A REVIEW ON CONCRETE FILLED DOUBLE SKIN STEEL TUBULAR COLUMNS

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Abstract – *Concrete-filled double-skin steel tubular (CFDST) Columns considered as a new type of Concrete Filled Steel Tubular (CFST) Columns. It consists of an inner and outer steel tube with the annulus between the skins filled with concrete. The concrete is properly compacted and filled in between the steel surfaces. CFDST are high performance composite columns that are increasingly being used in bridges and high-rise buildings as well as to reinforce CFST columns. CFDST has many advantages over CFST such as improved stability, section modulus, lighter weight and better damping characteristics. The inner tube increases their strength and ductility as compared to CFST. It is important to control the inner tube thickness to prevent the premature failure. The outer tube wall thickness increases the performance of the column therefore it reduces the susceptibility of the square tube to local buckling.*

The hollow steel tubes can be chosen with any type of cross section, commonly circular and square tubes are preferred. This paper investigates the characteristics of square Concrete-filled double-skin steel tubular (CFDST) columns with circular steel tubes in the interior. Non-linear FE analysis is performed in this paper on CFDST columns with SHS outer and CHS inner tubes under axial compression.

Key Words: **Concrete Filled Double Skin Tubes, CFDST Square Columns, Axial compression, Hollow Ratio.**

1. INTRODUCTION

The concept of CFDST has developed from the use of hollow steel tubes and they were firstly used in offshore and inland construction. Concrete- filled double- skin steel tubular column is a composite construction in which two hollow steel tubes are concentrically positioned and the annulus between each tube is filled with concrete. Due to the presence of inner steel tube, it increase strength-to-weight ratio, bending stiffness, ductility, and seismic performance of the column[1].The inner steel tubes eliminate the use of external formwork during the process of concreting. When it is compared to reinforced concrete and bare steel the strong mechanical characteristics of CFST reduces the cross sectional size of the column [2]. The choice of the cross section and geometry is depending upon the requirements such as the structural efficiency of the column, aesthetic criteria ,material availability, cost and method of construction . Commonly square and circular are preferred. Fig 1 shows different configuration of CFDST column.

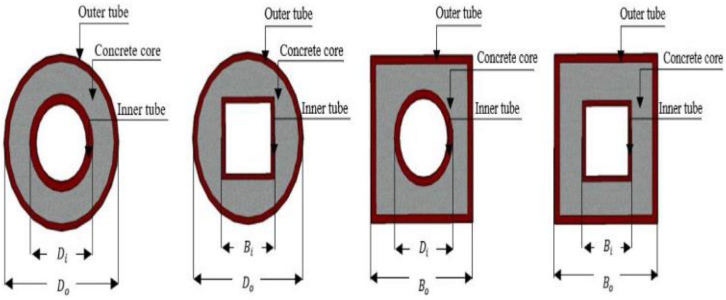
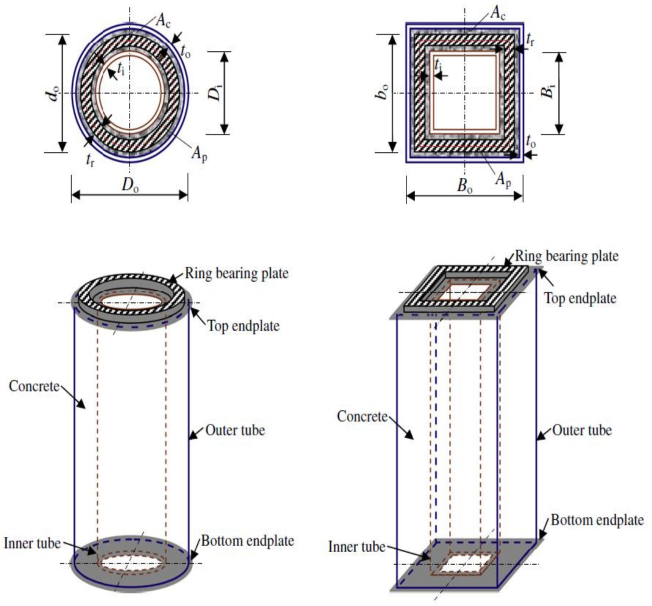


Fig-1: Different configuration of CFDST column

CFDST columns widely used in the construction of high-rise buildings, factories and bridges over past times. There have been several investigations are conducted on CFDST columns to understand the strength and behavior of CFDST columns. As a result of these studies found that double skin tubes have an improved ductility and strength due to the "composite action" between the steel tubes and sandwiched concrete.

2. STRENGTH OF CFDST COLUMN

A Series of test were conducted on concrete-filled double skin steel tubes (CFDST) columns under long-term sustained loads. The test was conducted by 2 stages , ie. Long-term service test and ultimate strength test. In the study there are six specimens such as two circular CFDST specimens, two square CFDST specimens and two reference conventional CFST specimens under concentrically long-term sustained loads. Also for comparing prepares ten CFDST and CFST reference specimens were tested. The test is conducted to measure the ultimate loads without long-term sustained loadings. It reduces the ultimate strength of the CFDST column and improves its deformation [3]. The structural characteristics of short CFDST columns under compression with circular inner and outer steel tubes with the use of finite element modeling. Due to the confinement provided by the steel tubes, circular concrete-filled double-skin tubular columns (CFDST) greatly increases the displacement ductility and peak strength of sandwiched concrete [4] . Tests was conducted on concrete filled double- skin steel tube (CFDST) under axially partial compression. Test were conducted on fourteen specimens with outer and inner steel tubes of circular hollow section (CHS) and fifteen specimens with outer and inner steel tubes of square hollow section (SHS).The study experimentally investigate the behaviour of partially loaded CFDST columns. Also the study compares CFDST and CFST columns under axially partial compression and study the bearing capacity of partially loaded CFDST sections. The test result shows that CFDST columns behaved in a ductile manner under partial compression. The below fig 2 shows the CFDST under axially partial compression [5].



(a)CHS outer and CHS inner

(b) SHS Outer and SHS inner

Fig-2: CFDST under axially partial compression

A circular concrete-filled double steel tubular column (CFDST) with a square hollow section (SHS) as an inner tube filled with concrete that are axially loaded and tests that were conducted on the CFDST column ie. Compression test. Test are carried out on eight CFDST stub columns. For comparative analysis with CFDST columns, two circular CFST columns and one double-skin concrete-filled steel tubular (DCFST) column are added. Circular CFDST columns with the inner SHS have increased strength and also increase the ductility when compared with the conventional CFST column and DCFST column [6]. The specimen consist of circular hollow section (CHS) outer and square hollow section (SHS) inner, with the space filled with concrete. And the inner tube of column is not filled with concrete. High nominal compressive strengths are in the parametric analysis, and steel tubes are cold-formed from various design yield strengths. Twenty columns were investigated and modelled in Abaqus to investigate the behavior of CFDST columns under axial compression [7].

3. MATERIAL PROPERTIES

Lately, stainless steel is more commonly used when compared to carbon steel due to its better corrosion, fire and impact resistance, and maintenances. Material properties of carbon and stainless steel given below in table 1 were obtained using tensile test [8].

Table-1: Material properties of carbon and stainless steel

	σ_y/MPa	σ_u/MPa	E_s/MPa	δ
Carbon steel(2.01mm)	275	351	$2.08x10^5$	0.22
Carbon steel(2.52mm)	276	384	$2.05x10^5$	0.25
Stainless steel(1.88mm)	322	703	$1.91x10^5$	0.46

To prepare the test specimen, the tensile coupons were cut from the steel tubes then tested according to the Chinese standard GB/T 228.1-2010. The tensile test coupons were shown below in fig 3 [6]. Cold-formed material was used for the manufacture of specimens [20] .

Fig-3: Tensile test strength

4. EFFECT OF HOLLOW RATIO

Hollow ratio (χ) is an important factor affecting the compressive behavior of CFDST. Investigated the Curves of average stress versus longitudinal strain, stress distributions of concrete and steel tubes and hollow ratio effect. The hollow ratios 0, 0.25, 0.5, 0.75 were defined. As hollow ratio χ increases, the location of maximum concrete stress moves from centre to the periphery of the cross-section. Commonly, hollow ratio on the concrete stresses with CHS outer is larger than SHS outer [9] . It is important to control the inner tube thickness to prevent premature failure. The performance of CFDST columns of the inner tube diameter were investigated by using hollow ratio (χ). The hollow ratios of 0.1, 0.2, 0.3, 0.5, 0.7 and 0.8 were defined by changing the inner tube diameter and other properties remained unchanged. The effect of hollow ration on the load axial-displacement curves were shown below in fig 4 [1]. It was shown that the ultimate axial strength of CFDST short columns improves with increasing the concrete compressive strength or with decreasing the hollow ratio [10] .

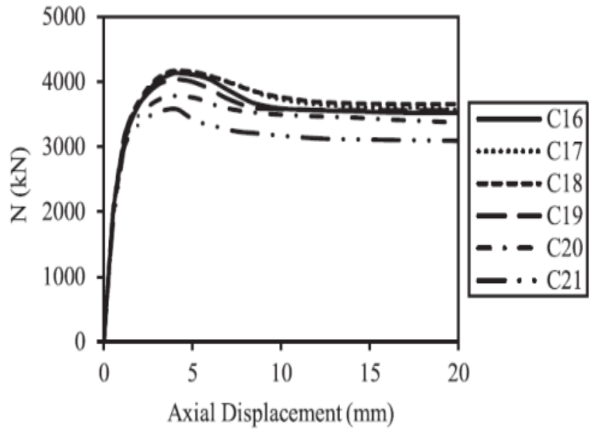


Fig-4: Axial force-displacement curve of CFDST columns

5. EFFECT OF STIFFENER

Investigates the behavior of stiffened CFDST members under axial compression and cyclic loading. In the tests all the specimens are behaved in a ductile manner. For stiffened CFDST, the outward buckling was found in the outer tube and the inward buckling was found in the inner tube [11] .

5.1 Effect of longitudinal stiffener

Due to the presence of stiffeners on the outer tube that reduces the local buckling. Additionally, the confinement on the concrete is improved as the stiffness of the outer tube was increased. In CFDST columns the stiffeners are used to increase the ductility and energy dissipation ability .The fig 5 shows the stiffened CFDST.[11].

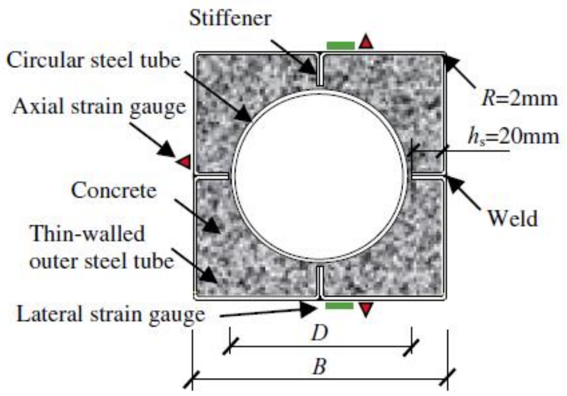


Fig-5 : Stiffened CFDST

CFDT columns generally used in high- rise buildings and the amount of steel used in CFDT column is high. To reduce the steel utilization, thin-walled steel tube with longitudinal stiffeners is maintained in the outer tube. According to the test results, the stiffened columns show high strength and good deformation capacity [12].

5.2 Behavioural Analysis

Behaviour of square CFDT columns with longitudinal stiffeners in detail analysed [11]. CFDT columns are allowing to local buckling when they have thin-walled outer tubes. When using thin-walled outer tubes that are not stiffened, local buckling might be a significant factor [13] .

6. PARAMETRIC STUDY

6.1 Effect of steel yield strength

When the yield stress of outer steel tube increases, then the ultimate load and ductility of CFDST column increases [14] . A fiber-based model was used to study the effect of yield stress of steel tube control the behavior of CFDST columns. When the steel yield stress increases then the ultimate strength of column improves ie. Increased by 4.7%, 7.5%, 13.4%, and 19.4%. And the yield stress is increased from 250MPa to 300MPa, 350MPa, 400MPa, and 450MPa. The Fig 6 shows the effect of steel yield strength on the axial load-strain curves of circular CFDST columns. [15].

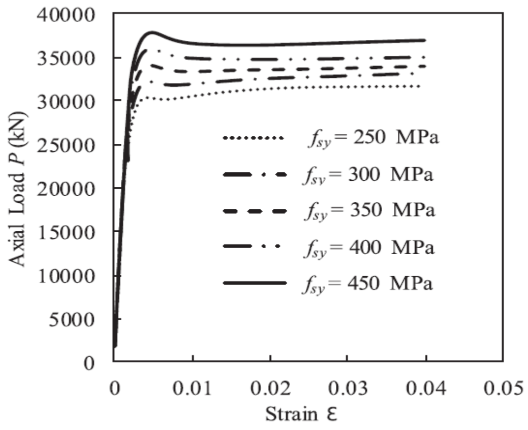


Fig-6 : Effects of steel yield strength on the axial load-strain curves of circular CFDST short columns.

6.2 Concrete compressive strength

In fibre analysis different compressive strength of concrete are used such as 55MPa, 75MPa, 95MPa, and 115MPa.Due to the use of higher strength of concrete then it improves the ultimate strength of CFDST columns. Similarly, due to the high strength of concrete used in CFDST columns are less ductile due to their stiffness [13] . Strength of concrete ranges from 40MPa to 100MPa. As the strength of concrete changes from 40MPa to 100MPa then the ultimate bending resistance raised by 102.3%. Due to the use of high strength concrete, then the curvature ductility decreases. The fig 7 shows the effect of concrete strength on the strength envelops of square CFDST columns. [16] .

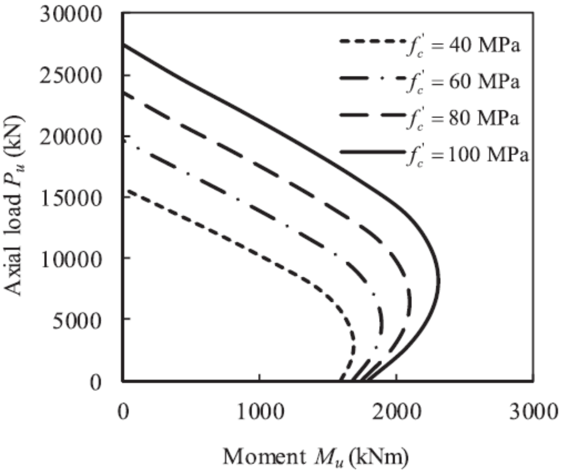


Fig-7: Effect of concrete strength on the strength envelops of square CFDST columns

When the compressive strength of concrete increases significantly it increases the initial bending stiffeness, and the compressive strength ranges from 40MPa to 100MPa. When the strength of concrete changes then the ultimate moment capacity increases and ductility index decreases [17]. In terms of ductility, the characteristics of HS and UHS are different from NS concrete and it has high strength. [19] .

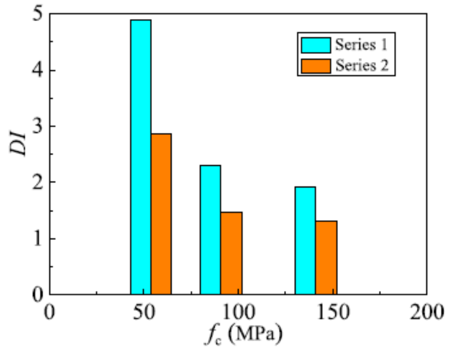
6.3 Ductility index

Ductility is defined as the ability to deform the member either from its beginning of yielding to the maximum bearing capacity or after it reaches the maximum bearing capacity. It is the ratio of total deformation at maximum load to the elastic limit deformation. It has been commonly used to calculate the axial ductility of columns. And also it is commonly used to calculate the ductility of composite columns. Due to the higher ductility index significantly it increases the ductility of CFDST column [6] .

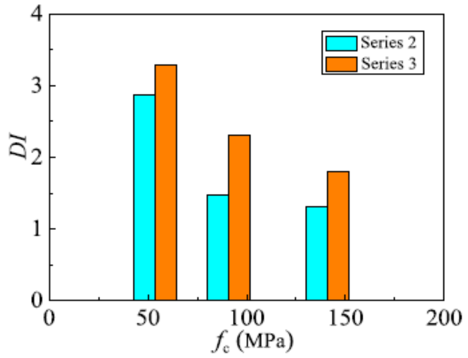
$DI = \varepsilon_{u,\,0.92}/\varepsilon y$

Where $\varepsilon_{u,\,0.92}$ is the axial strain after the specimens undergo ultimate axial strength. εy is the axial yield strain.

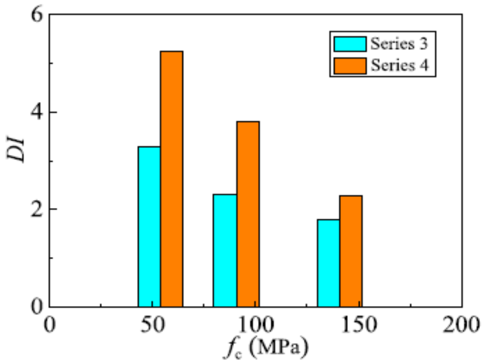
Fig 8 shows that the value of DI decreases when the strength of concrete increases. From the investigation it was found that with the increase in the strength of concrete the column has the tendency to brittleness failure. In fig 8(a) shows that when the hollow ratio increases then the DI decreases. Fig 8 (b),(c) shows that the value of DI increases when the wall thickness and yield stress of the outer tube increases[14].



(a)



(b)



(c)

Fig-8: Ductility index

7. LOAD AND BOUNDARY CONDITIONS

For applying load and boundary conditions, two reference point ie. Top reference point and bottom reference point were assigned to the ends of the CFDST column. Top reference point was fixed against all the lateral displacements and rotations. And the bottom reference point was fixed against all degree of freedoms[1] . For vertical bearing- members with θ = 90°, then at the top surface of BM the translation in X direction is U_X and in Z direction the translation is U_Z. At the bottom surface the translation occur in Y direction ie, U_Y and the surface were restrained. The fig 9 shows the vertical bearing member θ= 90° .

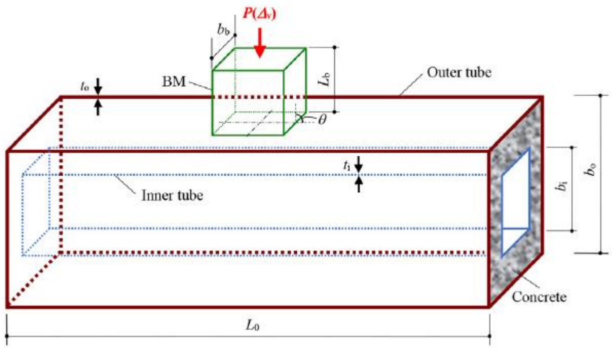


Fig-9: Vertical bearing member , θ = 90°

For inclined bearing members with θ=45°, the translatiom in X direction ie, U_X and in Z direction ie U_Z is restrained at the top surface of the column. And for inclined bearing members, the action was applied in the Y direction. The fig 10 shows the inclined bearing member, θ=45° [18] .

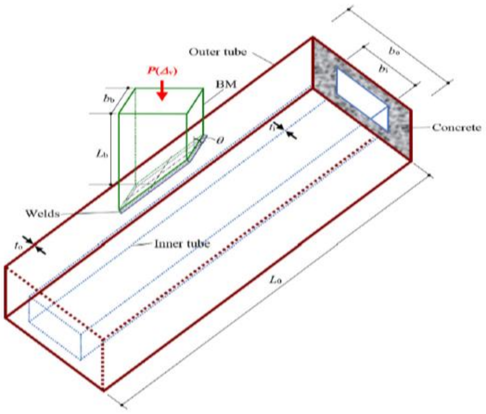


Fig-10: Inclined bearing member , θ=45°

CONCLUSIONS

CFDST columns significantly increase the axial load carrying capacity with less axial shortening. Due to the use of steel tubes and concrete, therefore increases the strength of the CFDST column. Finite element method is used to analysis of concrete filled double skin tube columns. The outcome of this paper can be summarized in below points :

- Minimizing the local buckling by increasing the outer tube thickness.
- Ultimate strength of CFDST column increase while increasing the strength of concrete.
- Elastic energy capacity absorption capacity of CFDST column increases while increasing the strength of concrete.
- Inner tube thickness must be controlled to prevent the premature failure.
- Delay the local buckling effect and reduce the buckling degree while using longitudinal stiffeners.
- In CFDST column when the compressive strength of concrete or hollow ratio decreased, significantly increase the ultimate axial load of CFDST column.
- Increasing the strength of concrete then the ductility of CFDST column decreases.
- In CFDST column the ultimate strength depends on the diameter and thickness of outer tube. And also the yield strength highly influence on the ultimate strength of CFDST column.
- Increasing the strength of concrete then the column has the tendency to brittle failure.

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