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# Investigation on the Behaviour of Stiffened Concrete-Filled Double Skin Steel Tubes

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**Abstract -** *Numerical study on the behaviour of stiffened concrete filled double skin steel tubes with a new arrangement of inner skin and stiffener are presented in this paper. Comparisons between stiffened and unstiffened concrete filled steel tubes (CFST and S-CFST), concrete filled double skin steel tubes (CFDST and S-CFDST) and rhomboidal inner core concrete filled double skin steel tubes (RCFDST and SR-CFDST) are made after analysing the axial capacities, their equivalent stress and strains. A total of 28 specimens were modelled and analysed based on the 1) hollow ratio (0.46 and 0.50); 2) Thickness of the skins (4mm and 8mm); 3) Height of the tubes (800mm and 1200mm); 4) Cross-section of the tube (square); 5) Length of stiffeners. 6) Width-to –thickness ratio of the inner and outer skins. Results imply that the effect of stiffeners is predominant in 800mm S-CFST unlike 1200mm S-CFST. In the case of CFDST for a hollow ratio of 0.46 the axial capacity increased for the stiffened specimens of both heights and decreased for specimens with a hollow ratio of 0.5. In case of RCFDST the axial capacities of stiffened specimens recorded lesser values than unstiffened specimens irrespective of the hollow ratio and height.*

***Key Words***: **CFDST, Axial Capacity, Stiffened, FEA, Hollow Ratio**

## 1.INTRODUCTION

Concrete–filled double skin steel tubes behave similar to concrete-filled tubes under the same dimensions and material properties. The prominent aspect of CFDST is its lighter weight when compared to CFST due to the absence of concrete in the core. By virtue of its lighter weight CFDST are useful in bridge piers, elevated corridors, buildings and towers. Studies show that columns with Smaller Width-to-Thickness ratio behave better [1]. Among the factors that affect the strength of the column, Slenderness ratio is the most significant [2]. The effect on ductility due to stiffeners by the increment in the inertia, hollow ratio has also been studied [6] [7]. Various studies have been conducted to comprehend the behaviour of concrete-filled double skin tubes subjected to torsion [8], fire performance, local bearing force yet the behaviour of CFDST is not aptly comprehensive compared to CFST. For the aforementioned condition it is essential to investigate its behaviour which can tremendously aid the design process. The aim of this investigation is to comprehend CFDST where our focus is on the axial capacity. A total of 28 specimens were modelled and analysed with a square cross section for the outer skin in most specimens and a rhomboidal inner skin for a few (R-CFDST and SR-CFDST). The specimens were tested for a hollow ratio of 0.46 and 0.5 with a wall thickness of 4mm and 8mm for a height of 800mm and 1200mm. Results imply that the effect of stiffeners improve the capacity of the column in few cases while the same trend is not observed in others.

## 2. ABBREVIATIONS & ACRONYMS

8004 - 800mm height and 4mm wall thick

8008 - 800mm height and 8mm wall thick

12004 – 1200mm height and 4mm wall thick

12008 – 1200mm height and 8 mm wall thick

P – Partial Length stiffeners

F – Full Length Stiffeners

$b_i$ – outside with of inner tube

$b_o$ – outside width of outer tube

$L_o$ – length of specimen

$t_i$ – wall thickness of inner tube

$t_o$ – wall thickness of outer tube

$P_u$ – Buckling load

χ – hollow ratio = $\frac{b_i}{b_o - 2t_o}$

## 3.BOUNDARY CONDITIONS

All the specimen lie on the X-Z plane. The X-Z plane is fixed at the bottom ($\theta_x = \theta_y = \theta_z = U_x = U_y = U_z = 0$) and the top is restrained against translation and rotation in all directions except Y ($\theta_x = \theta_y = \theta_z = U_x = U_z = 0$; $U_y$= Free).

## 4.MATERIAL PROPERTIES

### Concrete

Density - 2400 kg/m$^3$

Ultimate tensile strength - 5 N/mm$^2$

Ultimate Compressive Strength - 41 N/mm$^2$

**Steel**

Density - 7850 kg/m$^3$

Tensile yield Strength - 250 N/mm$^2$

Ultimate Tensile Strength - 460 N/mm$^2$

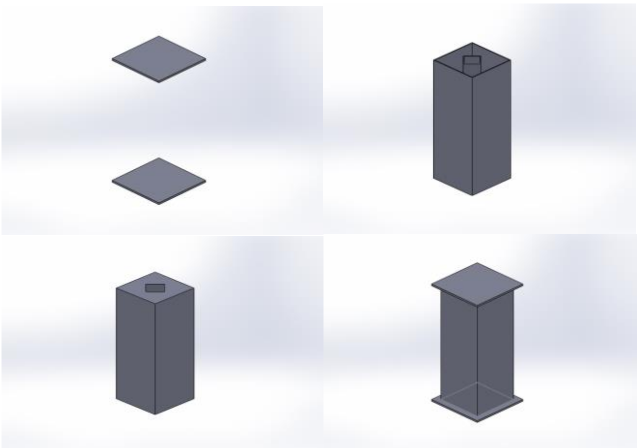


**Fig -1**: Sequence of Modelling (Solidworks)

## 5.TEST MODEL

The steel skins, sandwich concrete, stiffeners, the loading and base plates were modelled as parts and assembled into a column as per the required dimensions in Solidworks. Fig-1 shows the components of a column. Clockwise from left (Loading plate and base plate, steel skin, sandwich concrete, assembled specimen). A unit load of 1 Newton is applied in the negative Y direction for analysing the buckling load. The setup converted to (*.IGS) and imported to ANSYS Workbench for analysis. All the square cross-sections were taken as 230*230mm for outer skin and 100*100mm for inner skin including the rhomboidal inner core.

## 6.FINITE ELEMENT ANALYSIS

- Defining the analysis system (Static Structural)
- Entering the engineering data
- Modelling the Geometry (Solidworks)
- Assigning the properties, connections and mesh of the model
- Setting up the model (Applying loads and assigning supports)
- Setting up the solution (Eigen Value Buckling)
- Viewing the results

ANSYS Workbench 16.0 is used for analysis. The axial capacity is calculated by using the Eigen Value buckling tool. Eigen Value (or) Linear (or) Euler Buckling mean the same. A load of 1 Newton is assigned in the negative Y direction at the top of the loading plate and the solution is done. The load multiplier value that is obtained in the result is a measure of the load that the column can withstand. Since the analysis is linear in nature the column is considered to be purely elastic and results are generated for values greater than the buckling load when solved. However, to get a clear picture of the post buckling characteristics anon linear analysis would suffice. It is also advisable to study as many mode shape results on solving as it would compensate for the less accurate results of linear analysis compared to non-linear analysis.

## 7.RESULTS

**Table -1:** Summary of tested Specimens

| χ | CFST | $P_u$ (kN) | S-CFST | $P_u$ (kN) | % Inc/Dec |
|---|---|---|---|---|---|
| 0.46 | 8004 | 1598 | 8004 | 3269 | 104 |
| 0.50 | 8008 | 5590 | 8008 | 7210 | 28 |
| 0.46 | 12004 | 2841 | 12004 | 2129 | -25 |
| 0.50 | 12008 | 4197 | 12008 | 3147 | -25 |
| | **CFDST** | | **S-CFDST** | | |
| 0.46 | 8004 | 3708 | 8004 | 4172 | 12 |
| 0.50 | 8008 | 6921 | 8008 | 5399 | -21 |
| 0.46 | 12004 | 2065 | 12004 | 2309 | 11 |
| 0.50 | 12008 | 6532 | 12008 | 6316 | -44 |
| | **RCFDST** | | **SR-CFDST** | | |
| 0.46 | 8004 | 4413 | 8004F | 903 | -79 |
| | | | 8004P | 384 | -91 |
| 0.50 | 8008 | 12639 | 8008F | 1833 | -85 |
| | | | 8008P | 1197 | -90 |
| 0.46 | 12004 | 3253 | 12004F | 1068 | -67 |
| | | | 12004P | 876 | -73 |
| 0.50 | 12008 | 6216 | 12008F | 1755 | -71 |
| | | | 12008P | 1203 | -80 |

**Chart-1:** Axial Capacity - Height 800mm and 4mm thick

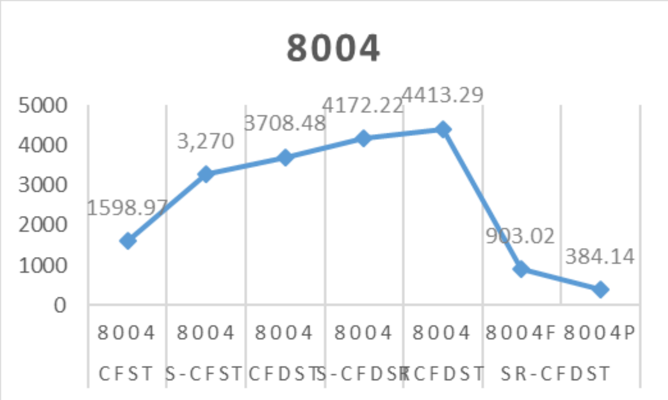



**Chart-2:** Axial Capacity - Height 800mm and 4mm thick

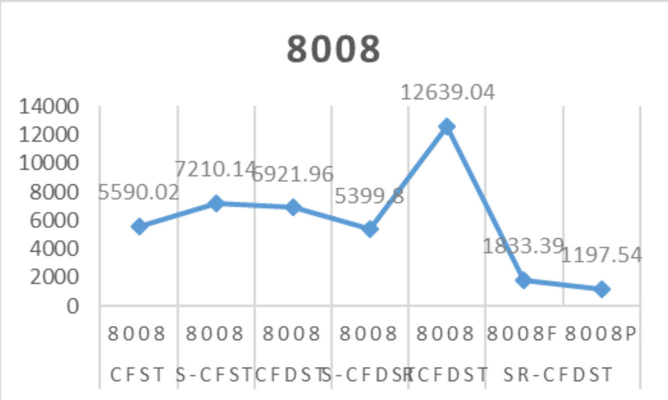



**Chart-3:** Axial Capacity - Height 1200mm and 4mm thick

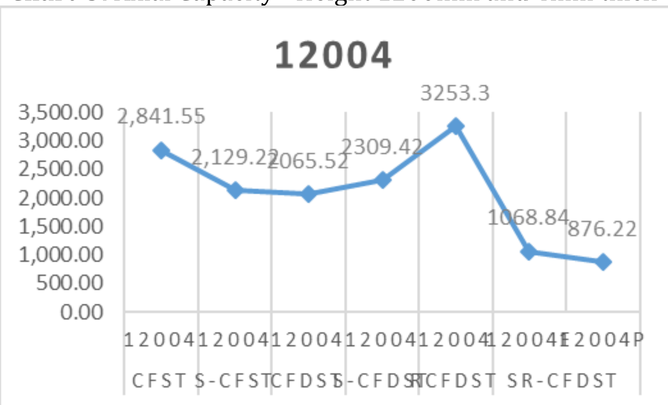
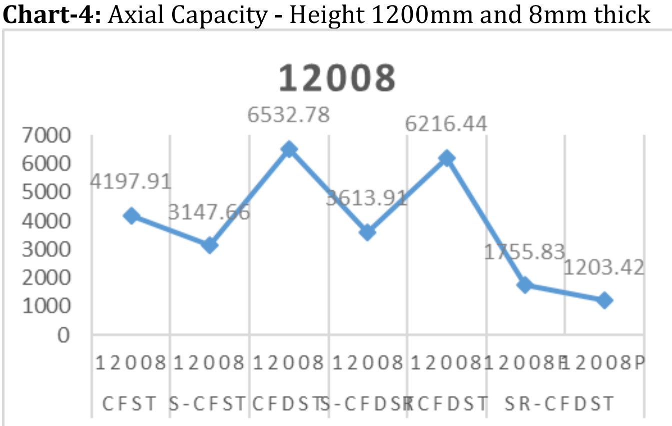



**Chart-4:** Axial Capacity - Height 1200mm and 8mm thick




The comparison of axial capacities between stiffened and unstiffened concrete-filled steel tubes are presented.

### CFST

In specimens of height 800mm the axial capacity increased whereas it decreased in specimens of height 1200mm.

### CFDST

For a hollow ratio of 0.46 the axial capacity increased in stiffened specimens irrespective of the height. For a hollow ratio of 0.50, the axial capacity decreased in both the stiffened specimens.

### RCFDST

- P and F indicate the length of the stiffeners
- P-Partial-Half the distance between the outer face of inner tube and inner face of outer tube.
- F-Full-Full distance between outer face of inner tube and inner face of outer tube.

The axial capacity has reduced significantly irrespective of the hollow ratio (0.46/0.50) and height of the specimen (800mm/1200mm).

**Chart-5:** Stress/Strain - Height 800mm and 4mm thick

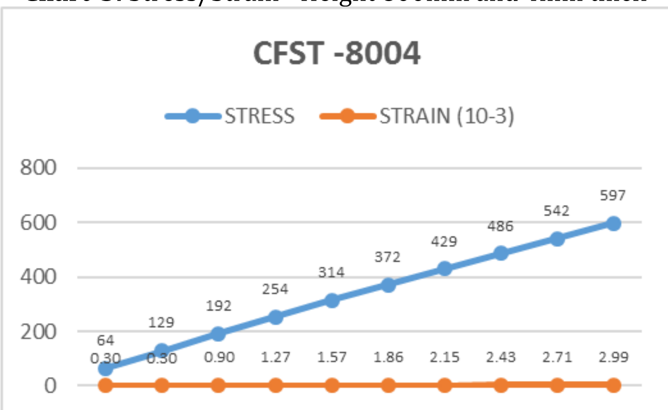



**Chart-6:** Stress/Strain - Height 800mm and 8mm thick

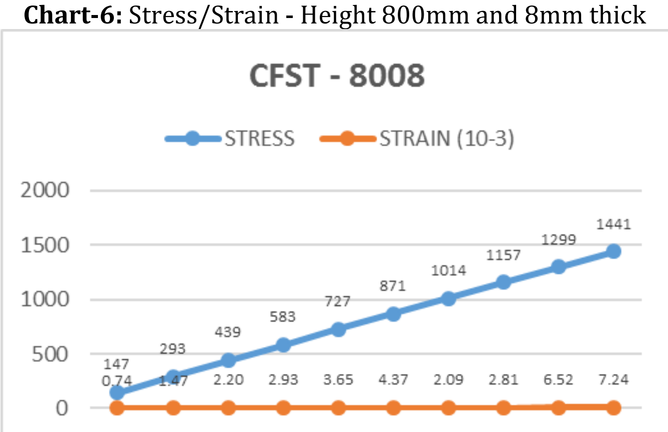


**Chart-7:** Stress/Strain - Height 1200mm and 4mm thick

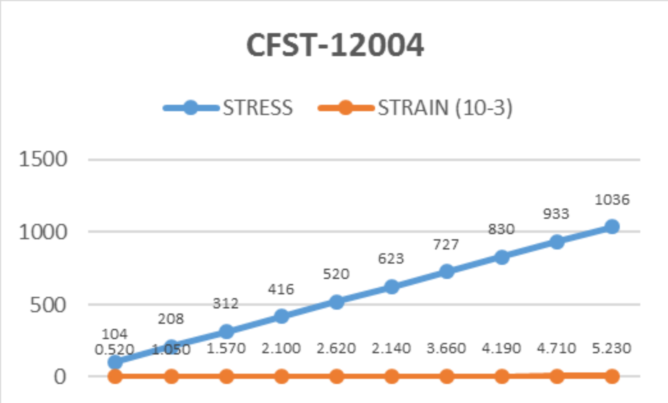



**Chart-8:** Stress/Strain - Height 1200mm and 8mm thick

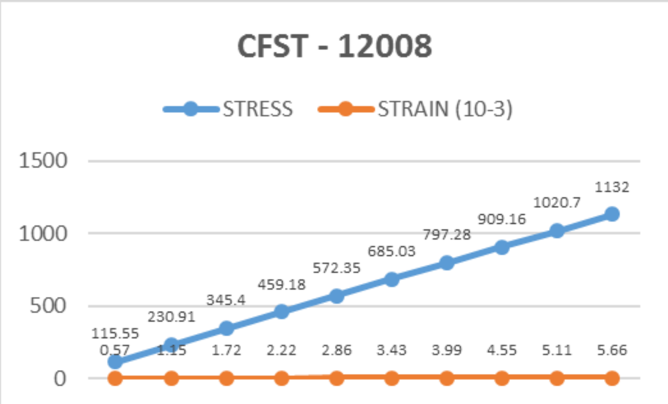



**Chart-9:** Stress/Strain - Height 800mm and 4mm thick

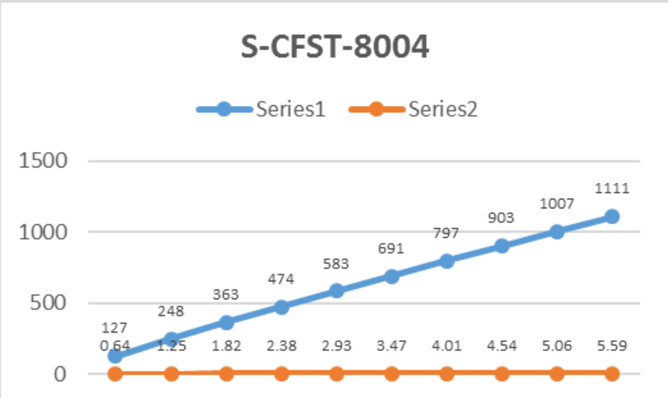



**Chart-10:** Stress/Strain - Height 800mm and 8mm thick

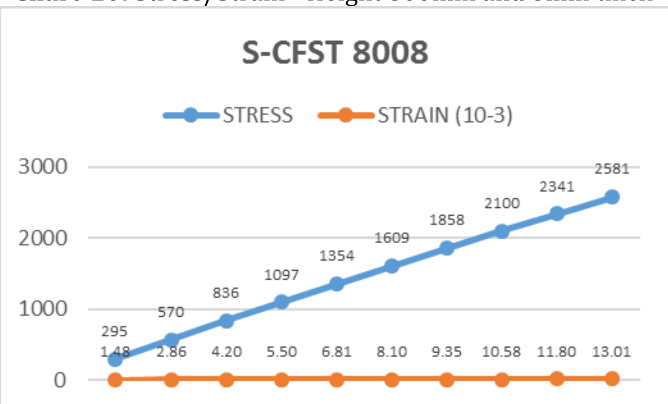



**Chart-11:** Stress/Strain - Height 1200mm and 4mm thick

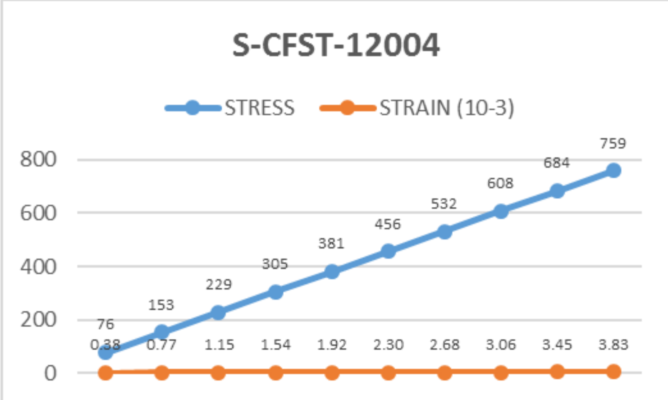



**Chart-12:** Stress/Strain - Height 1200mm and 8mm thick

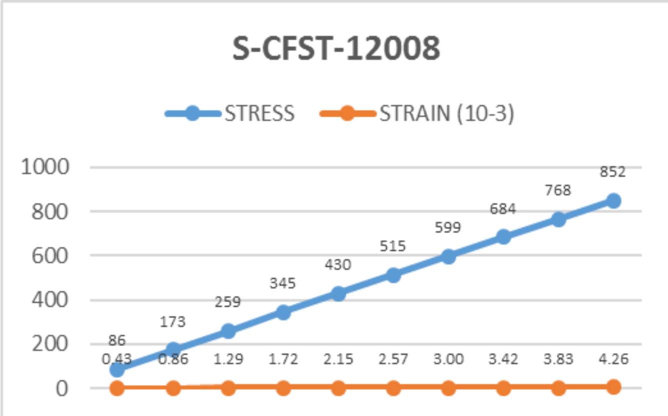



**Chart-13:** Stress/Strain - Height 800mm and 4mm thick

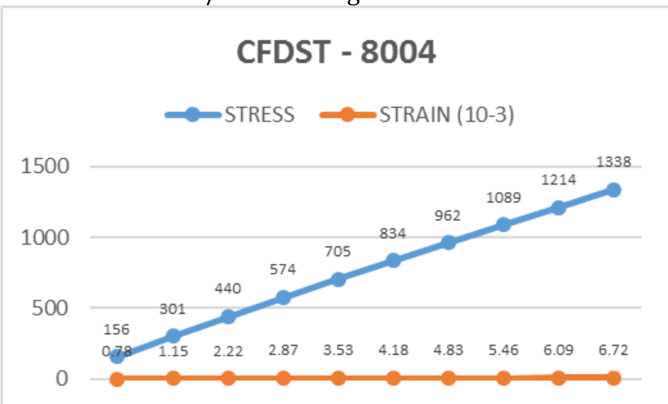



**Chart-14:** Stress/Strain - Height 800mm and 8mm thick

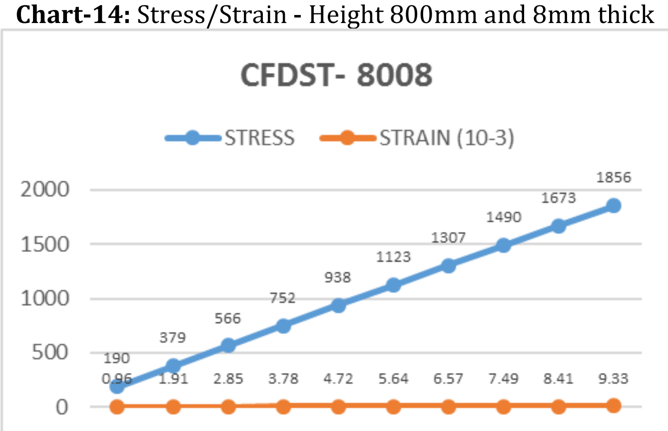


**Chart-15:** Stress/Strain - Height 1200mm and 4mm thick

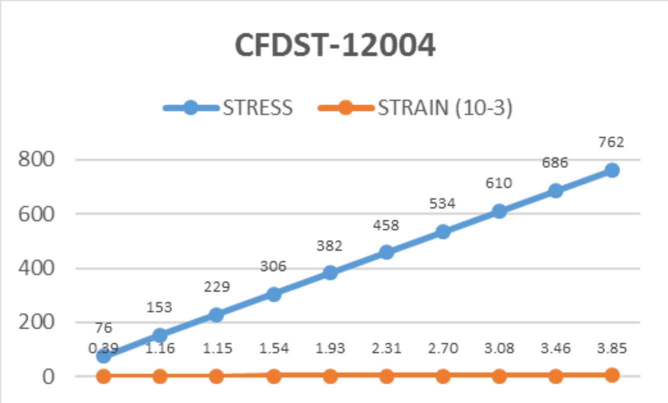



**Chart-19:** Stress/Strain - Height 1200mm and 4mm thick

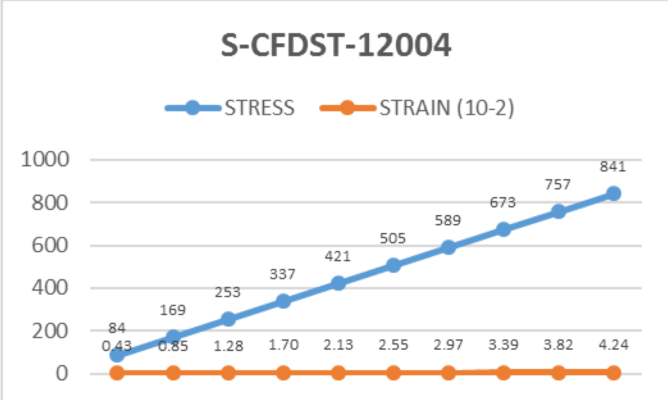



**Chart-16:** Stress/Strain - Height 1200mm and 8mm thick

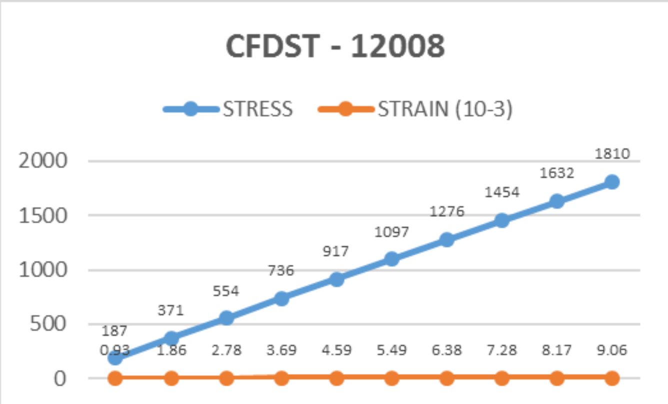



**Chart-20:** Stress/Strain - Height 1200mm and 8mm thick

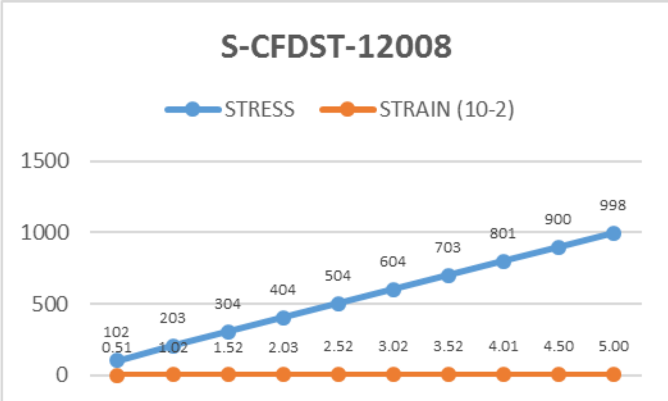



**Chart-17:** Stress/Strain - Height 800mm and 4mm thick

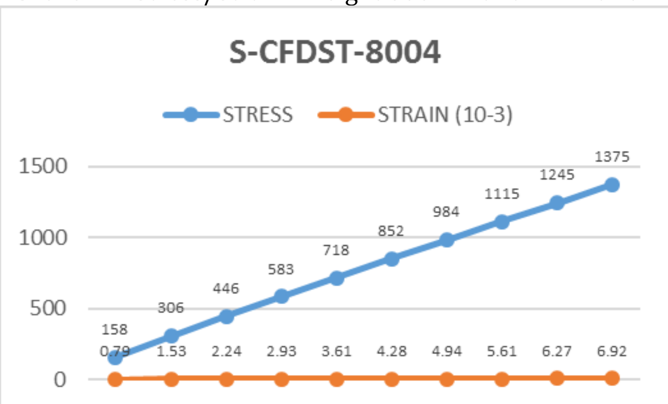



**Chart-21:** Stress/Strain - Height 800mm and 4mm thick

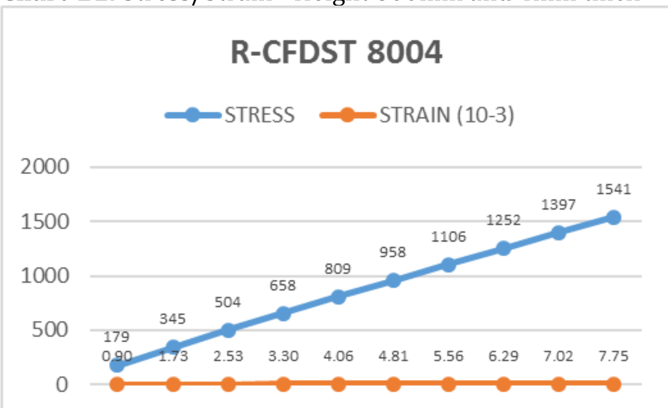



**Chart-18:** Stress/Strain - Height 800mm and 8mm thick

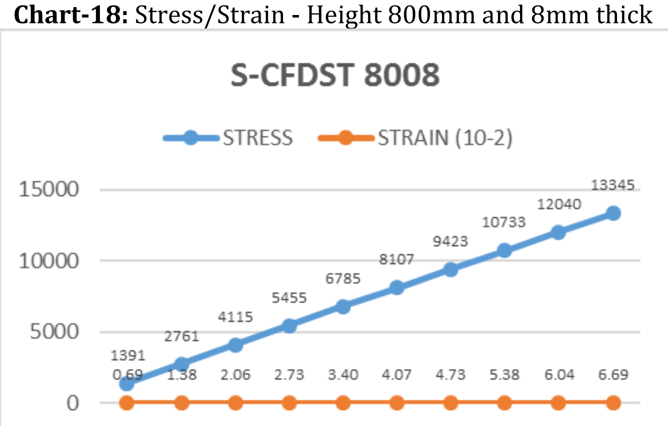



**Chart-22:** Stress/Strain - Height 800mm and 8mm thick

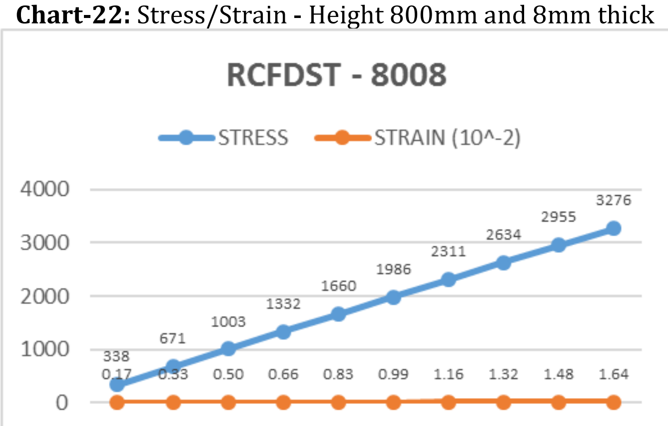


**Chart-23:** Stress/Strain - Height 1200mm and 4mm thick

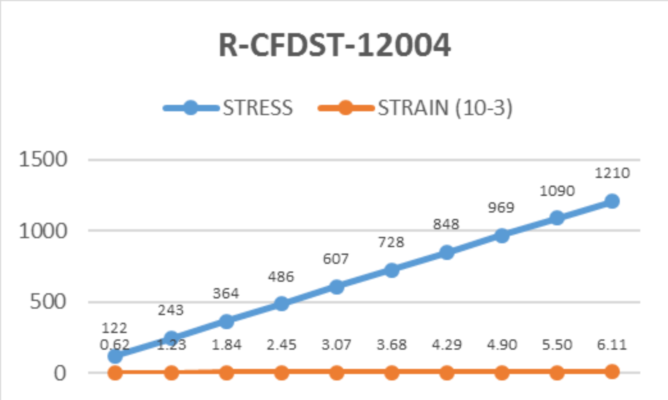



**Chart-24:** Stress/Strain - Height 1200mm and 8mm thick

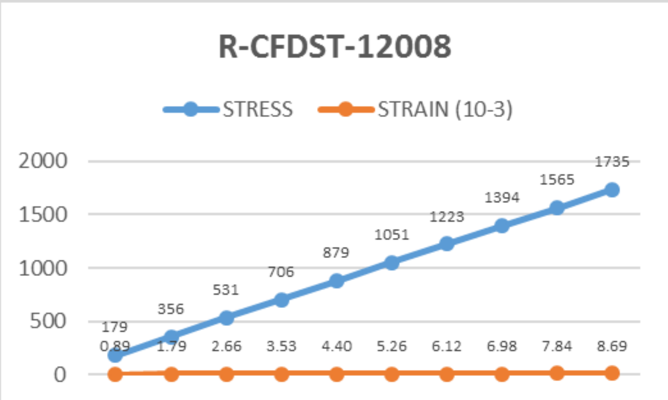



**Chart-25:** Stress/Strain - Height 800mm and 4mm thick

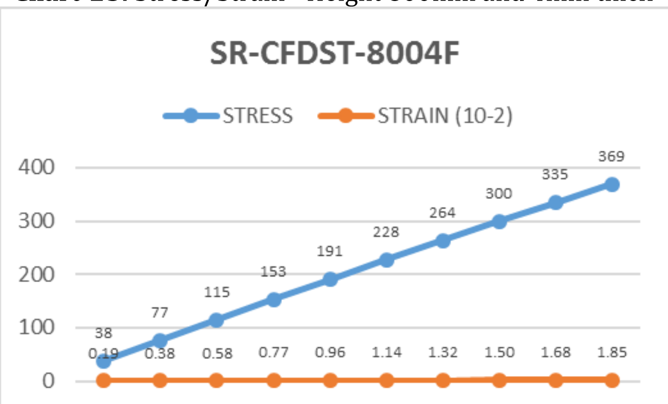



**Chart-26:** Stress/Strain - Height 800mm and 8mm thick

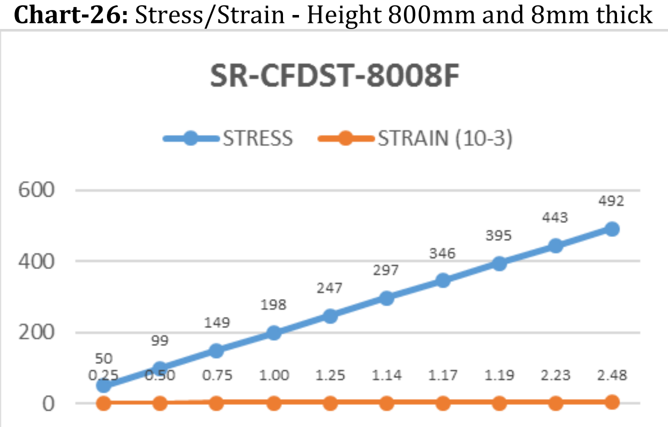



**Chart-27:** Axial Capacity - Height 1200mm and4mm thick

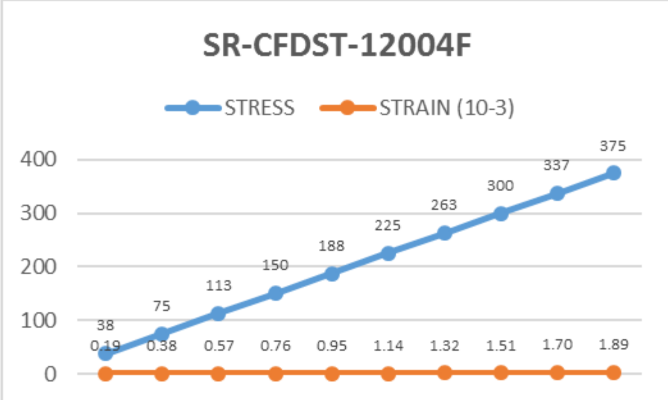
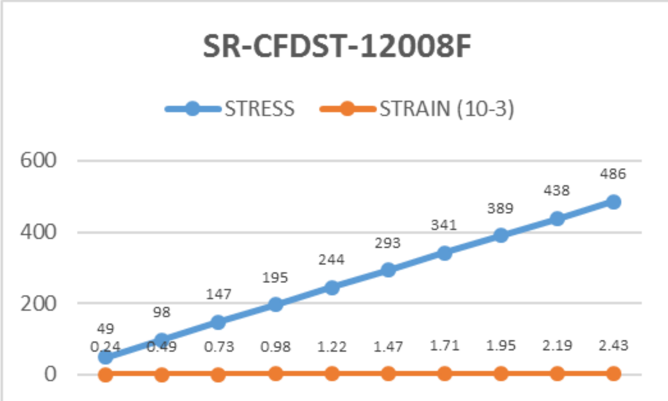



**Chart-28:** Axial Capacity - Height 1200mm and 8mm thick




## 8.CONCLUSION

- Hollow ratio is an inversely proportional to the density of the specimen. The higher the hollow ratio lower is the ultimate capacity i.e. a hollow ratio close to 1 indicates a less dense specimen and a hollow ratio lesser than 1 indicates a highly dense specimen.
- Here concrete which is excellent in compression contributes significantly in resisting the compressive load.
- Increase in number and thickness of the stiffeners increase the confinement effect with delays the local buckling thereby increasing the ultimate capacity of the specimen. For the same stiffener and wall thickness the ultimate capacity decreases with the increase in slenderness of the column.
- All the columns failed by local buckling which is desirable over global buckling. The core concrete prevents the steel skin from buckling inward. The outward bulge is due to the crushing of the concrete at the juncture.

The new arrangement of stiffeners and inner core has enhanced the ultimate capacity in some columns while in some columns it has reduced the ultimate capacity which is expected to be caused by the increase in ductility beyond required which is open to further research and analysis.

## REFERENCE


[1] Huang CS et al. "Axial load behaviour of stiffened concrete filled steel columns". Journal of Structural Engineering ASCE 2002;128(9):1222–30.

[2] Li W, Han L-H, Ren Q-X, Zhao X-L. "Behaviour and calculation of tapered CFDST columns under eccentric compression". Journal of Constructional Steel Research 2013; 83:127–36.

[3] Li W, Han L-H, Zhao X-L. "Axial strength of concrete-filled double skin steel tubular (CFDST) columns with preload on steel tubes". Thin-Walled Structures 2012; 56:9–20.

[4] K. Uenaka, H. Kitoh, K. Sonoda, "Concrete filled double circular stub columns under compression", Thin-Walled Structures. 48 (2010) 19–24.

[5] K. Uenaka, H. Kitoh, "Concrete filled double skin circular tubular members subjected to pure bending and centric compressive loading", Tubular Structures. 14 (2012) 81–87.

[6] Yang YF, Han LH, Sun BH. "Experimental behaviour of partially loaded concrete filled double-skin steel tube (CFDST) sections". Journal of Constructional Steel Research 2012;71:63–73.

[7] Z. Tao, L.H. Han and Z.B. Wang. "Experimental behaviour of stiffened concrete-filled thin-walled hollow steel structural (HSS) stub columns". *Journal of Constructional Steel Research*, 61:962-983, 2005.

[8] Hsuan-The Hu, Feng-Chien Su. "Nonlinear analysis of short concrete-filled double skin tube columns subjected to axial compressive forces". Journal of Marine Structures 24 (2011)319-337.

[9] Pagoulatou M, Sheehan T, Dai XH, Lam D. "Finite element analysis on the capacity of circular concrete-filled double-skin steel tubular (CFDST) stub columns". Engineering Structures 2014;72:102–12.

[10] Uenaka K. "Concrete filled double skin circular tubular beams with large diameter-to-thickness ratio under shear". Thin-Walled Structures 2013;70:33–8.

[11] Huang H, Han LH, Zhao XL. "Investigation on concrete filled double skin steel tubes (CFDSTs) under pure torsion". Journal of Constructional Steel Research 2013;90:221–34.

[12] Li W, Han LH, Chan TM. "Tensile behaviour of concrete-filled double-skin steel tubular members". Journal of Constructional Steel Research 2014;99:35–46.

[13] Zhao XL, Han LH. "Double skin composite Construction". Progress in Structural Engineering Mater 2006;3:93–102.

[14] Huang H, Han LH, Tao Z, Zhao XL. "Analytical behaviour of concrete-filled double skin steel tubular (CFDST) stub columns". Journal of Constructional Steel Research 2010;66 (4):542–55.

[15] Wei S, Mau ST, Vipulanandan C, Mantrala SK. "Performance of new sandwich tube under axial loading: experiment". Journal of Structural Engineering ASCE 1995;121 (12):1806–14.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