Analysis of Concrete Filled Double Skin Steel Tube (CFDST) column with CFRP wrapping

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Abstract - *CFDST consists of two steel layers embedding a concrete layer in between. CFDST have many advantages such as high strength, high bending stiffness, good seismic and fire performance. But the columns were proven to have certain shortcomings such as ageing of structures, corrosion of steel tubes. Therefore, the implementation of strengthening techniques with the new material is essential to eliminate this problem. Carbon Fibre reinforced polymer (CFRP) can be used as an external reinforcement to strengthen the structure. This paper investigates the behaviour of CFDST circular column with steel tubes wrapped with CFRP compressed under axial loads .The parameters considered in this study are number of FRP layers (2, 4 and 6), spacing between the FRP strips(25 mm, 50 mm and 100 mm) length of columns (1 m, 2 m and 3 m) and hollow section ratio(0.25, 0.5) . The Load – Deformation and Axial Stress – Axial Strain behaviour of CFDST circular column with steel tubes wrapped with CFRP considering the above parameters are assessed using ANSYS software.*

Key Words: CFDST, FRP, GFRP, CFRP

1. INTRODUCTION

CFDST column is a composite member, which consists of inner and outer steel skins with the annulus between the skins filled with concrete. From structural point of view, this form of column has higher strength (uni-axial, flexural and torsion). By replacing the central concrete with a steel tube of much smaller cross section area, the strength-to-weight ratio of the columns is improved significantly. Furthermore, the inner tube expands laterally during compression and hence increases the confining pressure provided to the concrete. Thus, the initial confining pressure builds up more rapidly than that in CFST columns that enhances the elastic strength and stiffness. From environmental point of view, CFDST column uses less concrete, which creates a more sustainable environment by reducing the embodied energy levels of the column. From cost effectiveness point of view, the tubes act as both the longitudinal reinforcement and formwork that save the construction cost and cycle. Lastly, the cavity inside the inner tube provides a dry atmosphere for possible catering of facilities or utilities like power cables, telecommunication lines and drainage pipes. This form of construction is particularly useful for maritime structures, in which the subsea facilities can be accommodated in the dry atmosphere. In recent years, many steel and CFDST structures have been found to be suffering from a variety of deteriorations, including cracking, yielding and large deformation. These deteriorations are caused by a variety of factors, including fire, ageing, environmental degradation and corrosion. There are several strengthening or rehabilitation techniques that can be applied to enhance performance, including section enlargement, external bonding using steel plates and fibers, among others. Fibre Reinforced Polymer (FRP) composites can be used for rehabilitation. One of the main forces driving the development of external strengthening methods that uses the FRP composite is that they enable deteriorated members to be upgraded without significantly altering the appearance of the member. In addition, FRP composites are light weight, durable, and resistant to corrosion, and have high tensile strength, stiffness and fatigue strength.

2. SCOPE

In this thesis, the behaviour of CFDST hybrid column circumscribed with FRP layers compressed under axial loads were studied. The parameters used in this study are number of FRP layers (2, 4 and 6), spacing between the FRP strips (25mm, 50mm and 100mm) length of columns (1m, 2m and 3m) and hollow section ratio (0.25, 0.5).The non - linear static analysis is carried out in order to determine the deformation, axial stress and strain of different models.

3. FINITE ELEMENT MODELLING

3.1 Material properties

i. Steel: The Steel is assumed to have isotropic hardening behaviour, i.e., the yield surface changes uniformly in all directions so that yield stresses increase or decrease in all stress directions when plastic straining occurs. For the specimen, the elastic Elastic modulus (Es) and Poisson's ratio for steel are taken as 200,000 N/mm^2 and 0.3. The yield strength of steel tube (fy) is taken as 265 N/mm^2 .The Density of steel is considered as 78.5 kN/m^3. A bilinear property of steel tube is used in the analysis.

ii. Concrete: The poissons ratio and elastic modulus of concrete is taken as 0.18 and 300,00 N/mm2. The density of concrete is 23 kN/m3.

iii. CFRP: Fibre with a stiffness value of 230 kN/mm2 and density of 1800 N/mm2 is used. Poisson's ratio is assumed as 0.1.

iv. GFRP: Fibre with a stiffness value of 80 kN/mm2 and density of 1800 N/mm2 is used. Poisson's ratio is assumed as 0.1.

v. Geometry: The length of column is taken as 1000 mm. The inner and outer steel tube diameter is taken as 100mm and 400mm respectively. The thickness of steel tube is 5.6 mm. FRP strips of 0.17 mm thickness and 100 mm width is used.

vi. Boundary condition: The loads were applied using the boundary conditions. The bottom end is fixed with no degrees of freedom and the top end is fixed against all types of rotation and against lateral displacements(x and y directions).

3.2 MODELLING

Eighteen CFDST column with FRP wrapping were modelled in ANSYS Workbench 16 having different column height, spacing, number of layers and hollow section ratio. FE Model of CFDST column wrapped with FRP for different spacing, number of layers of CFRP strips , height of the column having different hollow section ratios is shown in fig 3.1, 3.2 and 3.3 respectively

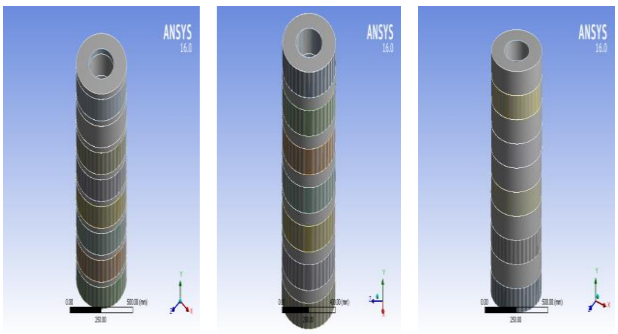


Fig 3.1 CFDST column wrapped with CFRP(0.5 hollow section ratio) for different spacing (i) 25mm (ii) 50mm (iii) 100mm

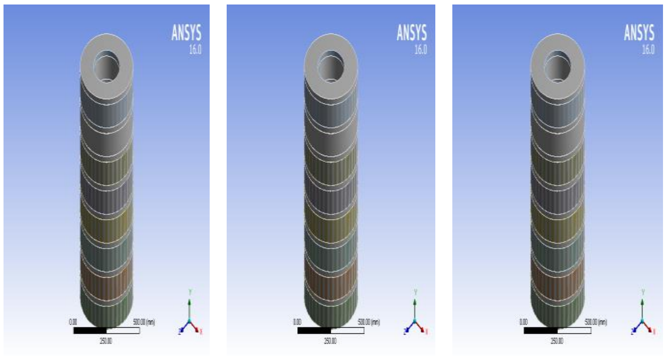


Fig 3.2 CFDST column wrapped with CFRP (0.5 hollow section ratio) for different layers (i) 2 (ii) 4 (iii) 6

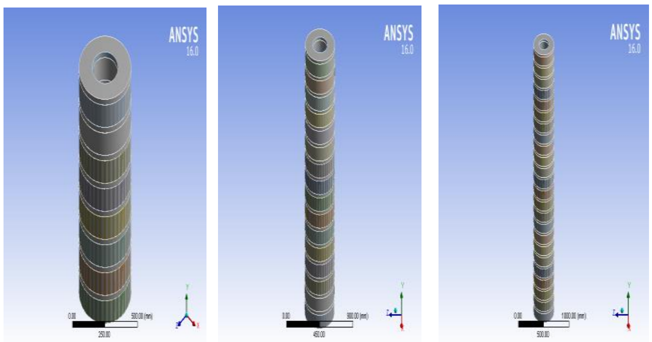


Fig 3.3 CFDST column wrapped with CFRP (0.5 hollow section ratio) for different height (i) 1m (ii) 2m (iii) 3m

4. ANALYSIS

Static structural analysis is performed on all the eighteen CFDST column models. Deformation and stress characteristics of columns are studied. Total Deformation of CFDST column wrapped with CFRP for different spacing and number of FRP strips and height of column is shown in fig: 4.1, fig: 4.2 and fig: 4.3 respectively.

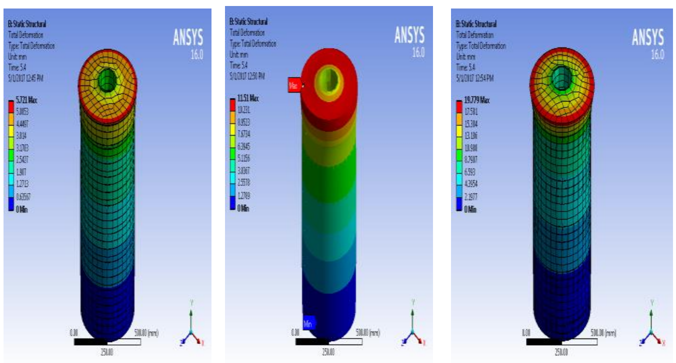


Fig 4.1 CFDST column wrapped with FRP (0.5 hollow section ratio) for different spacing (i) 25mm (ii) 50mm (iii) 100mm

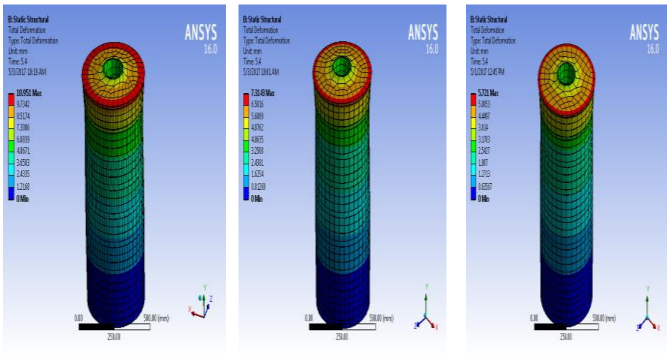


Fig 4.2 CFDST column wrapped with FRP(0.5 hollow section ratio) for different number of layers (i) 2 (ii) 4 (iii) 6

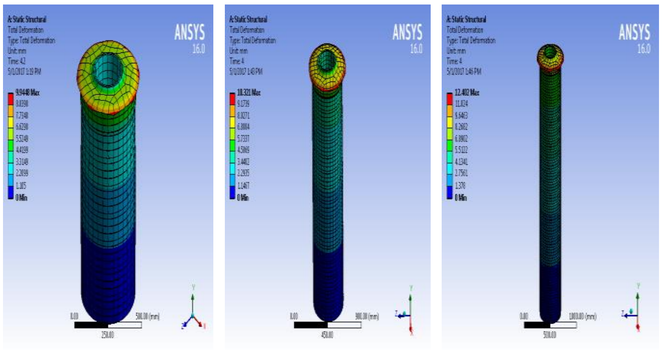
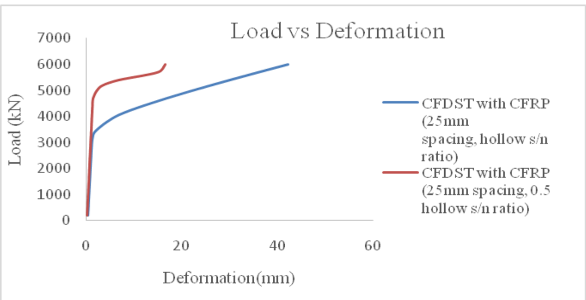


Fig 4.3 CFDST column wrapped with FRP(0.5 hollow section ratio) for different height (i) 1m (ii) 2m (iii) 3m

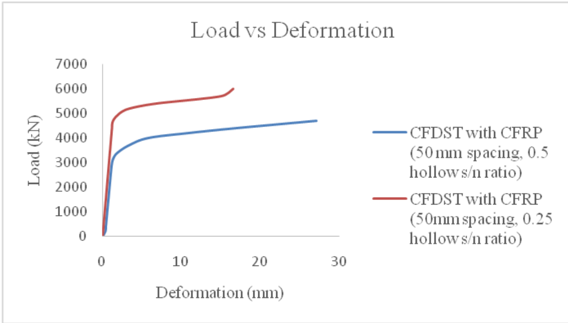
5.RESULTS AND DISCUSSIONS

5.1 Effect of spacing of FRP strips

The spacing of FRP strips (CFRP and GFRP) is varied as 25mm, 50mm and 100mm. The column height is kept constant as 1m and hollow section ratio is taken as 0.25 and 0.5 respectively. The number of FRP strips are taken as 2.



(a)



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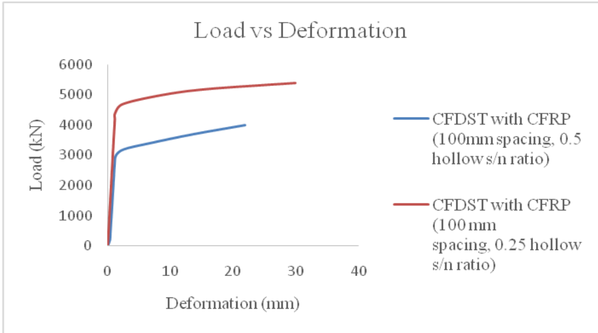


(c)

Fig 5.1 Load deformation graph variation of deformation of CFDST column with varying hollow section ratio and (a) 25 mm spacing of CFRP strips (b) 50 mm spacing of CFRP strips (c) 100 mm spacing of CFRP strips

From fig 5.1 it is clear that, the load carrying capacity is higher for CFDST column of 0.25 hollow section ratio with FRP wrapping than CFDST column of 0.5 hollow section ratio with FRP wrapping. This is because, the self-weight of concrete is higher for column of 0.25 hollow section ratio than that of 0.5 hollow section ratio. The load deformation graph shows similar behavior for all the spacing of CFRP strips.

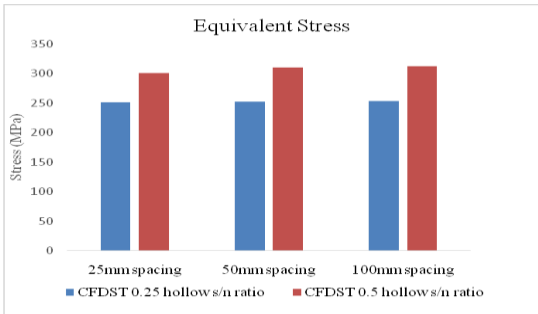
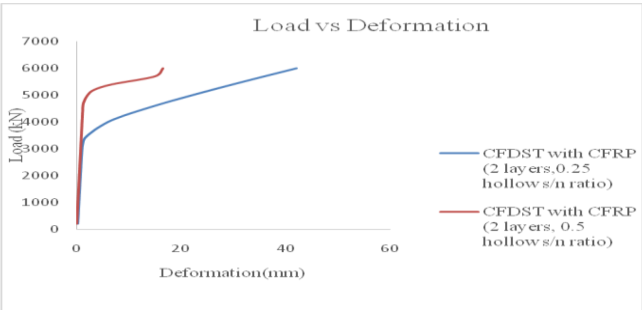


Fig 5.2 Stress of CFDST column with varying hollow section ratio and spacing of CFRP strips

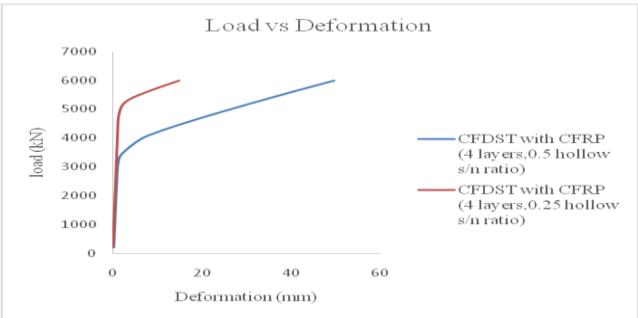
Fig 5.2 shows that the stress on CFDST column of 0.25 hollow section ratio with FRP wrapping is lesser than the CFDST column of 0.5 hollow section ratio with FRP wrapping. The high stress value is because of the decrease in self-weight of CFDST column of 0.5 hollow section ratio.

5.2 Effect of number of layers of FRP strips

The number of CFRP strips is varied as 2, 4 and 6. The column height is kept constant as 1m and hollow section ratio is varied (0.25 and 0.5). The spacing of FRP strips are taken as 25.



(a)



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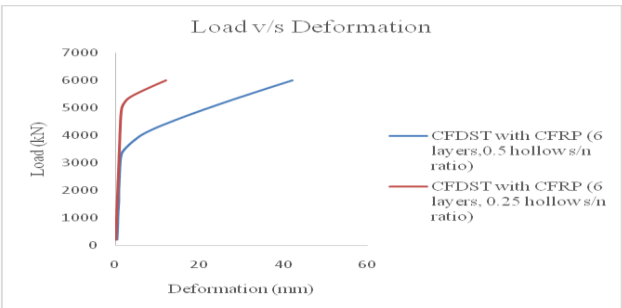


(c)

Fig 5.3 Load deformation graph of variation of deformation of CFDST column with varying hollow section ratio and (a) 2 layers of CFRP strips (b) 4 layers of CFRP strips (c) 6 layers of CFRP strips

Fig 5.3 shows that the deformation is lesser for CFDST column of 0.25 hollow section ratio with FRP wrapping than CFDST column of 0.5 hollow section ratio with FRP wrapping. This is because, the self-weight of concrete is higher for column of 0.25 hollow section ratio than that of 0.5 hollow section ratio.

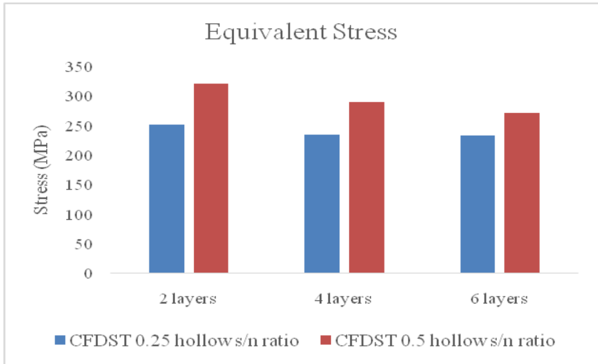
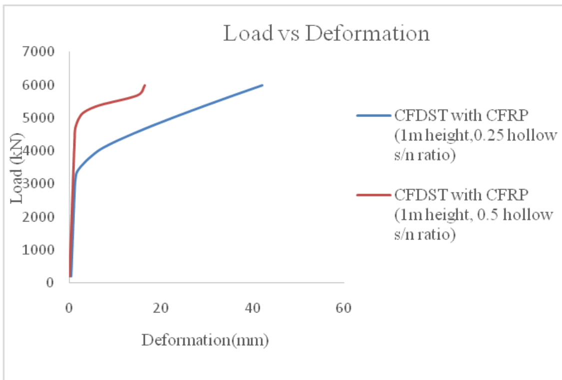


Fig 5.4 Equivalent stress of CFDST column with varying hollow section ratio and number of CFRP strips

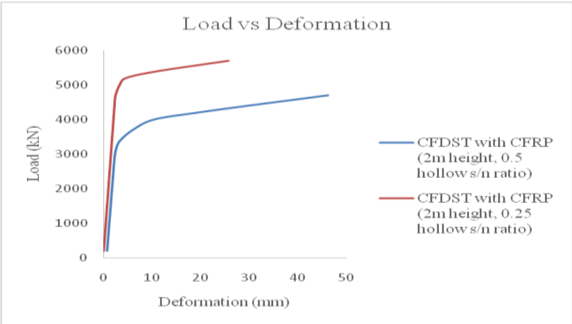
From fig 5.4, it is clear that the stress on CFDST column of 0.25 hollow section ratio with FRP wrapping is lesser than the CFDST column of 0.5 hollow section ratio with FRP wrapping. The high stress value is because of the decrease in self-weight of CFDST column of 0.5 hollow section ratio

5.3 Effect of height of column

The height of column is varied as 1m, 2m and 3m. The hollow section ratio is kept constant as 0.25 and 0.5. The spacing and number of FRP strips are taken as 25 mm and 2.



(a)



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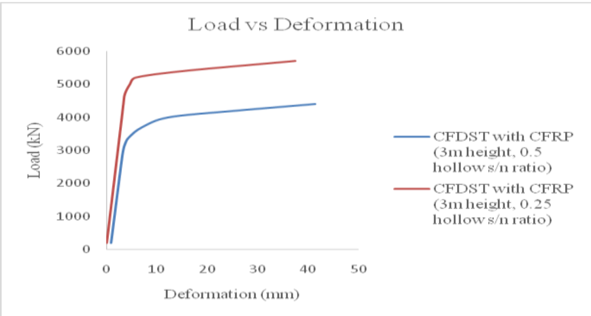

(c)

Fig 5.5 Load deformation graph of variation of deformation of CFDST column with varying hollow section ratio and (a) 1m height of column (b) 2m height of column(c) 3m height of column

Fig 5.5 shows that the deformation is lesser for CFDST column of 0.25 hollow section ratio with FRP wrapping than CFDST column of 0.5 hollow section ratio with FRP wrapping. This is because, the self-weight of concrete is higher for column of 0.25 hollow section ratio than that of 0.5.

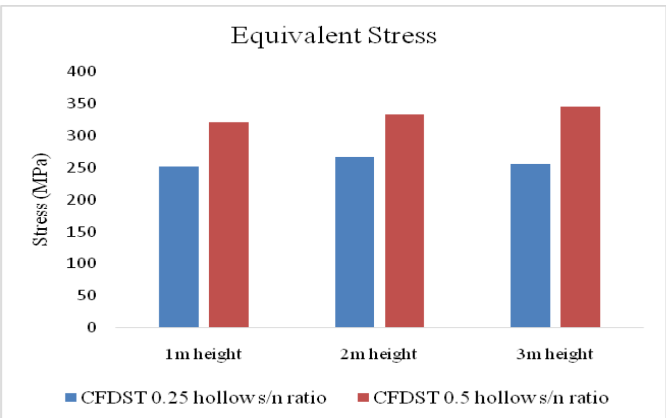

Fig 5.6 Equivalent stress of CFDST column with varying hollow section ratio and height of column

Fig 5.6 shows that the stress on CFDST column of 0.25 hollow section ratio with FRP wrapping is lesser than the CFDST column of 0.5 hollow section ratio with FRP wrapping. The high stress value is because of the decrease in self-weight of CFDST column of 0.5 hollow section ratio. The stress value increases with increase in height of the column.

6. SUMMARY AND CONCLUSION

Analysis on the application of FRP strips to strengthen the CFDST column member under axial loading by changing parameters (spacing of FRP strips , number of FRP strips , hollow section ratio and height of column) were done and following conclusions were made

i. The deformation and stress value is lesser for CFDST column wrapped with FRP at 0.25 hollow section ratio than column with 0.5 hollow section ratio for all the cases (number of layers, spacing of CFRP strips and height of the column)

ii. The CFDST column of 0.25 hollow section ratio which is wrapped with FRP strips shows better performance compared with column of 0.5 hollow section ratio.

REFERENCES

[1] Lin-Hai Han, Qing-Xin Ren, Wei Li, “Tests on stub stainless steel–concrete–carbon steel double-skin tubular (DST) Columns”, Journal of Constructional Steel Research 67 (2011) 437–452

[2] Jun wang, ding zhou, ” Mechanical behaviour of concrete filled double skin steel tubular (CFDST) stub columns confined by FRP under axial compression”, Steel and Composite Structures (2014)17(4):431-452

[3] J.C.M. Ho ,C.X. Dong, “Improving the strength, stiffness and ductility of CFDST columns by external confinement “,Thin-Walled Structures 75 (2014),18–29

[4] Jin-Kook Kim, Hyo- Gyoung Kwak ,”Behavior of Hybrid Double Skin Concrete Filled Circular Steel Tube Columns“ Steel and Composite Structures 14(2)(2013)