINO3 "strength and behavior of slender concrete filled steel tubular columns " 2000

[6] Chen, S.F., Teng, J.G. and Chan, S.L. "Design of Axially Loaded Short Composite Columns of Arbitrary Section", Journal of Structural Engineering, ASCE, Vol. 127, No. 6, June, pp 678-685, 2001.

[7] Teng, J.G., Chen, J.F. and Lee, Y.C. "Concrete Filled Steel Tubes as Composite Columns", Proceedings, Second International Conference on Advances in Steel Structures, pp 15-17, 2001

[8] Chamila rajeev,Jayanath batuwitage , Xuemei Liu "Composite Columns of Arbitrary Section" pp 124-129,2004

[9] Muhammad Naseem Baig, Nie,Jianguo "Composite columns of steel and concrete have been used and studied world wide, but filled tubular columns need more attention." 2006

[10] Helena et al. "The load-deformation behaviour of concrete filled rectangular sections" 2007

[11] Shanmugapriya, R. Uma.N (2012) "Optimization Of Partial Replacement Of M-Sand By Natural Sand In High Performance Concrete With Silica Fume" International Journal of Engineering Sciences & Emerging Technologies. ISSN: 2231 – 6604 Volume 2, Issue 2, pp: 73-80