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Research Article
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Behaviour of Double Skinned Composite Columns with Concrete Filled Tubular Columns

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Abstract

This paper comprises of the experimental study of five (5) double skinned concrete filled steel tubular (DSCFT) columns of concentrically placed circular sections filled with self-compacting concrete (SCC). Tests on the specimens were made by applying axial loads. The main experimental parameter varied for columns were slenderness ratio. The test results of DSCFT columns are compared with another five (5) concrete filled tube (CFT) columns of same area of steel (Ast) and outer diameter as in DSCFT columns. Both filled with self-compacting concrete of grade M50. Testing of specimens investigates the behaviour on load deflection, confinement effect, and the strength of the columns. Various characteristics such as stiffness, ductility and failure mode are also discussed with the help of load deflection curves. The comparison with concrete filled tube (CFT) to the double skinned concrete filled tube (DSCFT) columns likely to be show that DSCFT columns are similar to CFT columns in performance and DSCFT shows better in cost concern than CFT. Theoretical analysis was also done and compared with the experimental results. Comparison of various codes like (EC4, LRFD, ACI) was also done. The results reveal that EC4 is better predictable than others).

An ANSYS modelling was also done for two specimens to calibrate the test results obtained from experiments. The results from the experimental study were compared with the ANSYS results. The result shows that there is little difference in deformations between the ANSYS and experimental results.

Keywords: Double skinned concrete filled steel tubular (DSCFT); Self-compacting concrete (SCC); Concrete filled tubes (CFT); Load deflection; Failure mode

Introduction

Hollow columns consisting of two concentric circular thin steel tubes with filler between them have been investigated for different applications. Figure 1 shows the cross section view of hollow steel column in-filled with concrete.

In composite construction, the concrete and steel are combined in such a fashion that the advantages of both the materials are utilized effectively in composite column. The lighter weight and higher strength of steel permit the use of smaller and lighter foundations. The subsequent concrete addition enables the building frame to easily limit the sway and lateral deflections. Hollow column has less self-weight and a high flexural stiffness and hence its usage in seismic zone proves promising. It reduces requirements on labour, construction time and formwork also maintains the construction quality. Self-compacting concrete (SCC) is an innovative concrete that does not require vibration for placing and compaction. It is able to flow under its own weight, completely filling formwork and achieving full compaction, even in the presence of congested reinforcement. The hardened concrete is dense, homogeneous and has the same engineering properties and durability as traditional vibrated concrete.

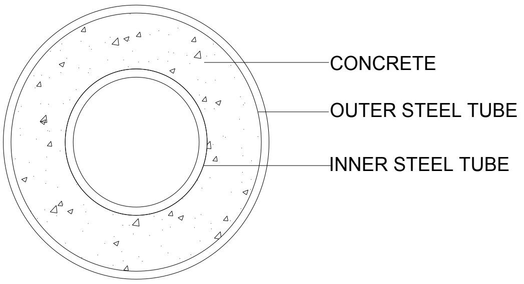

Figure 1: The cross section view of hollow steel Column in-filled with concrete.

Principle of concrete filled steel composite columns

Local buckling of the steel tube is delayed by in-filled concrete, steel confines the concrete, concrete in turn prevents the local buckling of hollow steel sections, both due to the restraining effect of the concrete and it also increases the strength and ductility of the section.

Progressive load resisting concept of concrete filled

Tubular columns: It is the opinion of the many researchers that at the initial stage, the applied load is resisted individually by the steel and concrete elements. That too, the steel sustains larger part of the loading, until yielding. At the early stages of increment of loads, the poison's ratio of concrete lies far below than that of the steel whereas, steel tube causes no confinement on the concrete. With the increase in the longitudinal strain beyond a particular stage, an increase in the poison's effect in the concrete attains, as a result of lateral expansion of the concrete. At this stage, the longitudinal and hoop stresses in the steel plate are becoming equal. Steel plate is bi-axially stressed and concrete being tri-axially stressed the expansion of the concrete takes place more than that of the steel. It is followed by the redistribution of load from concrete to outer steel mainly. At this stage, the steel shows hardening character.

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Research significance: This Experimental program on composite columns is focused on the structural behaviours of circular Column with different slenderness ratio and hollow section ratios in order to obtain, Ductility of the member, load carrying capacity and flexural stiffness.

Required fresh properties of SCC include adequate flow ability, good passing and filling abilities and segregation resistance, which are achieved by properly proportioning the constituent materials and related admixtures. But only limited literature is available to evaluate the hardened behaviour of SCC members.

Here an attempt has been made to evaluate the properties of DSCFT and CFT columns in-filled with SCC under compression. The results should be of interest to engineers considering the use of such columns in various structural applications.

Practical use of DSCFT requires knowledge of the basic compressive behaviours of the concrete as well as knowledge of the interrelationship between stress and strain. The research discussed herein focuses on determining these basic behaviour's and defining the interrelationships.

Literature Review

Zhi-Wu et al. conducted an Experimental behaviour of circular concrete-filled steel tube stub columns. This paper presented on experimental study on behaviour of circular in-filled steel tube (CFT) stub columns with self-compacted concrete (NC) concentrically loaded in compression to failure. Seventeen specimens were tested to investigate the effects of concrete strength and different loading conditions on ultimate capacity and load—deformation behaviour of columns. Specimens with entire section loaded experience a significant increase in ultimate capacity, but their residual after failure is almost constant. Euro code 4 provides a good prediction of the ultimate capacities of the stub columns with SCC and NC when entire section was loaded [1].

Han et al. conducted an Experimental behaviour of thin walled hollow structural steel (HSS) columns filled with self-consolidating concrete. This experimental study is an attempt to study the possibility of using thin walled hollow square section (HSS) columns filled with SCC. 38 HSS columns filled with SCC to investigate the influence of concrete compaction methods on the member capacities of the composite columns are reported. The main parameters varied are column section type (circular and square), tube diameter-thickness ratio from 33-67, load eccentricity ratio from 0-0.3 mm. Comparisons are made with predicted column strength using existing codes. It was found that the features of the specimens with SCC compacted without any vibrators and compactors with hand were very similar [2].

Kuranos et al. conducted an experimental and theoretical program to evaluate the Behaviour of Hollow concrete Effect of stirrups on behaviour of Normal and High Strength Concrete Columns**.** Differences and similarities in behaviour of solid concrete and hollow composite members with different number of concrete core layers are discussed in this paper. Experimental investigations show that behaviour of hollow CFST elements is more complicated than that of solid ones because of its complex stress states. Multilayered elements had greater load bearing capacities with respect to single layered hollow CFST elements [3].

Experimental Program

General

For this experimental investigation a self-compacting concrete mix grade of M50 was designed. In order to study the structural behaviour of composite columns, 5 numbers of circular hollow double skinned columns (DSCFT) of different slenderness ratio and hollow section ratios and another 5 numbers of concrete filled tubes (CFT) of same area of steel (Ast) and same outer diameter compared with DSCFT columns, were casted and in-filled with SCC. The summary of the composite column details is given in Table 1. The fresh concrete was tested for satisfying the basic requirements of SCC by using slump flow test, U-box, V funnel test and L box test. The tests mix design ratio - 1:1.52:1.71 water cement ratio - 0.45. Super plasticizer (conplast - 430) added-0.75% of cement by weight.

V – Funnel test for filling ability, Result - in 9 sec. V – Funnel test at T5 minutes for segregation resistance, Result - in 11 sec. L – Box test for passing ability, Result – H2/H1=0.88. For 25% of silica fume – average cube strength attained at 28 days=29 N/mm^2. For 20% of silica fume – average cube strength attained at 28 days=42 N/mm^2. For 15% of silica fume – average cube strength attained at 28 days=55 N/mm^2. Therefore 15% of silica fume replacement shall be adopted. The stress-strain values and load displacement curve is to be plotted, through which the load carrying capacity, ductility and stiffness of the member is to be studied [4].

Materials used

Cement: Ordinary Portland cement of (43 grade cement) confirming to IS: 8112-1989 is used. The properties of cement are given in Table 2.

Fine aggregate: Natural River Sand of size below 4.75 mm confirming to zone II of IS 383-1970 is used as fine aggregate. Laboratory tests were conducted for fine aggregate to determine its physical properties as per IS: 2386 (Part III). The test results are shown in Table 3 [5].

Identity	Outer identity tube dia (mm)	Inner tube dia (mm)	Outer tube thickness (mm)	Inner tube thickness (mm)	Length (mm)	Slenderness^ (ratio)
DSC1	139	75	2	3	117	3
DSC2	139	75	2	3	234	6
DSC3	139	75	2	3	351	9
DSC4	139	75	2	3	468	12
DSC5	139	75	2	3	585	15
CFT1	139	-	3.5	-	105	3
CFT2	139	-	3.5	-	210	6
CFT3	139	-	3.5	-	310	9
CFT4	139	-	3.5	-	420	12
CFT5	139	-	3.5	-	525	15

DSC: Double Skinned Columns, CFT: Concrete Filled Tubes, ^: Slenderness Ratio.

Table 1: Geometrical properties of the specimens.

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S. No	Tests	Results
1	Specific gravity	3.15
2	Initial setting time	80 min
3	Final setting time	453 min
4	28 day compressive strength	45.33 N/mm^2

Table 2: Properties of Cement.

Sl. No	Tests	Results
1	Specific gravity	2.72
2	Fineness modulus	2.67
3	Bulk Density	1806 kg/m^3
4	Water absorption	1.10%

Table 3: Properties of Fine Aggregate.

MATERIALS	UNITS	M50
Cement (kg)	kg/m^3	460
Silica Fume	kg/m^3	70
River Sand	kg/m^3	702
Gravel 12mm	kg/m^3	821
Water	L/m^3	228
Superplasticizer	L/m^3	3.45
W/C	-	0.40
Unit Weight	kg/m^3	2336

Table 4: Mix proportions of self-compacting concrete.

Coarse aggregate: Coarse aggregate used in this study consist of crushed stone of size 12 mm and below. Laboratory tests were conducted on coarse aggregate to determine the different physical properties as per IS: 383-1970.

Super plasticizer: Conplast SP 430 is based on Sulphonated Naphthalene Polymer and supplied as brown liquid instantly dispersible in water, having specific gravity of 1.220 to 1.225@ 30°C.

Silica fume: Silica Fume is a by-product of electric arc furnace used for the production of silicon metal or alloy, having specific gravity of 2.2 and bulk density of 720 kg/m^3.

Mix proportions

The mixtures were designed to achieve compressive strength of 50 Mpa. The mix designs were in accordance of ACI method and EFNARC guidelines. The details of mix proportions were given in Table 4.

Test programme

The cement, silica fume, fine aggregate was mixed dry until the mix was thoroughly blended. The coarse aggregate was then added and mixed to distribute uniformly. Initially 70% of water is added to the dry mixture to attain the homogeneity and then remaining 30% of water is used to prepare suspension of Super plasticizer and the mixing was continued to obtain the homogenous mix. The SCC mix was determined by conducting different test like slump flow, V-Funnel, L-Box, U-Box. The results obtained for fresh properties are shown in Table 5 [6].

Structural steel

The experimental programme included the casting and testing of steel sections of different sizes given in Table 1. Base plate is welded and Self compacting concrete (SCC) are in-filled between the steel sections and after curing the top plate has to be welded and painted for testing under axial load.

Along with specimen, three cubes of size 150 × 150 × 150 were cast for same grade of concrete. The compressive strength results of M50 grade of concrete are shown in Table 6.

All Specimens has to be tested under axial compression having load capacity of 1000 kN testing machine. From the stress-strain curves and load deflection curves the load carrying capacity, ductility and stiffness of the member is to be studied. The load set up is shown in Figure 2 [7].

From the cube strength result, 15% of silica fume replacement shall be adopted to get M50 grade of concrete.

Theoretical Calculation

Details of the section

Diameter of inner tube=75 mm,

Thickness of the inner pipe=3 mm

Diameter of outer tube=139 mm,

Thickness of the outer pipe=2 mm

Height of column=468 mm,

Concrete grade=M50

S. no	Tests	Fresh properties SCC	Typical range of values	
			Minimum	Maximum
1	Slump (mm)	667	650	800
2	V-Funnel (sec)	9	6	12
3	V-Funnel test at T5-min in(sec)	11	9	15
4	L-Box (mm)	0.88	0.8	1

Table 5: Fresh Properties for SCC Mix.

TRAILS	Average compressive cube strength of concrete (N/mm^2)
TRAIL 1	29
TRAIL 2	42
TRAIL 3	55

Percentage% of silica fume by weight of cement (replacing the amount in coarse aggregate)

Trail 1 - 25%

Trail 2 - 20%

Trail 3 - 30%

Table 6: 28-Day compressive strength.

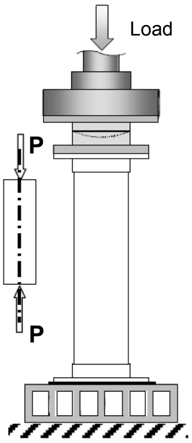

Figure 2: Load setup.

Material Properties

Structural steel

F_Y=250 N/mm^2

Ea=200000 N/mm^2

Concrete

Concrete grade=M50

E_{cm}=5000 × (50)$^{0.5=}$27386.13 N/mm^2

Partial safety factors

ϑ_P=1.15

ϑ_C=1.50

Section Properties

Steel section

Aai=π/4 (75^2 – 69^2)=678.584 mm^2

Aao=π/4 (139^2 – 135^2)=860.79 mm^2

Aa=1539.38 mm^2

Iai=π/64 (754 – 694)=440.485 × 103 mm^4

Iao=π/64 (1394 – 1354)=2019966 mm^4

Ia=Iai+Iao=2460451.322 mm^4

Concrete

Ac=π/4 (135^2 - 75^2)=9896.01 mm^2

Ic=π/64 (135^4 – 75^4)=1.4751 × 10^7 mm^4

Design checks

Plastic resistance of the section

=(1539.38 * 250)/1.15+(1*9896.01*50)/1.5

$P_{P=}(A_P f_{y/}\vartheta_P)+\alpha_c\,(A_C\,(f_{ck/})_{cy}/\vartheta_C)+(A_s f_{st}/\vartheta_s)$=702.034 kN

Calculation of effective flexural stiffness of the section

$(EI)_{e=}E_\alpha I_{\alpha+}0.8\,E_{cd}I_c+E_sI_s$ (EC-4 Cl.6.4)

$I_{\alpha=}$2460451.322 mm^4

$I_{c=}$1.475 × 10^7 mm^4

$I_{s=}$0

$E_{\alpha=}$2 x10^5 N/mm^2=0

$E_{s=}$0

$E_{cd=}E_{cm/}\vartheta_{*C=}$35355.339/1.35=26189.14 N/mm^2

$(EI)_{e=}$2 x10^5 × 2.46 × 10^6+0.8 × 26189.14 × 1.47 × 10^7

=4.92 × 10 ^{11} mm^2

Non-dimensional slenderness

$$\lambda = \sqrt{\frac{P_{pu}}{P_{cr}}}$$

(Cl.6.39)

P_{Pu}=1539 × 250+1 × 9896.01 × 50=879 KN

= π^2 x145026.731 x10 ^{11}/468 ^{2}

$P_{cr=}\pi^2\,(EI)_{e/}l^2$=36256.668 KN

$$\lambda = \sqrt{\frac{P_{pu}}{P_{cr}}} = 0.1557.$$

Resistance of the composite column under axial compression

Buckling resistance of the section should satisfy the following condition.

P_b or $\chi\,P_p$

Reduction factor

$$\chi = \frac{1}{(\phi + \sqrt{\phi^2 + \lambda^2})}$$

Φ=0.5[1+α(λ-0.2)+λ^2]

=0.5 [1+0.21 (0.155 – 0.2)+0.155^2]

=0.507

χ=1/[0.507+{0.507 ^{2} – 0.155^2} ^{½}=1.009

Hence the lower value of plastic resistance against buckling,

$P_{b=}$1.009 × 702.034=709 KN.

The above design is based on Euro code 4: Design of composite steel and concrete structures and IS 11384-1985: Code of practise for composite construction in structural steel and concrete [8-11].

Results and Discussion

Theoretical analysis was also done and compared with the experimental results. The ultimate yield strength value was found both experimentally and theoretically. The experimental values and theoretical are shown in Tables 7 and 8. For the length of 525 mm

Identity	Grade	X	λ	Nue
DSCFT 1	M50	0.55	3	879
DSCFT 2	M50	0.55	6	930
DSCFT 3	M50	0.55	9	807
DSCFT 4	M50	0.55	12	810
DSCFT 5	M50	0.55	15	877
CFT 1	M50	0	3	875
CFT 2	M50	0	6	810
CFT 3	M50	0	9	939
CFT 4	M50	0	12	811
CFT 5	M50	0	15	920

Table 7: Results for Experimental Analysis.

Identity	Grade	X	λ	Nut	DI
DSCFT 1	M50	0.55	3	910	0.4
DSCFT 2	M50	0.55	6	860	0.46
DSCFT 3	M50	0.55	9	836	0.59
DSCFT 4	M50	0.55	12	709	0.66
DSCFT 5	M50	0.55	15	780	0.68
CFT 1	M50	0	3	930	0.38
CFT 2	M50	0	6	878	0.41
CFT 3	M50	0	9	851	0.51
CFT 4	M50	0	12	829	0.55
CFT 5	M50	0	15	960	0.57

Table 8: Results for Theoretical Analysis.

specimen the compressive strength is 59.779 N/mm^2. For the length of 310 mm specimen the compressive strength is 60.981 N/mm^2. For the length of 234 mm specimen the compressive strength is 86.459 N/mm^2. So with the decrease in length the compressive strength increases.

Variation of Load with deflection: Deflections of the specimens at the centre are shown with the applied load P. The Load versus corresponding axial deformation curves were drawn for M50 grade concrete columns are shown in Figures 3-7. These diagrams give a better picture of the behaviour of columns. The deflection of all the composite columns increased linearly with the applied load P up to the yield point. Beyond that for a very small increment of load, the beam showed large deformation. The Load deflection response curves show that a fairly ductile response in DSCFT than in CFT columns, with large deflections being achieved in the in elastic region.

Variation of stress vs. strain: Figures 8-13 shows stress vs. strain for M50 grade of concrete. The strains linearly increased until the steel yielded. After the yield, the strains of the steel became plastic. The steel strains extend far beyond yield of the steel (Figure 8-16).

Variation of stress vs. displacement: Figure 14-16 shows stress vs. displacement for M50 grade of concrete.

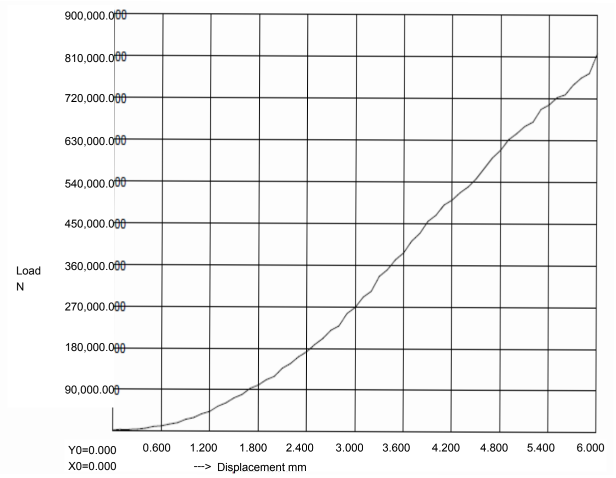

Figure 3: Load vs. Displacement-CFT 2.

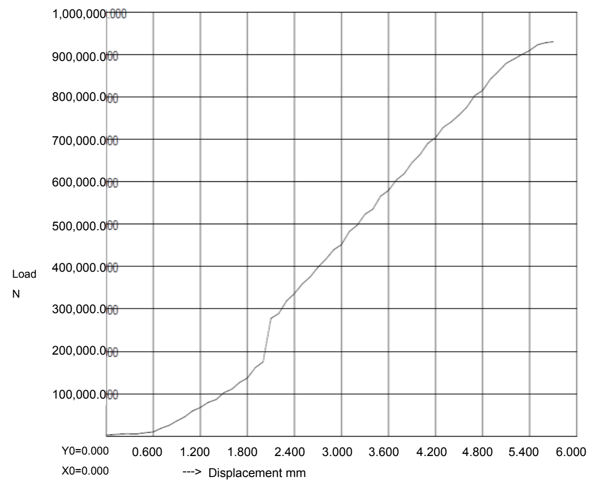

Figure 4: Load vs. Displacement-DSC 2.

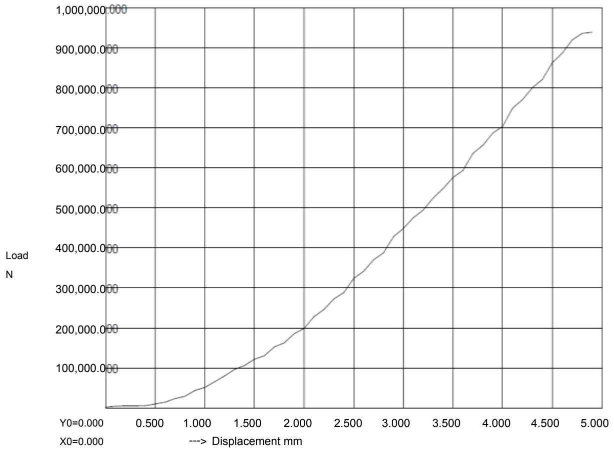

Figure 5: Load vs. Displacement-CFT 5.

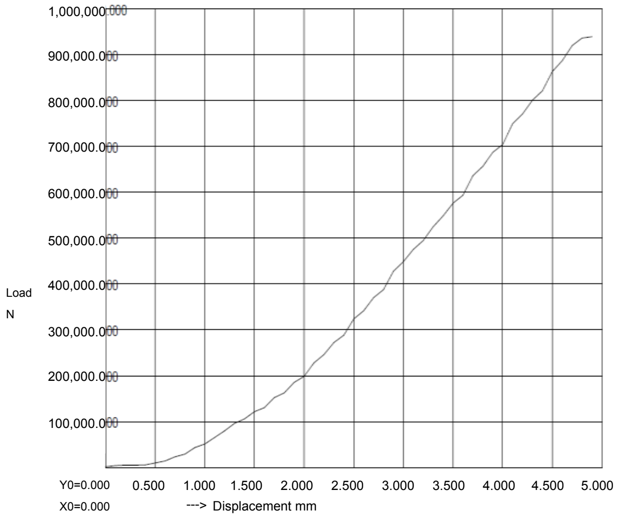

Figure 6: Load vs. Displacement-CFT 3.

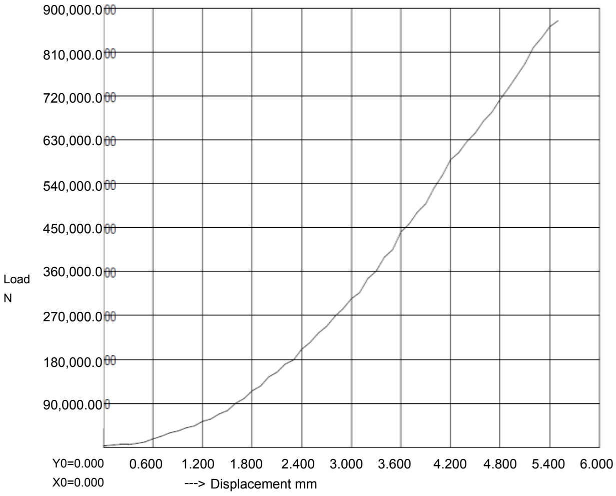

Figure 7: Load vs. Displacement-CFT 1.

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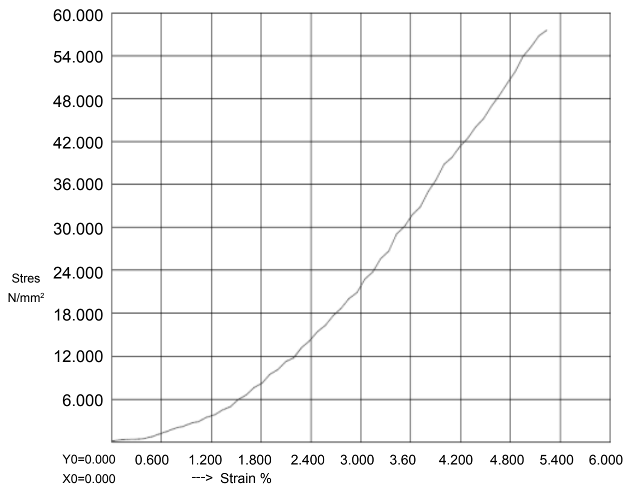

Figure 8: Stress vs. Strain-CFT 1.

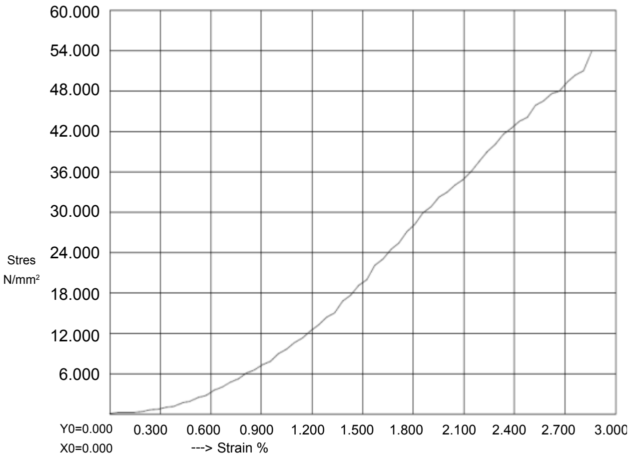

Figure 9: Stress vs. Strain-CFT 2.

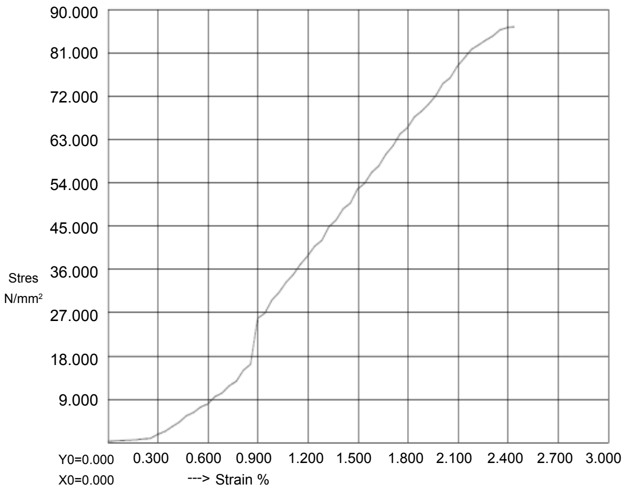

Figure 10: Stress vs. Strain-DSC 2.

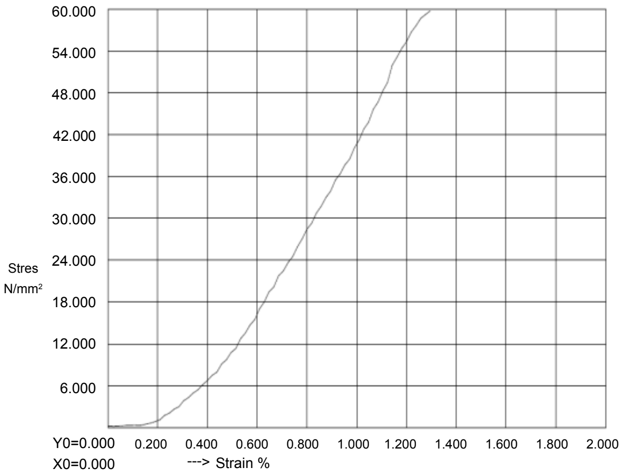

Figure 11: Stress vs. Strain-CFT 5.

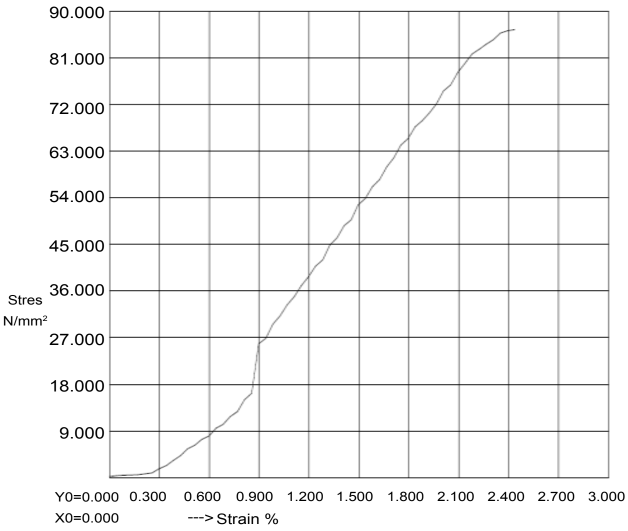

Figure 12: Stress vs. Strain-DSC 2.

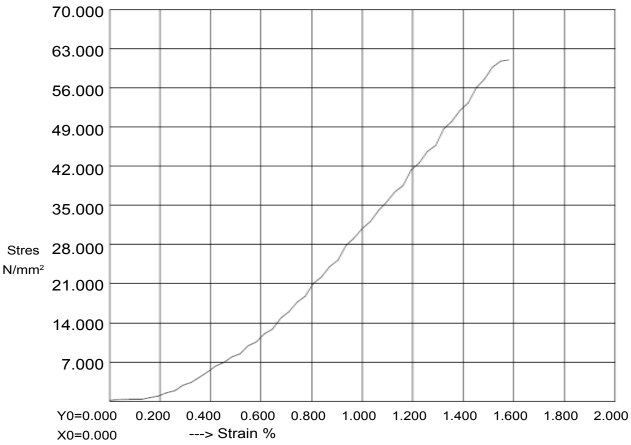

Figure 13: Stress vs. Strain-CFT 3.

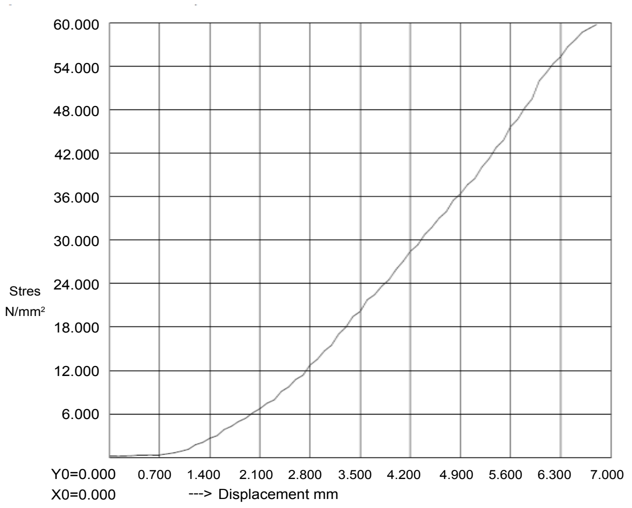

Figure 14: Stress vs. Displacement-CFT 5.

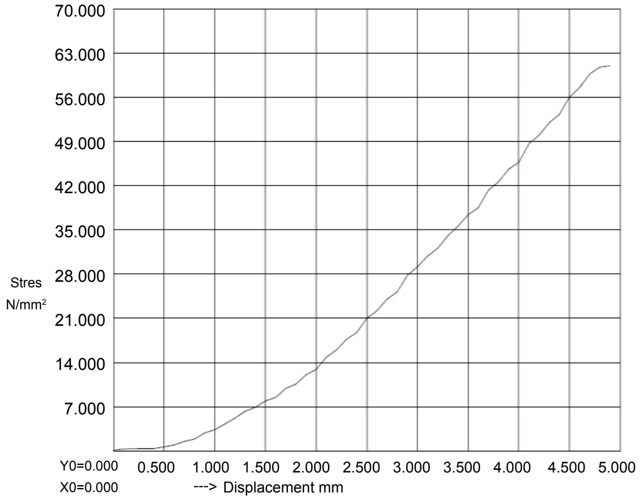

Figure 15: Stress vs. Displacement-CFT 3.

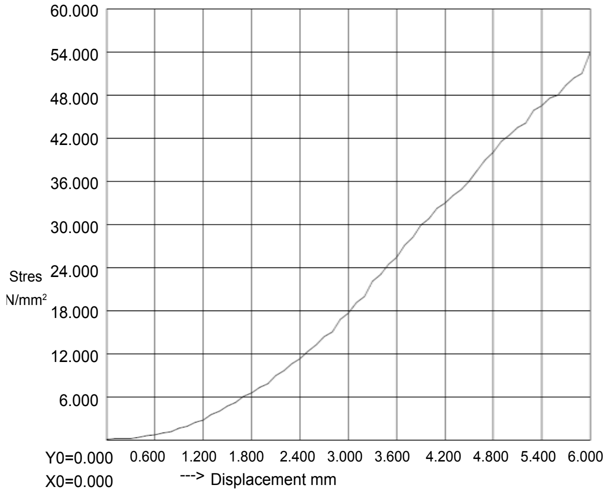

Figure 16: Stress vs. Displacement-CFT 2.

Double skinned columns fail in the same pattern of overall buckling and local buckling of outer steel plate in compression flange in the vicinity of mid height leads the failure. It was found that because of the infill of concrete, the tested beam-columns behaved in a relatively ductile manner and testing proceeded in a smooth and controlled way. The enhanced structural behaviour of the composite specimens can be explained in terms of 'composite action' between the steel tubes and the filled SCC concrete. CFT columns carry almost similar load but the failure is sharp and brittle as in a RCC column. The ductility and strength index shows DSCFT are much better in ductility behaviour and Stress carrying capacity. Figures 17 and 18 show the variations in ductility and strength index respectively for different specimens of CFT and DSCFT.

The above Figure 19 shows the comparison of theoretical and experimental results of DSCFT and CFT. Figure 20 shows only the experimental ultimate load of DSCFT and CFT.

Analytical work has been carried out to compare the results with experimental results and theoretical calculations, thus showing a good result in DSCFT. it is seen that the experimental values are about 16% more than the analytical values for the DSCFT columns and about 19% for CFT columns.

Loading and Boundary Conditions

The finite element models were loaded at top. Point loads are applied at the top. A one-inch thick steel plate, modelled using Solid 45 elements was added at support and load locations (at top and bottom)

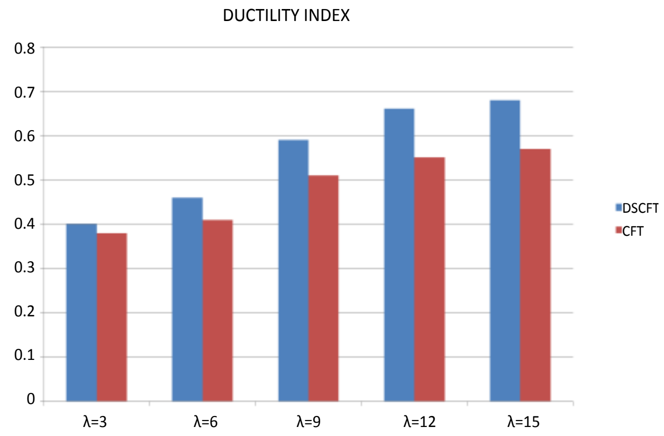

Figure 17: Variations in Ductility Index.

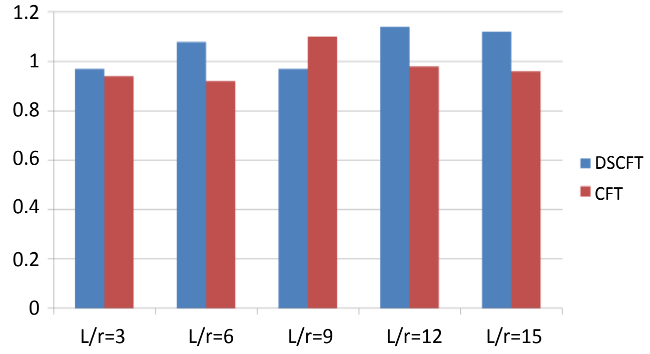

Figure 18: Variation in strength index.

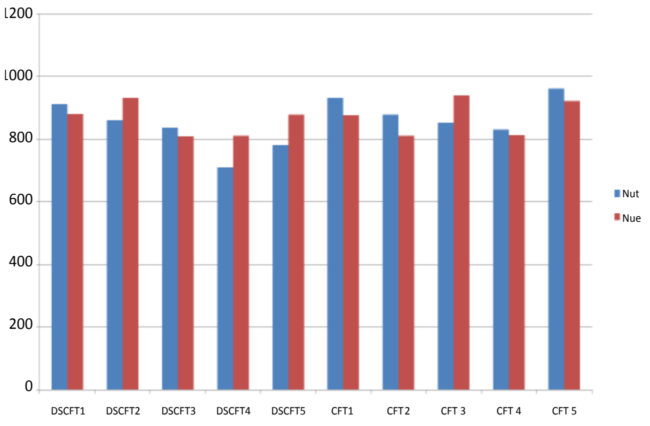

Figure 19: Comparison between DSCFT and CFT.

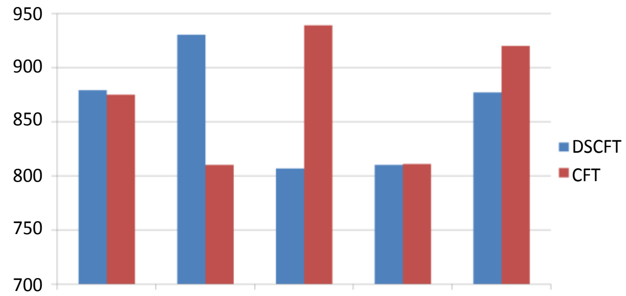

Figure 20: Experimental results of DSCFT and CFT.

of the model in order to avoid stress concentration problems. This provided a more even stress distribution.

The model of the hollow column is shown in Figures 21 and 22. The meshed column is shown in Figures 23 and 24. The column after applying load and boundary conditions are shown in Figure 25. The deformation of meshes of hollow column is shown in Figure 26 the deformation of contours of hollow column is shown in Figures 27 and 28. The maximum displacements compared with analytical results are shown in Figure 29.

The Mode of Failure of DSCFT is by folding of plates in the middle part of the total height of the column and by elephant foot failures at the bottom of the specimen. Figures 30 and 31 shows the failure pattern of the Double skinned composite columns, these shows that it is very ductile in nature.

Conclusions

1. The use of SCC reduced significantly the time of in-fill of the concrete between the steel tubes.
2. The cubes were attained strength by replacing 15% of coarse aggregate weight with silica fume. The strength is also excepting in column.
3. Since the Double Skinned section (DSCFT) columns are hollow in the core part, it significantly reduces the self-weight of the member and also better in performance and Cost Efficiency than concrete filled tube CFT) columns.

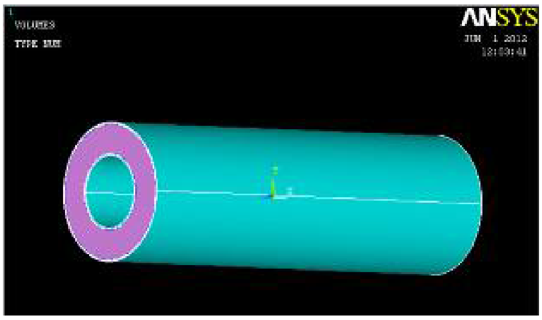

Figure 21: Model of hollow column.

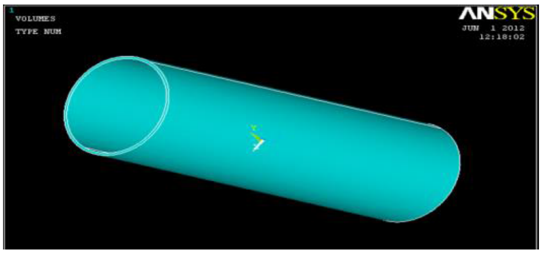

Figure 22: Model of CFT columns.

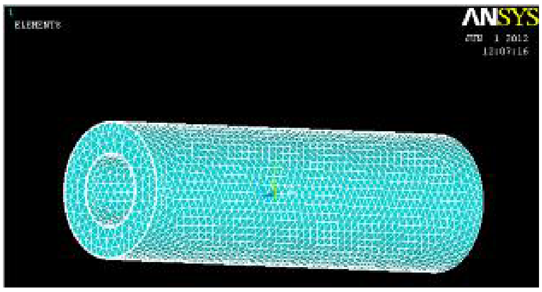

Figure 23: Meshing of hollow column.

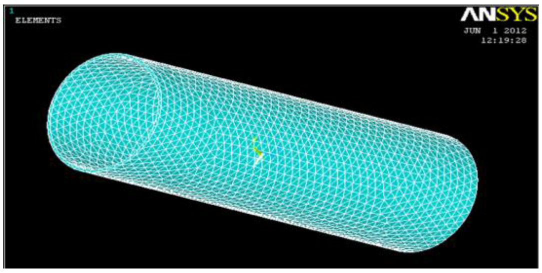

Figure 24: Meshing of CFT columns.

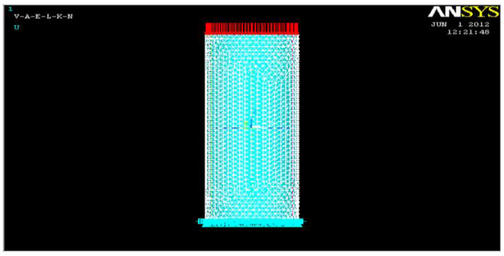

Figure 25: Loads and Constraints.

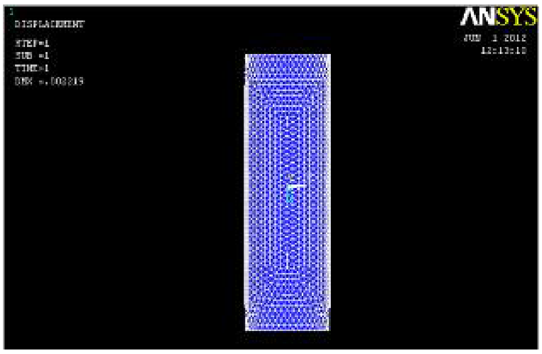

Figure 26: Deformation of meshes.

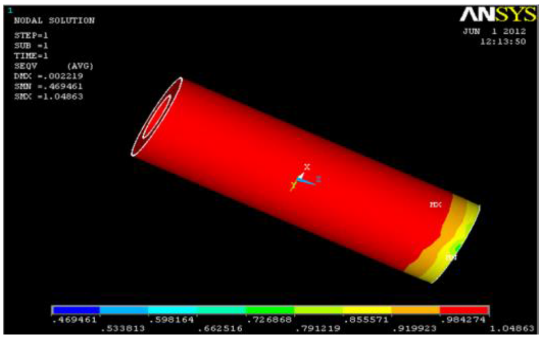

Figure 27: Deformation contours for CFT.

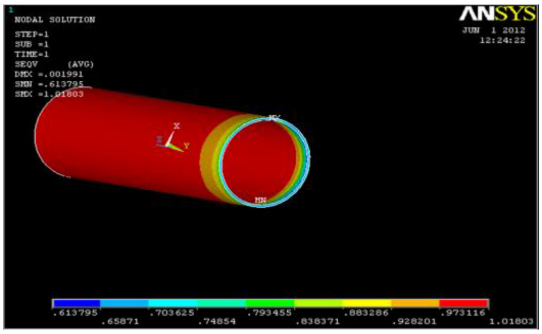

Figure 28: Deformation contours for DSCFT.

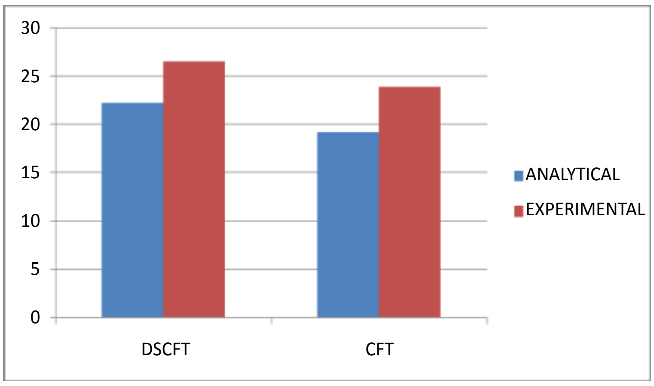

Figure 29: The maximum displacements compared.

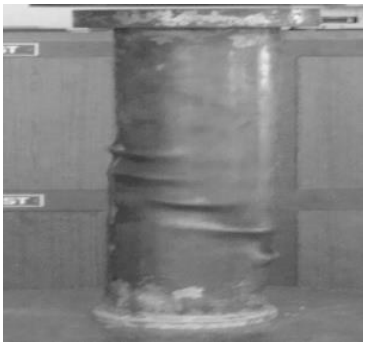

Figure 30: Failure pattern of DSCFT – Folding of Plates with analytical results (ANSYS).

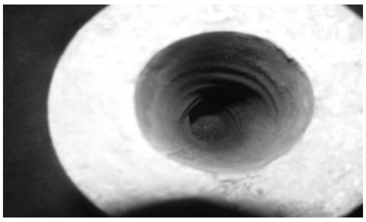

Figure 31: Failure pattern of inner tube – Top view of DSCFT specimen.

4. Because of the in-fill of concrete and a hollow core a relatively ductile behaviour of the Columns are observed.

5. The load carrying capacity of the DSCFT is almost similar to the CFT columns but the overall weight of DSCFT is reduced when compared with the CFT columns.

6. It was observed from the tests, that the failure modes of the hollow composite columns depend on slenderness ratio. When the slenderness ratio is very less, the column fails due to yielding of steel and crushing of concrete under direct compression. When slenderness ratio is more, the column fails by elastic buckling.

7. For the increase of slenderness ratio by 3 the ultimate load decreases by 4%.

References

1. Yu ZW, Ding F, Cai (2007) Experimental behaviour of circular concrete-filled steel tube stub columns. Journal of constructional steel research 63: 165-174.
2. Han LH, Yao GH (2004) Experimental behavior of thin walled hollow structural steel (HSS) columns filled with self-consolidating concrete (SCC).
3. Kuranos A, Kvedaras AK (2007) Behaviour of Hollow concrete – filled steel tubeular composite elements. Journal of civil engineering and management 13: 131-141.
4. Mohanraj EK, Kandasamy S (2008) Experimental behavior of axially loaded hollow steel columns in filled with concrete. Journal-CV p: 88.
5. Tao Z, Han LH, Zhao XL (2004) Behavior of concrete-filled double skinned CHSinner and CHS outer steel tubular columns. Journal of construction steel research 60: 1129-1158.
6. Giakoumelis G, Lam D (2004) Axial capacity of circular concrete-filled tube columns. Journal of Constructional Steel Research.
7. Han H (2002) Tests on stub columns of concrete-filled RHS sections. Journal of Constructional Steel Research.
8. Elchalakani M, Zhao XL, Grzebieta R (2002) Tests on concrete filled double

skinned CHS outer and SHS inner composite short columns under axial compression. Thin walled structures 40: 415-441.

9. EFNARC – specification and guidelines for self-compacting concrete.
10. Su N, Hsu KC, Chai HW (2001) A simple mix design method for self-compacting concrete. Cement and concrete research pp: 799-807.
11. Subramanian S, Chattopadyaya D (2002) Experiments for mix proportioning of Self Compacting Concrete. Indian Concrete Journal 76: 13-20.

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