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Numerical Study on Axial Behaviour of Concrete Filled Double Skin Steel Tubular (CFDST) Column with Cross Helical FRP Wrappings

Anna Skaria [1] and Mariamol Kuriakose [2]
[1]PG student, Department of Civil Engineering, St. Joseph's College of Engineering and Technology, Palai, Kottayam, Kerala, India.
[2]Assistant professor, Department of Civil Engineering, St. Joseph's College of Engineering and Technology, Palai, Kottayam, Kerala, India.
Email: annaskaria16@gmail.com

Abstract. Composite columns offers many structural benefits and widely used in civil engineering structures. CFDST consist of inner and outer steel tubes, and concrete sandwiched in between tubes. The steel tubes and concrete work together well and integrity of steel concrete interface is maintained. Steel tubes in inner and outer can acts as permanent formwork and primary reinforcement. Steel tubes provides a confinement effect to concrete and in turn concrete prevents the inward buckling of tubes. As there is deteriorations due to ageing and corrosion strengthening techniques are used. Strengthening can be done by using fibre reinforced polymer (FRP) as an external reinforcement. This paper aims to study about the load carrying capacity of fibre reinforced CFDST columns under axial load using ANSYS 16.2 (Workbench) software. The modeling of CFDST columns were studied with variation in angle (40°, 45°,50°,60°), material change and thickness change of FRP sheets.

Keywords- CFDST, strengthening, axial load, external reinforcement.

1. Introduction

Composite columns have the potential of becoming a part of structural members in low rise and high rise buildings, as it utilize the advantages of both concrete and steel. Due to their excellent static and earthquake resistant properties, such as high strength, high durability, large energy absorption capacity, bending stiffness, fire performance along with favorable construction ability concrete filled steel tubular (CFST) columns are increasingly used in construction industry. The composite action of steel and concrete makes the concrete filled tubular (CFT) columns better than the standard steel or reinforced concrete columns. These potential benefits of composite action largely depends on the steel-concrete interface.

CFDST columns are another advancement of CFT structures in which concrete is sandwiched between steel tubes. The in-filled concrete prevents the inward buckling of concrete while steel tube prevents the lateral deformation of concrete. CFDST have properties similar to that of CFT columns but in addition they are lighter, stronger and posses more energy absorption capacity. From the environmental point of view, CFDST uses less concrete, and therefore more sustainable. Steel tubes provided inside can acts as reinforcement as well as formwork, thereby reducing the cost of construction. The inner cavity can be used for placing power cables, drainage pipes, telecommunication lines etc.

In recent years, it is observed that many deteriorations are occurring on the CFDST structures due to ageing, cracking, yielding, large deformation. Therefore, necessary strengthening techniques such as use of fibre reinforced polymer (FRP) are applied. FRP have high tensile strength, more ductility, corrosion resistant and in addition they will not cause any alteration to the appearance of the members. From the past researchers, the use fibres as strengthening material will significantly improves the strength and stiffness of steel tubular members. A numerical study has been carried out to investigate the suitability of cross helical fibre reinforced polymer fabrics in strengthening of CFDST members under axial load.

2. Scope

In this paper, the behavior of CFDST columns surrounded by FRP layers under axial load were studied. The FRP is provided as cross helical strips circumscribed about the column. The parameters used in this study is change in fibre material (glass fibre reinforced polymer(GFRP),carbon fibre reinforced polymer(CFRP), basalt fibre reinforced polymer(BFRP), aramid fibre reinforced polymer(AFRP), change in helix angle(40°,45°,50°,60°)and change in thickness (0.3mm, 0.6 mm, 0.9 mm).The non linear static analysis is carried out to determine the deformation, axial stress and strain of different models.

3. Validation

3.1 Experimental test

CFDST column specimens with outer diameter 205.3 mm, inner diameter 140.3 mm and a height of 400 mm were casted. These specimens were then tested under monotonic axial compression. LVDTs were used to obtain the axial deformation. All compression tests were carried out with an MTS machine of displacement control rate of 0.24 mm/min. All tests data, including loads, strains and displacement were recorded simultaneously by a data logger [1].

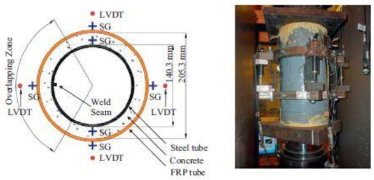

Fig 1.Experimental setup

3.2 Finite element model

Finite element model was developed using finite element analysis software ANSYS 16.2. The cross section was modeled by using circle and column geometry is obtained by extruding it. Bottom end is fixed with no degrees of freedom and load is applied axially at top.

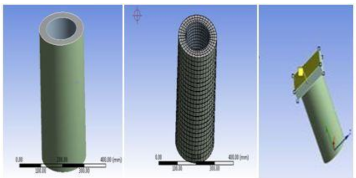

Fig 2. Numerical model

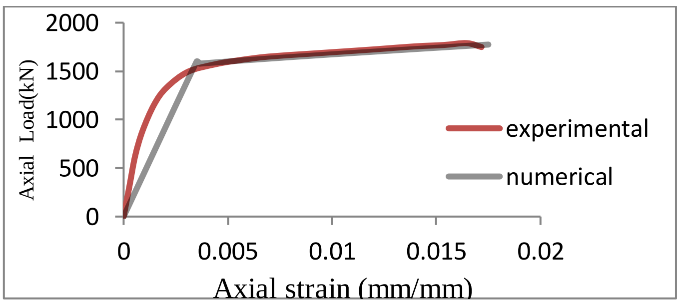

Fig 3. Validation curve

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Fig 3 shows the validation curve. Both the experimental and numerical curves were found to be in good agreement. Therefore, numerical validation is considered to be acceptable.

4. Finite element analysis

4.1 Material specification

The material properties of concrete, steel and fibre reinforced polymer (FRP) are shown in table 1, table 2 and table 3 respectively.

Table 1. Material properties of concrete

Density	2400 kg/m^3
Poisson's ratio	0.18
Elastic modulus	31622.7 N/mm^2
Characteristic compressive strength	40N/mm^2

Table 2. Material property of structural steel

Density	7850 kg/m^3
Poisson's ratio	0.30
Elastic modulus	1.9x10^5 N/mm^2
Yield strength	250 N/mm^2

Table 3. Material properties of FRP

Properties	GFRP	CFRP	BFRP	AFRP
Density	2000 kg/m^3	1700 kg/m^3	2650 kg/m^3	1400 kg/m^3
Elastic modulus N/mm^2	Ex-45000 Ey-10000 Ez-10000	Ex-240000 Ey-4830 Ez-4830	Ex-37700 Ey-5237 Ez-5237	Ex-13600 Ey-1482 Ez-1482

4.2 Meshing

Different grid sizes are considered to reach to appropriate mesh size. The adopted element meshing is shown in fig 4.

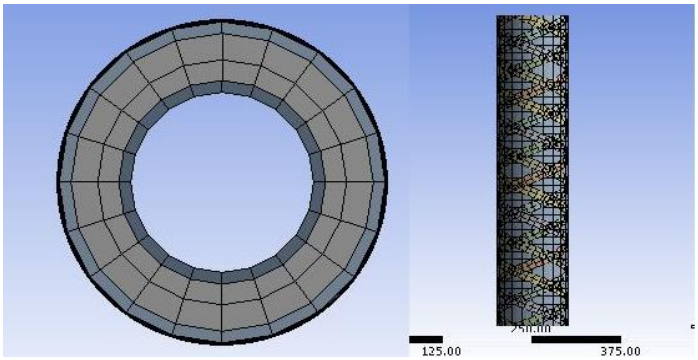

Fig 4. Meshed specimen

4.3 Geometry

All CFDST columns selected are 600 mm in height, outer diameter of 91.5 mm and inner diameter of 62.543 mm, thickness of steel tube is 3.6 mm. Hard contact is used in both normal and tangential direction of the contact between steel tube and concrete, and outer steel tube and FRP.

4.4 Boundary conditions

The end plate is assumed to be an elastic rigid plate. An axial load is applied to the top end plate along the respective axis and other end is provided as fixed support.

4.5 Modeling

About 6 numbers of CFDST columns are modeled. Out of this one model is considered as control specimen, without the FRP wrapping and 4 other models are prepared with FRP wrapping cross helically provided with an angle of 40° , 45°, 50°, 60° and are shown in fig 5, fig 6, fig 7, fig 8, fig 9. Table 4 shows the details of the model created.

Table 4. Model details

Model no	Designation	FRP wrappings	Helix angle	Pitch length
1	Control specimen	-	-	-
3	Model-40	Cross helical	40	241.207
4	Model-45	Cross helical	45	287.46
5	Model-50	Cross helical	50	342.58
6	Model-60	Cross helical	60	497.89

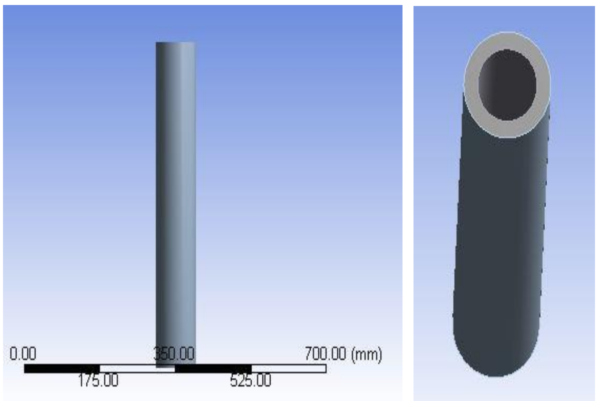

Fig 5. Control specimen

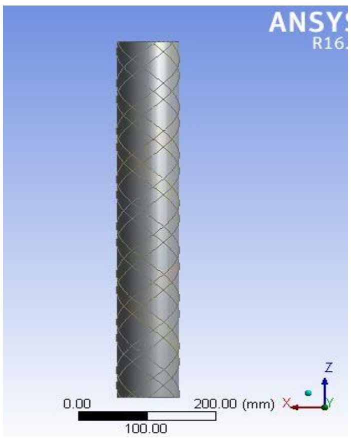

Fig 6. Model- 40

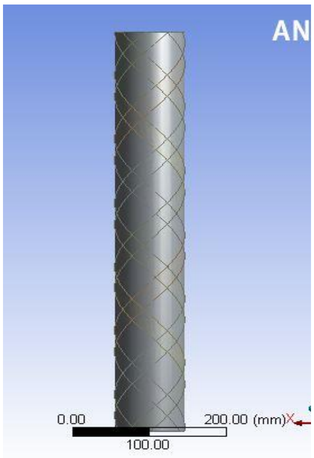

Fig 7. Model- 45

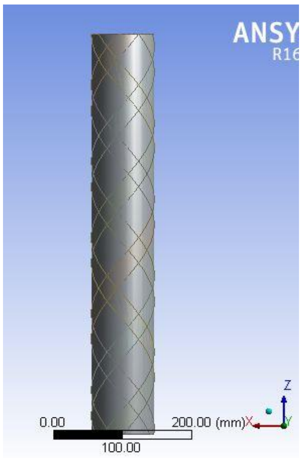

Fig 8. Model-50

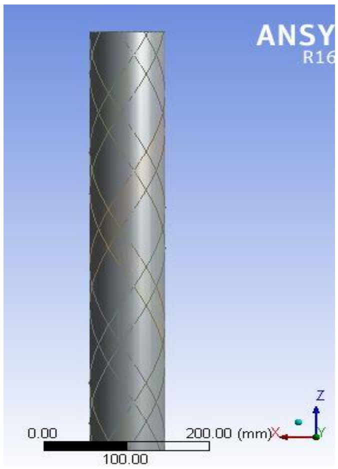

Fig 9. Model-60

5. Analysis

Static structural analysis in ANSYS gives the deformation, force reaction and stresses. Fig 10, fig 11, fig 12, fig 13, fig 14 shows the deformation of control specimen and specimen with FRP wrapping with various helix angle.

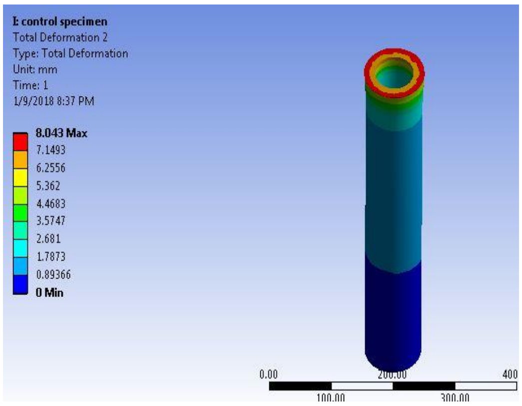

Fig 10. Deformation diagram without FRP

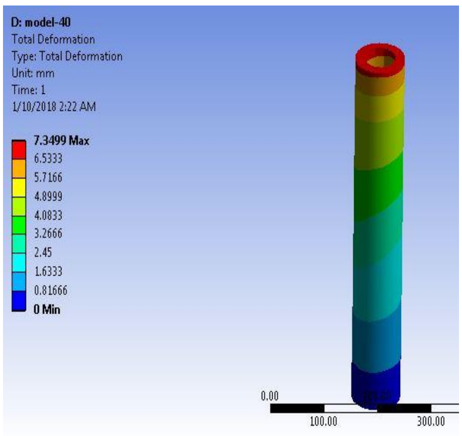

Fig 11. Deformation diagram of model-40

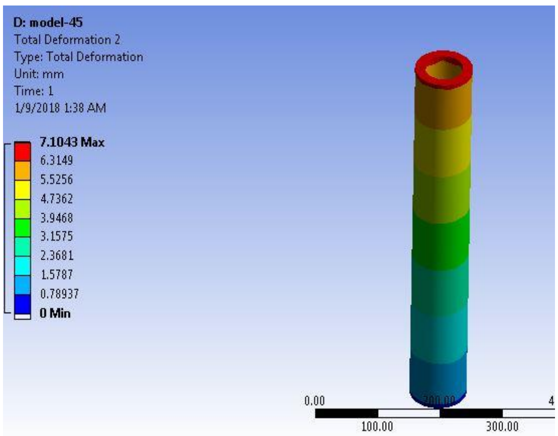

Fig 12. Deformation diagram of model-45

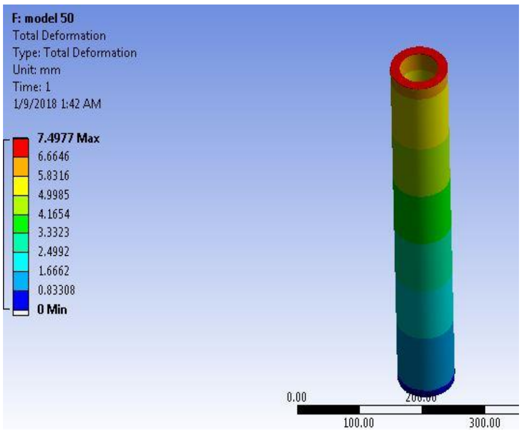

Fig 13. Deformation diagram of model-50

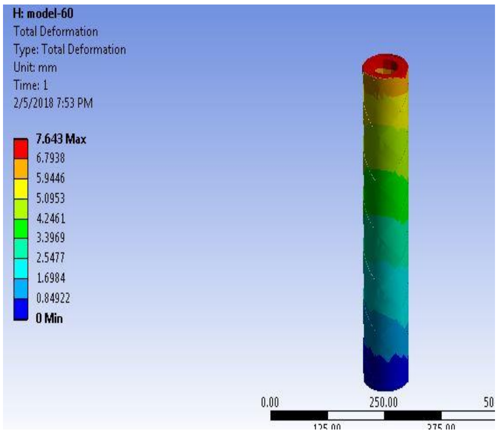

Fig 14. Deformation diagram of model-60

6. Results and discussions

6.1 Effect of change in helix angle

The FRP is provided with varying the helix angle 40°, 45°, 50° and 60°. The yielding load and ultimate load carrying capacity is studied.

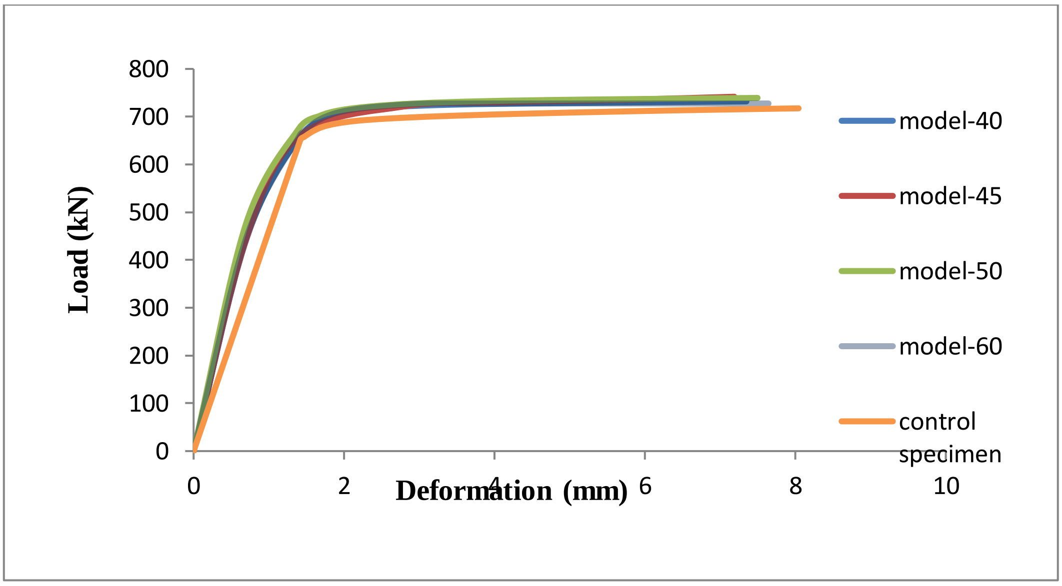

Fig 15. Load-deformation graph

Fig 15 shows the load deformation graph for CFDST columns with different helix angle of FRP strips. Graph shows that the model with FRP with helix angle 45° have a higher yield point compared with the control specimen. The CFDST column with FRP strip at an angle of 45° shows lesser deformation and a higher stiffness. This is mainly due to the confinement effect by the FRP strip.

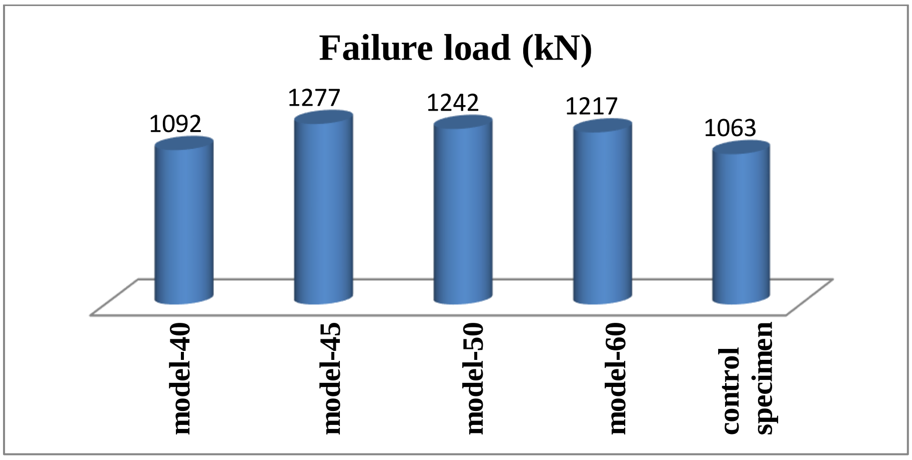

Fig 16. Failure load for different specimens

Fig 16 shows the failure load of CFDST columns determined by using failure criteria. The load carrying capacity increases with an increase in the helix angle up to 45° and then decreases. The specimen with FRP of helix angle 45° has higher load carrying capacity. The external wrapping of FRP strips provides external confinement pressure effectively and enhances the load carrying capacity.

6.2 Effect of change in material

The material of FRP is changed and the materials used are glass fibre reinforced polymer(GFRP), carbon fibre reinforced polymer(CFRP), basalt fibre reinforced polymer(BFRP) and aramid fibre reinforced polymer (AFRP). For study helix angle is kept constant as 45°. The failure load determined by using equivalent stress failure criteria for different material is shown in Fig. 17.

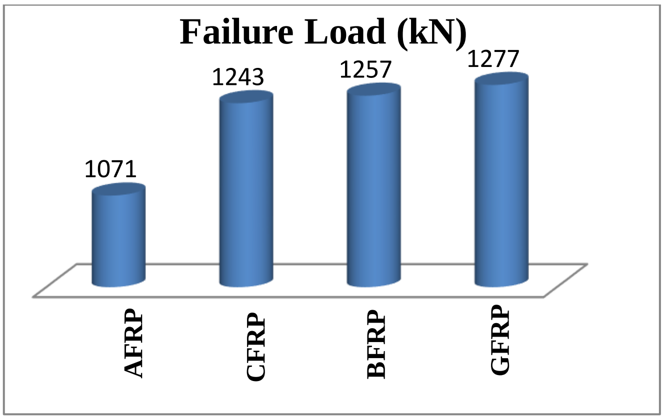

Fig 17. Failure load for different material

6.3 Effect of change in thickness of FRP

The thickness of FRP is varied and is as 0.3 mm 0.6mm and 0.9mm. The helix angle is kept constant (45°) for the study. Fig 18 shows the failure load by different thickness.

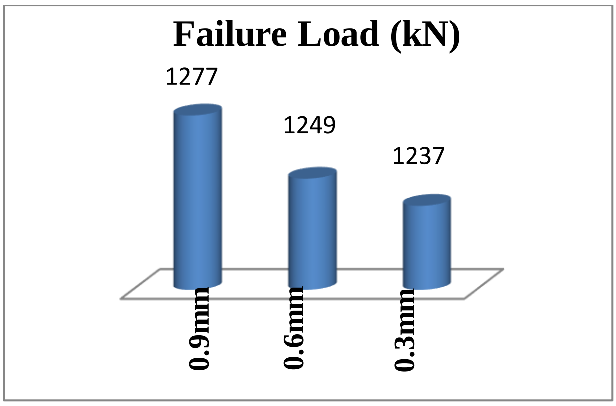

Fig 18. Failure load for different thickness

7. Conclusion

The present study is an investigation of the axial behavior of concrete filled double steel tubular columns with FRP wrappings. Based on the results obtained from study, following conclusions can be obtained.

- The load bearing capacity of columns with FRP wrapping with helix angle 45° is greater than the specimen without wrappings. This is mainly due to the proper confinement.
- The load carrying capacity increases up to 45° and then decreases.
- Load–deformation graph indicates that the stiffness will be higher than control specimen.
- The application of GFRP strips increases axial load carrying of CFDST columns compare with BFRP, CFRP and AFRP.
- With the increase in the thickness the ultimate load carrying capacity also increases.
- Stress concentration is more at the interface between steel and concrete and it does not have any adverse change with change in helix angle.
- It can be concluded that the strength of the CFDST column can be increased by providing FRP wrappings.

8. References

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