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Experimental Study compared with Euro code - Concrete- filled – Double skin Circular Tubular Steel Concrete column

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ABSTRACT

Six Specimens with three different volume fractions of steel fibers are cast and tested. Experiments on circular steel tubes in –filled with steel fiber reinforced concrete (SFRC) and normal concrete have been performed to investigate the contribution of steel fibers to the load bearing capacity of Short Composite Columns . The main Variable considered in the test study is the percentage of steel fibers added to the in –filled concrete. All the specimens were tested under axial compression until failure state realization. This project presents the percentage Variation in the compression strengths of the 3 types of Composite members taken under Study. The results show that 1.5% SFRC in filled steel columns exhibit enhanced ultimate load carrying capacity.Experimental studies compared with Euro code

Keywords:- Composite columns, Optimization of steel

1.Introduction

The main aim of the project is to use utilize the properties of concrete and steel effectively as a composite column. The in-fill material inside steel tubes is required to be of the quality as to increase the ductility of composite columns. Hence steel fiber reinforced concrete is chosen as the in-fill material and its optimum volume fraction in concrete is to be found out. This project further inspires studies on the ductility, flexural strength and slenderness characteristics of double skin columns in-filled with fiber reinforced concrete.

To determine the compressive strength of the double skin composite concrete-filled steel tubular members in-filled with SCC mixed with fiber, subjected to axial loading.

1) To study the stress-strain behavior of the members in the different stages of axial loading.
2) To discuss the effect of variations in the volume fractions of steel fibers used in the concrete.
3) To propose the optimum fiber content to be used in double skin composite columns.

a) **Dalin Liua , Wie-Min Ghob** , **Thin Walled Structures 43 (2005)1131-1142:** Experimental investigation into the axial load behavior of rectangular concrete-filled steel tubular (CFT) stub columns. A total of 26 specimens were tested under concentric compression. The primary test parameters were material strengths (fc' = 55 - 106 MPa; fy = 300 and 495 MPa) and cross-sectional aspect ratio (1.0–2.0). Favorable ductility performance was observed for all specimens during the tests. A comparison of axial load capacity between the tests and the design codes shows that ACI and AISC give safe estimation by 7 and 8%, respectively. On the other hand, EC4 overestimates the ultimate capacity of the specimens fabricated from mild steel and high-strength concrete. A fiber model is developed to evaluate the axial load behavior of the specimens. Calibration of the model against the test data suggests that it can closely predict the non-linear behavior of high-strength rectangular CFT stub columns.

b) **Zhong Tao, Lin-Hai Han , Xiao-Ling Zhao, Journal of Constructional Steel Research 60 (2004) 1129-1158:** A series of tests on concrete filled double skin steel tubular (CFDST) stub columns (14) and beam-columns (12) were carried out. Both outer and inner tubes were circular hollow sections (CHS). The main experimental parameters for stub columns were the diameter-to thickness ratio and hollow section ratio, while those for beam-columns were slenderness ratio and load eccentricity. A theoretical model is developed in this paper for CFDST stub columns and beam-columns. A unified theory is described where a confinement factor (n) is introduced to describe the composite action between the outer steel tube and the sandwiched concrete. The predicted load versus deformation relationships are in good agreement with stub column and beam-column test results. Simplified models are derived to predict the load carrying capacities of the composite members.

2) Experimental Procedure:

In order to study the behavior of Double Skin Concrete Filled Tubes (DSCFT) in-filled with steel fiber-reinforced self-compacting concrete (SCC) under compression, six specimens with three different volume fractions of steel fibres are cast and tested. Steel pipes of 165mm and 89mm diameter with 3.2mm and 3mm wall thickness respectively were cut to 300mm height. The outer and inner tubes were fixed in concentric position by welding with 6mm diameter rod at top and bottom. The summary of the composite column details are given in Table 1.

Table. 1 Details of the Specimen

Data	Outeube dia (mm)	Inner tube dia (mm)	Outer tube thick (mm)	Inner tube thick (mm)	L (mm)	VolFibres (V_f) %
a	165	89	3.2	3	300	0
b	165	89	3.2	3	300	0
1a	165	89	3.2	3	300	1%
1b	165	89	3.2	3	300	1%
1.5a	165	89	3.2	3	300	1.5%
1.5b	165	89	3.2	3	300	1.5%

Fig. 1 concentrically welded steel tub

Fig-1 Cube Compression Test

Fig. 2 concentrically welded steel tubes

Fig. 3 Experimental Setup

The experimental work carried out is divided into the following parts:

1. Preliminary tests on materials used
2. Test on fresh concrete
3. Casting and curing
4. Compression tests

2.MIX DESIGN FOR M30 GRADE CONCRETE

Grade Designation = M30

Type of Cement = PPC

Maximum size of aggregate = 12 mm

Minimum cement content = 372 kg

W/C ratio = 0.45

Slump = 275 mm

Test data

- Specific gravity of cement = 3.15
- Specific gravity of coarse aggregate = 2.78
- Specific gravity of fine aggregate = 2.65

1. Calculation of target mean strength:

Target mean compressive strength fck = fck + 1.65 s = 30 + 1.65 x 5 = 38.25 N/mm2

Where fck = 30 N/mm2

s = standard deviation = 5 **(From Table 1, IS 10262:2009)**

2. Selection of Water-Cement Ratio

From Table 5 of IS 456, maximum water-cement ratio = 0.45

Based on experience, adopt water-cement ratio as 0.40. 0.40 < 0.45, hence O.K.

3. Calculation of water content:

From Table 2, of IS 456maximum water content for 12 mm aggregate = 203.6 litres (for 25 to 50 mm slump range) According to IS 10262:2009, water content is increased by 3% for every additional 25 mm slump,

Estimated water content for 275 mm slump = 203.6 + 27100 x 203.6 = 258.57 litres 20% decrease in water content due to use of super plasticizer

Hence, the arrived water content = 258.57 x 0.80 = 206.86 litres

4.Determination of cement content:

Water-cement ratio = 0.40

Cement content = 206.860.40 = 517.15 kg/m3

From Table 5 of IS 456, minimum cement content for M35 grade concrete with 12 mm size aggregate= 340 + 32 = 372 kg/m3 517.15 kg/m3 > 372 kg/m3, hence O.K.

5. Proportion of volume of coarse aggregate and fine aggregate

From Table 3 of IS 10262:2009, volume of coarse aggregate corresponding to 12 mm size aggregate and fine aggregate (Zone II) for water-cement ratio of 0.50 = 0.492

In the present case water-cement ratio is 0.40. Therefore volume of coarse aggregate is required to be increased to decrease the fine aggregate content. As the water-cement ratio is lower by 0.10. The proportion of volume of coarse aggregate is increased by 0.02 (at the rate of -/+ 0.01 for every ± 0.05 change in water-31 cement ratio).

Therefore corrected proportion of volume of coarse aggregate for the water-cement ratio of 0.40 = 0.512

Volume of coarse aggregate per unit Volume of Total aggregate = 0.512

Volume of fine aggregate per unit Volume of Total aggregate = 1 - 0.512 = 0.488

6. Mix Calculations

a) Volume of concrete = 1 m3
b) Volume of cement = Mass of cement Specific gravity of cement x 11000 = 517.153.15 x11000 = 0.164 m3
c) Volume of water = Mass of water Specific gravity of water x 11000 = 206.861 x11000 = 0.207 m3
d) Volume of super plasticizer (@ 600ml per 100 kg of cement) = 600100x11000 x 517.15 x11000 = 0.0031 m3
e) Volume of all in aggregate = [a – (b + c + d)] = [1 - (0.164 + 0.207 + 0.0031)] = 0.626 m3

7.Determination of cement content:

Water-cement ratio = 0.40

Cement content = 206.860.40 = 517.15 kg/m3

From Table 5 of IS 456, minimum cement content for M35 grade concrete with 12 mm size aggregate= 340 + 32 = 372 kg/m3 517.15 kg/m3 > 372 kg/m3, hence O.K.

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e) Volume of all in aggregate = [a – (b + c + d)] = [1 - (0.164 + 0.207 + 0.0031)] = 0.626 m3

APPENDIX - II

CALCULATIONS

1. TESTS ON CEMENT

a) FINENESS TEST
Fineness of the cement = Weight of sample retained on the sieve Total weight of the sample x 100 = 7100 x 100 = 7%

b) CONSISTENCY TEST
Consistency of the cement = Weight of water added Weight of cement x 100 = 145500 x 100 = 29%

c) SPECIFIC GRAVITY OF CEMENT
Specific gravity of cement = (W2− W1) [(W2− W1) − (W3− W4)] ×0.79 = (86.23−37.47) [(86.23−37.47) − (105.35−76.16)] ×0.79 = 3.15 34

2. TESTS ON FINE AGGREGATE

a) PARTICLE SIZE DISTRIBUTION
Coefficient of Uniformity Cu = D60D10 = 1.260.29 = 4.34
Coefficient of Curvature Cc = D302D60 × D10 = 0.5221.26 × 0.29 = 0.74

b) SPECIFIC GRAVITY OF FINE AGGREGATE
Specific gravity of fine aggregate = (W2− W1) (W2− W1) − (W3− W4) = (1.445−0.690) (1.445−0.690) − (2.035−1.565) = 2.65

1. TEST ON COARSE AGGREGATE

SPECIFIC GRAVITY OF COURSE AGGREGATE

Specific gravity of coarse aggregate = (W2− W1) (W2− W1) − (W3− W4)
= (1.455−0.690) (1.455−0.690) − (2.055−1.565) = 2.78 35

4. COMPRESSIVE STRENGTH OF CUBE
Compressive Strength of cube = Peak Load Cross−sectional area = 902 ×1000150 × 150 = 40.09 N/mm2

2. COMPRESSIVE STRENGTH OF COLUMN
Compressive Strength of column = Peak Load Cross−sectional area = 1370 ×1000π4 × (161.82− 892) = 93 N/mm
f) Mass of coarse aggregate = e x Volume of coarse aggregate x Specific
Gravity of coarse aggregate x 1000 = 0.626 x 0.512 x 2.78 x 1000 = 891.02 kg

Tubular COMPOSITE column	**Steel Design**
[As per BS EN 1994-1-1:2004}	
Type of Steel Used	Mild Steel-Hot rolled steel

Steel Modulus of Elasticity		Ea=		200000
Concrete Modulus of Elasticity		E_{cm}=		22360.68
Yield strength of steel		F_y=		250
Design Yield strength of steel		F_{yd}=		217.3913
Concrete comp Strength:		F_c=		20
Design value of Comp. strength	F_{cd}=	13.33333		
Length of member				L=
Thickness of Outer tube section		$T_{(outer)}$		3.2
Thickness of Outer tube section		$T_{(inner)}$		3
Outer Dia of outer tube section		$do_{(outer)}$		165
Inner dia of outer tube section		$do_{(inner)}$		161.8
Outer dia of inner tube section		$di_{(outer)}$		89
Inner dia of inner tube section	$di_{(inner)}$	86		
D/t =	51.5625			< 90*235/Fy = 84.6
(As per table 6.3)	Hence Compact Section			
Moment of Inertia				. do^4-di^4)/64)
Outer steel tube $Ia_{(outer)}$			3E+06	mm^4
Inner steel tube $Ia_{(inner)}$			4E+05	mm^4
M.O.I of the steel section = (Ia_{outer} + Ia_{inner})	3E+06	mm^4		
Area=		. do^2-di^2)/4)		
Area of outer tube section $As_{(outer)}$=			820.9	mm^2
Area of inner tube section $As_{(inner)}$=			412.1	mm^2
Area of the steel section A_a= (As_{outer} + As_{inner})	1233	mm^4		
Radius of gyration		r= (I/A)^0.5		
		R =		
M.O.I of the Concrete section = (I_C)	. $do_{(inner)}^4$-$di_{(outer)}^4$)/64)			
Concrete section size: Ac	. $do_{(inner)}^2$-$di_{(outer)}^2$)/4)			
	Ac =	14333mm2		
Support Condition		Pinned		
K=			1	
Column Effective Length, KL=			600	
Slenderness ratio =	KL/r			
	=		11.9	< 40

$N_{pl.Rd}$=	$A_{a*}F_{yd+}A_{c*}F_{cd}$	5E+05	
	$N_{pl,Rk}$ =	6E+05	
	N_{cr} =	$(\pi^2 * EI_{eff})/Kl^2$ =	
Effective Flexural Stiffness: Eleff =	$E_a * I_a + 0.6 * E_{cm} * I_c$	(As per (6.40 of EN 1994-1-1:2004) 1E+12	
	λ =	0.136	
Reduction factor,	χ =	$1/(\varphi+(\varphi^2+\lambda^2)^{\wedge 0.5}$	(As per (6.3.1.2 of EN 1993-1-1:2004)
	φ =	$0.5(1+\alpha(\lambda-0.2)+\lambda^2)$	0.50254281
	α =	0.21	
	χ =	0.977	
	Resistance of member for axial compression	$\chi * N_{pl.Rd}$ =	448754.9
	Design Normal force strength =	**448.8**	**kN**

4 CONCLUSION

The primary aim of this project is to determine the axial load capacity of the double skin steel tubes in –filled with self compacting steel fiber reinforced concrete. To that end, the project has been carried out and completed successfully. In order to understand the behavior of SFRCFT columns under pure compression, axial load tests were carried out and the following conclusions were drawn. The use of SCC reduced significantly the time of in – fill of the concrete between the steel tubes. There is a uniform increase in ultimate load with increase in percentage of steel fibers up to 1.5% in both the concrete cubes and the columns.However, the percentage increase in the compressive strengths of the columns with addition of steel fibers was not as high as that in the concrete cubes. Compared to all other columns, 1.5% SFRCFT columns exhibit significantly improved performance with large ductility and load carrying capacity . The column specimen having 1.5% steel fiber exhibits maximum strain. Hence there is a significant increase in the strength of double skin composite columns with the use of steel fiber reinforced concrete.

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