Analysis of Concrete Filled Double Skin Steel Tube (CFDST) column with FRP 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. Fibre reinforced polymer (FRP) 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 FRP compressed under axial loads .The parameters considered in this study are types of FRP (Glass Fibre Reinforced Polymer (GFRP), Carbon Fibre Reinforced Polymer (CFRP)), number of FRP layers (2, 4 and 6), spacing between the FRP strips(25 mm, 50 mm and 100 mm) and length of columns (1 m, 2 m and 3 m) . The Load – Deformation and Axial Stress – Axial Strain behaviour of CFDST circular column with steel tubes wrapped with FRP considering the above parameters are assessed using ANSYS software.*

Key Words: CFDST, FRP, GFRP, CFRP

INTRODUCTION

Composite columns are widely used in the construction of modern buildings, even in the regions of high seismic risk. Composite columns combines the advantages of both steel and concrete namely light weight and high strength of steel, speed of construction and stiffness, damping and inherent mass of concrete. 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 sub-sea 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.

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 FRP types (Carbon Fibre Reinforced Polymer (CFRP), Glass Fibre Reinforced Polymer (GFRP)), number of FRP layers (2, 4 and 6), spacing between the FRP strips (25mm, 50mm and 100mm) and length of columns (1m, 2m and 3m).The non -linear static analysis is carried out in order to determine the deformation, axial stress and strain of different models.

FINITE ELEMENT MODELLING

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 k N/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/mm^2. The density of concrete is 23 kN/m^3.

iii. CFRP: Fibre with a stiffness value of 230 kN/mm^2 and density of 1800 N/mm^2 is used. Poisson's ratio is assumed as 0.1.

iv. GFRP: Fibre with a stiffness value of 80 kN/mm^2 and density of 1800 N/mm^2 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).

MODELLING

Eighteen CFDST column with FRP wrapping were modelled in ANSYS Workbench 16 having different column height, spacing, number of layers and types of FRP strips. FE Model of CFDST column wrapped with FRP for different spacing, number of layers of FRP strips and height of the column is shown in fig 4.1, 4.2 and 4.3 respectively

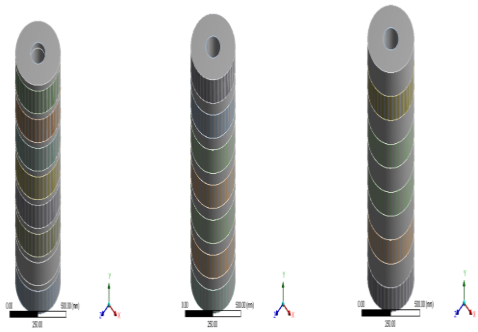

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Fig 3.1 CFDST column wrapped with FRP for different spacing (i) 25mm (ii) 50mm (iii) 100mm

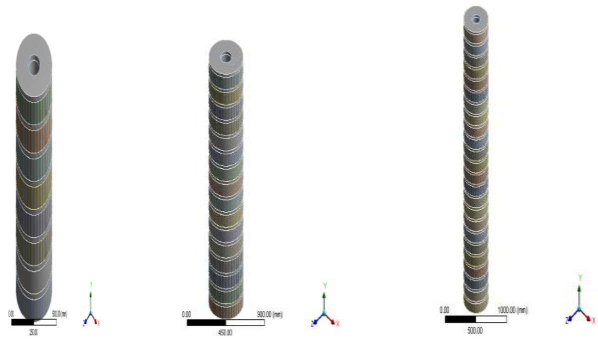

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Fig 3.2 CFDST column wrapped with FRP for different height (i) 1000mm (ii) 2000mm (iii) 3000mm

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 FRP for different spacing and number of FRP strips and height of column is shown in fig: 4.3, fig: 4.4 and fig: 4.5 respectively.

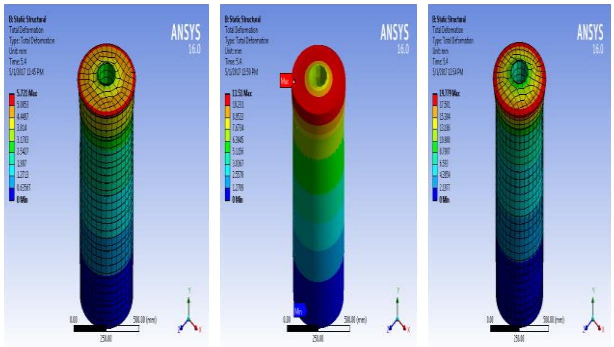

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Fig 3.3 CFDST column wrapped with FRP for different spacing (i) 25mm (ii) 50mm (iii) 100mm

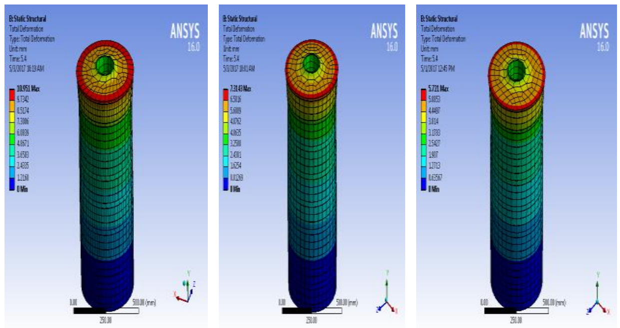

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Fig 3.4 CFDST column wrapped with FRP for different number of layers (i) 2 (ii) 4 (iii) 6

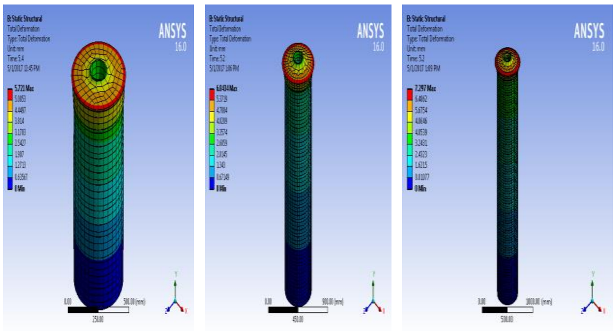

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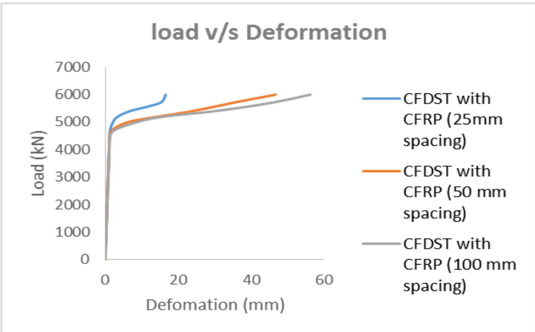
Fig 3.5 CFDST column wrapped with FRP for different height of column (i) 1m (ii) 2m (iii) 3m

RESULTS AND DISCUSSIONS

4.1 Effect of spacing of FRP strips

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



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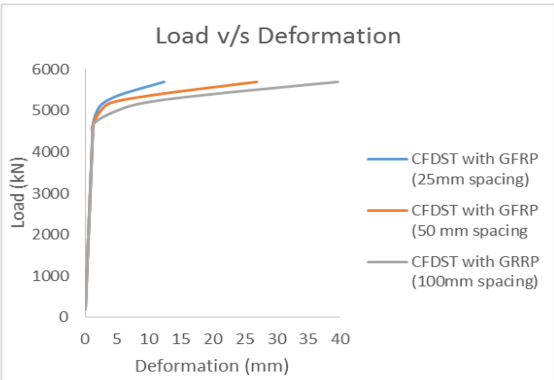


Fig 4.1 load deformation graph (i) CFDST column with varying spacing of CFRP strips (ii) CFDST column with varying spacing of GFRP strips

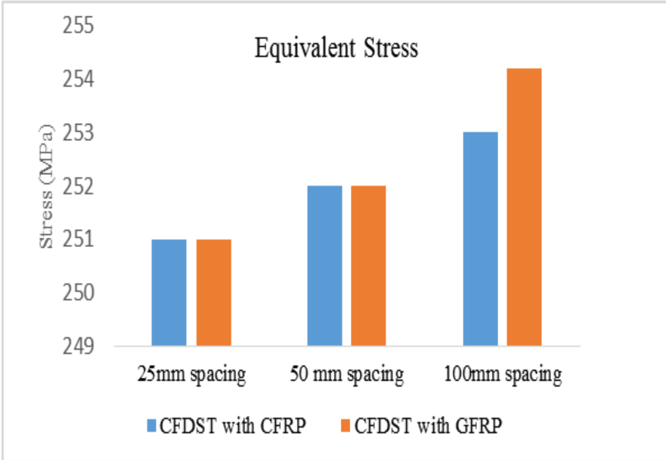
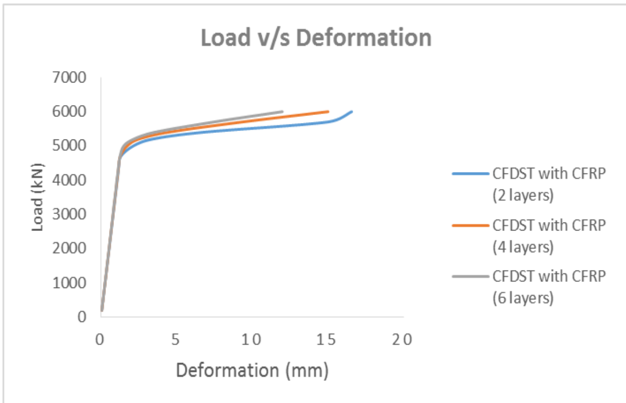


Fig 4.2 Equivalent Stress CFDST column with varying spacing of FRP strips

Fig 4.1 shows the load deformation graph of CFDST column with different spacing of CFRP and GFRP strips. Graph shown that the deformation increases with the increase in the spacing of both the FRP strips. It is clear from the graph that the CFDST column wrapped with CFRP strips at 25mm spacing shows lesser deformation. This is of the increase in the bonding area between the CFST column and FRP strips for 25mm spacing. The CFDST column wrapped with CFRP shows lesser deformation compared to CFDST column wrapped with GFRP strips. Fig 4.2 shows the equivalent stress value of CFDST column with with different spacing of CFRP and GFRP strips. The stress value increases with increase in spacing of FRP strips

4.2 Effect of number of layers of FRP strips

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



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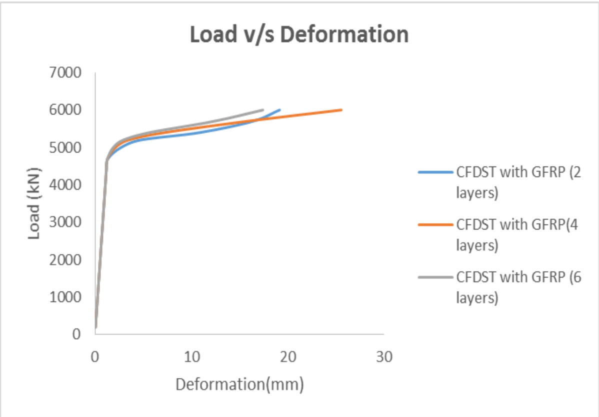

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Fig 4.3 Load deformation graph (a) CFDST column with varying number of CFRP layers (b) CFDST column with varying number of GFRP layers

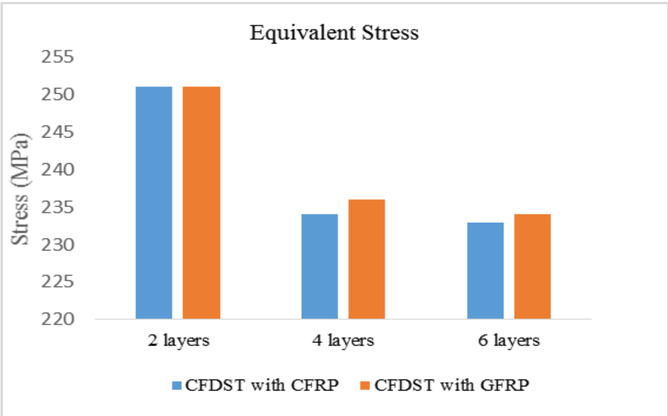
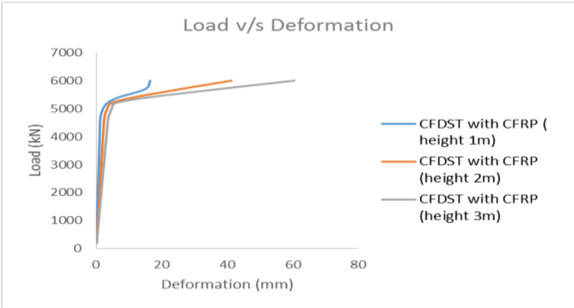


Fig 4.4 Equivalent Stress value of CFDST column with varying number of FRP layers

Fig 4.3 shows the load deformation graph of CFDST column with different number of CFRP and GFRP strips. Graph shown that the deformation decreases with the increase in the number of both the FRP strips. It is clear from the graph that the CFDST column wrapped with 6 number of FRP strips shows lesser deformation.This is because of the restraining effect by FRP against deformation. The deformation is lesser for CFDST column wrapped with CFRP strips compared to CFDST column wrapped with GFRP wrapping. Fig 4.4 shows the equivalent stress value of CFDST column with different number of CFRP and GFRP layers. The stress value decreases with increase in number of layers.

4.3 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. The spacing and number of FRP strips are taken as 25 mm and 2.



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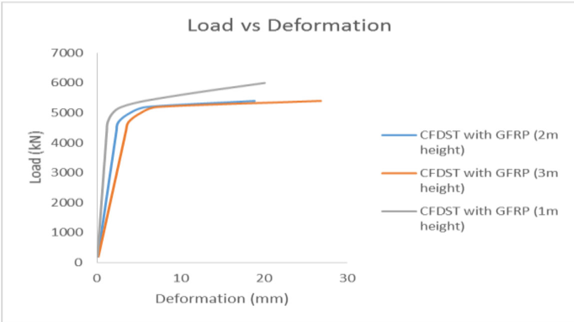

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Fig 4.5 load deformation graph (a) CFDST column with varying height of column wrapped with CFRP (b) CFDST column with varying height of column wrapped with GFRP

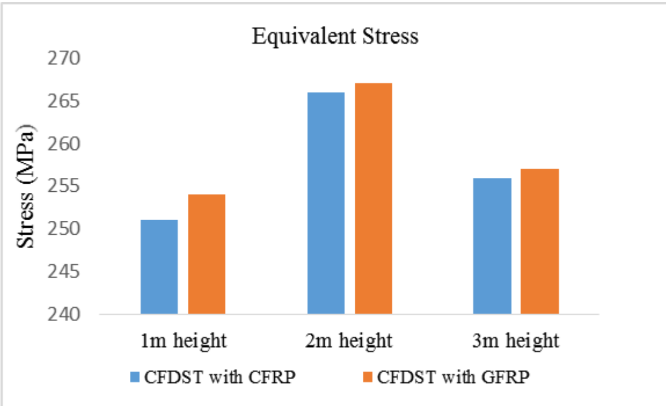

Fig 4.6 Equivalent Stress value of CFDST column with varying height of column wrapped with FRP

Fig 4.5 shows the load deformation graph of CFDST column with different height of column. Graph shown that the deformation decreases with the increase in the height of column but the failure is ductile. The deformation increases gradually for 3m height column and hence shows sufficient warning. The deformation is lesser for CFDST column wrapped with CFRP strips compared to CFDST column wrapped with GFRP wrapping. Fig 4.6 shows the equivalent stress value of CFDST column with varying height of column wrapped with CFRP and GFRP strips. The stress value increases with increase in height of the column up to 2metre and there after the stress value decreases.

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, types of FRP strips (CFRP, GFRP), number of FRP strips , hollow section ratio and height of column) were done and following conclusions were made.

i. CFDST column wrapped with FRP strips at 25 mm spacing shows lesser deformation compared to CFRP strips at 50 mm and 100 mm.
ii. The stress value increases with increase in spacing of FRP strips.
iii. CFDST column wrapped with 6 number of FRP strips shows lesser deformation than that of CFDST column wrapped with 2 and 4 number of FRP strips. Thus, the deformation decreases with increase in number of FRP layers.
iv. The stress value decreases with increase in number of FRP layers.
v. The deformation increases gradually for CFDST column wrapped with FRP strips of 3 m height than columns with 1m and 2m heights and hence it shows ductility.
vi. The stress value increases with increase in height of column.
vii. The deformation is lesser for CFDST column wrapped with CFRP than CFDST column wrapped with GFRP.

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