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Strength and Deflection of Axially Loaded DSHCFT ColumnsHaving PVC Inner - Steel Outer Pipes Annuarly In-filled with SCC M35

N. Balasubramani[1]* and R. Thenmozhi[2]

[1]Department of Civil Engineering, Sri Ramakrishna Mission Vidyalaya Polytechnic College, Coimbatore 641 020, Tamilnadu, India; nbscivil@gmail.com
[2]Department of Civil Engineering, Government College of Technology, Coimbatore, 641 013, Tamilnadu, India

Abstract

This paper presents the experimental study of six Double Skinned Hollow Concrete Filled steel Tubular (DSHCFT) columns consisting of PVC inner and mild Steel outer pipes in-filled with Self Compacting Concrete (SCC). The grade of SCC and the yield strength of steel used were M35 and 250 MPa respectively. The Columns were tested for axial load and Load-deflection, Ultimate compressive strength were studied and reported. The experimental results are verified with European Code (EC4) and found as conservative. The PVC tube is found as a reasonably suitable alternate material for moderately loaded DSHCFT columns.

Keywords: DSHCFT, Ductility, Load – Deflection, PVC Inner-Steel Outer, SCC, Ultimate Load

1. Introduction

The construction of structural members using Concrete and Steel combined as composite material is quite familiar over the decades. The steel concrete composite columns are adopted in various cross sectional forms. Initially concrete filled tubes of square, circular and rectangular steel tubes known as CFT columns were used. Then, two tubes of same or different cross sectional shapes were concentrically placed and their annular space is in-filled with concrete. Such types of sections are called Double Skinned Hollow Concrete Filled steel Tubular (DSHCFT) columns. The main principle underlying in these composite columns that steel tubes act as form work as well as the main and lateral reinforcement. The section when loaded partially or fully, the filled concrete prevents local buckling of the tubes and in turn the tubes confines the concrete, resulting in an increased load resistance of concrete. The important advantages of steel-concrete composite columns are; speed of construction, eliminating form work, light in weight, higher stiffness and load capacity and ductility etc., The composite columns are generally adopted in high rise structures and heavy loaded bridge piers.

2. Literature

Kalil[1] studied Potentials of practical application of Composite double skinned sheets with respect to BS 5400. Elchalakani et al[2] reported that at ultimate stage, there were no strain gauge measurements of steel and concrete, it is possible that cracking of concrete allowed further buckling and at the end of elastic stage, the bond loss between steel and concrete is expected. Tao[3] reported that D/t ratio is indirectly proportional to the ductility and confinement is proportional to the ductility. According to Kim et al[4], contribution of inner tube to the Ultimate compression is negligible. Mohanraj and Kandasamy[5] studied the effect of various infill materials in CFT

**Author for correspondence*

columns. From the reference of literature, DSHCFT columns made of PVC inner and steel outer pipes in-filled with Self Compacting Concrete (SCC) of grade M35, and steel yield strength 250 MPa is not evidenced. Codal guidelines for composite column are yet to be released in India. Hence, this paper presents experimental findings of axial load test made on the DSHCFT columns with PVC-inner and Steel outer pipe in-filled with SCC of grade M35.

List of Notations

A_a, A_c, A_p: Area of -outer steel tube, in-filled concrete and plastic tube respectively

d: diameter of the circular column (here, =Dso)

DSHCFT: Double Skinned Hollow Concrete Filled steel Tube Columns

D_{so}, D_{pi}: Diameter of outer and inner tube of outer steel tube

f_{ck}: Characteristics cube compressive strength of concrete

f_c: Cylinder compressive strength of concrete (0.8fcc)

f_y : Yield strength of steel; n1,n2: Confinement coefficients.

N_{EC4} :Ultimate strength of the DSHCFT column as per EC4

N_{ue} : Experimental Ultimate strength

t: Thickness of steel tube; tc=Thickness of sandwiched concrete.

t_{sc} : Thickness of composite column (=Dso+tc)

L : Effective length of a column

λ:Relative slenderness as per EC4

3. Specimen Fabrication

3.1 Steel Tubes

For outer skin, steel tubes available in the market Coimbatore, India satisfying thickness needed as per ACI 318-1995 code [6] to avoid undue local buckling, were cut to the required length. The PVC tube of suitable diameter and length were also cut and both the pipes were kept concentrically on a base plate, to fill concrete.

Specimen details: The thickness of inner PVC tube in SP-2 was 3mm and it was 2mm in all other specimens. The thickness of outer steel in SP-4 was 3.26mm (10 SWG) and in all other specimens it was kept as 2.03mm (14 SWG). Further details of the specimens are presented in Table 1

3.2 Casting

The following are the materials used as per Mix design (M35):

Cement	:612 kg
Flyash	:162kg
Sand	:676 kg
Coarse aggregate	:705kg
Viscosity Modifying Agent	:0.36%
Water retarding agent	:6.2%
Water	:314 kg
Water / (cement+Fine aggregate)	:0.41

Mechanically mixed SCC mix of measured quantity as per European Guidelines 2005 7 was then filled in the specimens. The samples were cured in controlled humid condition for 28 days. Small level reductions at ends of specimens due to shrinkage of concrete were found and finished a layer of plaster of paris, well in advance to the testing.

4. Sest Setup and Procedure

The entire tests were carried out using 3000kN compression testing machine at Sri Ramakrishna Mission Vidyalaya Polytechnic College Coimbatore, Tamilnadu, India. The test arrangement and instrumentation are shown in Figure 1. An initial load of 5 kN was applied to hold the specimen upright. Magnetic type dial gauges were used to measure the deflections at mid span and at end plates. Both the longitudinal and lateral deformations of the column specimens were measured. Axial compressive load was applied in an increment of one tenth of the predicted load capacity. For each load increment, the deformations were recorded. All specimens were subjected to load up to failure. Each specimen test consumed almost an hour.

5. Eurocode 4 (EC4) Guidelines

Eurocode 4 guides for the design of composite columns with concrete encased, partially encased steel sections and concrete in-filled tubular sections with and without reinforcement. In this code, long-term loading the effect is considered separately and the partial safety factors for load and materials are adopted to ensure serviceability and safety conditions. The ultimate axial compressive load is given by the code,

$$N_{EC4} = A_a n_2 f_y + A_c f_c \left[1 + n_1 (t/d)(f_y/f_c)\right] \quad (1)$$ Where and $n_1 = 4.9 - 18\bar{\lambda} + 17\bar{\lambda}^2$ and $n_2 = 0.25(3 + 2\bar{\lambda})$

The values of Ultimate compressive load calculated as per Eurocode4 code is shown in Table 1. In this investigation, the load resistance of the inner PVC tubes is neglected and the PVC tubes are taken as only a simple from work.

Figure 1. Test arrangement.

6. Result and Discussion

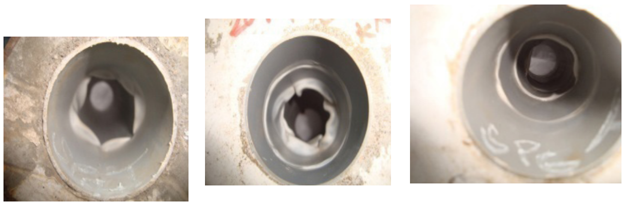
6.1 Failure Modes

First yield occurred around 65% to 75% of the ultimate load. The local buckling of outer tubes of all the specimens shown in Figure 2, which took place folding outward, either at middle of the span or at either end with a marginal distance equal to thickness of the composite column (tc).

(a)

SP-1 SP-2 SP-3

The inner plastic tube failures are shown in Figure 2b and found folded inward almost at the same section where external plate locally folded. A sort of torsional compression was prominently noticed in almost all columns. SP-1 shows spiral fracture lines. All other specimens except in



SP-4 SP-5 SP-6

(b)

Figure 2. (a). Specimens after testing. (b). Failures of inner PVC pipes.

SP-2, formed one or more inscribed polygonal folded r ibs of around 6 to 10mm width made of chord lines at the vicinity of failure zone.In case of SP-2, either owing to the lesser L/D or comparatively more thickness of inner PVC tube, the failure at far end as seen from top formed such a polygon with the folded ribs with lesser width of around 3 to 4mm. Further researches needed to confirm this.

6.2 Load Deflection Curve

The DSHCFT specimens of all the groups showed fair ductile behaviour. Figure 3a and 3b show Load Vs Midspan deflection plots. Generally, the initial shift from elastic to elasto-plastic region took place around 70% to 75% of ultimate load. The deflection plot in the post Ultimate load state, past a mild strain softening almost until 75% of ultimate load. However, it deformed almost 2 times beyond ultimate load point.

6.3 Load Vs Axial Deformation

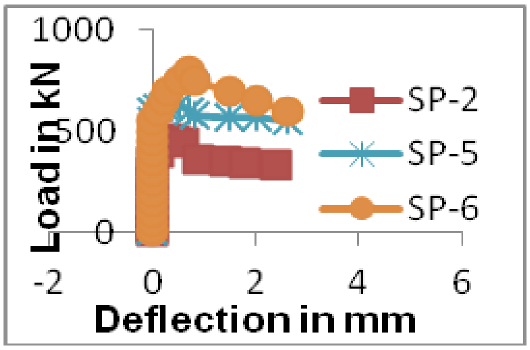
The Figure 4 shows Load vs Axial deformation Upto 60 to 65% of peak load, the initial stiffness was present. Upto peak load around, 35% of deformation took place. Then, slowly after reaching maximum load, the descending portion existed up to 75% of the ultimate load.

6.4 Ultimate Compressive Load

On analysis, 'SP-1 Vs SP3', and 'SP-5 Vs SP-6' lesser L / D leads to higher Ultimate load. SP-3 Vs SP-4, for the same L / D, increase in inner diameter, causing lesser area of concrete; but, outer plate thickness increases the ultimate load. In 'SP-2 Vs SP-5', even for the lesser L / D, the higher hollowness in the former specimen results with lesser area of concrete and hence lead to lesser Ultimate load. The experimental ultimate compressive loads of the DSHCFT specimens compared with EC4 predictions they are presented in Tabe 1.

7. Conclusion

Load deformation character is presented as a plot of Load Vs Midspan deflection. The experimentally observed values of axial ultimate compressive load of the DSHCFT PVC-Steel specimens, Eurocode 4 predicts with 20% conservation. In DSHCFT PVC-Steel Composite action of concrete and the outer steel, evidenced based on higher load resistance compared to the simple super-position strengths of steel and concrete without any reduction factor for their stresses. The potential utilisation of PVC inner pipe as an alternate for steel in DSHCFT column is thus verified and found feasible for moderate load conditions.



(b)

Figure 3. (a) Load vs deflection. (b) Load vs deflection.

8. Aknowledgement

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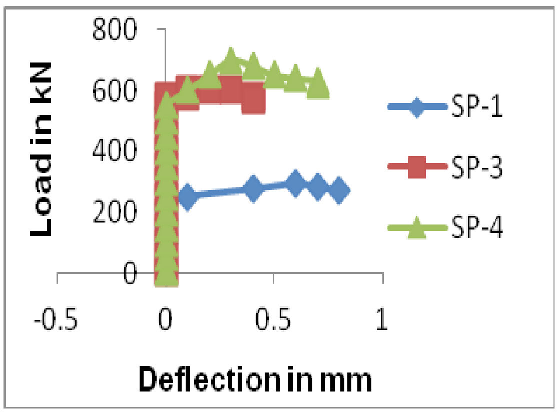
Table 1. Specimen geometry and ultimate loads

ID	D_{so} (mm)	D_{pi} (mm)	Length (mm)	N_{EC4} (kN)	N_{ue} (kN)	N_{EC4} / N_{ue}
SP1	90	50	385	277.03	291.6	0.95
SP2	114	75	210	368.21	460	0.80
SP3	114	50	385	449.54	600	0.75
SP4	114	60	385	534.40	700	0.76
SP5	114	50	270	465.28	635	0.73
SP6	135	50	300	636.62	800	0.80



(a)

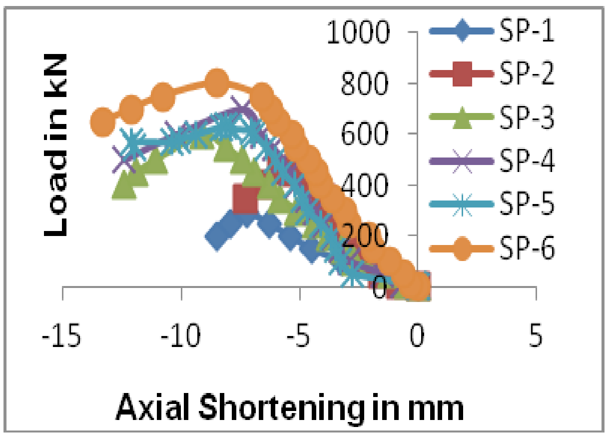


Figure 4. Load vs axial shortening.

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