ANALYTICAL STUDY ON CONCRETE FILLED STEEL TUBULAR COLUMNS WITH BFRP WRAPPING UNDER AXIAL LOAD

Silgy Salim[1], Pinky Merin Philip[2]

1PG Student, Civil Engineering, Saintgits College Of Engineering, Pathamuttom,Kottayam,Kerala,India.
2Assistant professor, Civil Engineering, Saintgits College Of Engineering, Pathamuttom,Kottayam,Kerala,India.

Abstract - *Composite columns have been widely used in the construction industry mainly due to its high strength, durability, ease of construction and cost saving. Concrete Filled Steel Tubular (CFST) columns combine the structural properties and advantages of both steel and concrete materials. As the steel tubes eliminates the need of formwork, it leads to accelerated construction and cost saving. The steel tube provides confinement to the concrete infill, which in turn acts as a support to the steel tube and prevents local inward buckling of the section. But these members can get deteriorated due to corrosion and ageing. New materials and strengthening techniques need to be introduced to combat this problem. Strengthening methods using fiber reinforced polymer (FRP) can eradicate the difficulties caused due to traditional strengthening techniques like section enlargement and external wrapping using steel plates. This paper aims to study the load carrying capacity of Basalt Fiber Reinforced Polymer (BFRP) wrapping in strengthening of CFST long columns under axial load by using ANSYS 17.0 (WORKBENCH) software. The modelling of CFST columns with BFRP wrapping were studied with variation in parameters such as spacing of sheets (20mm,30mm,40mm) and effect of fibre orientation. 0° and 45° angle orientation is provided for each variation in spacing of the FRP sheets.*

Key Words: Buckling, BFRP, CFST, Finite Element Analysis ,Strengthening.

1. INTRODUCTION

The Concrete Filled Steel Tubular (CFST) columns are evolved as an alternative to the conventional techniques in the recent years .CFST members utilize the advantages of both steel and concrete materials. It comprises a steel hollow section of square, rectangular or circular shape filled with plain or reinforced concrete. Steel sections with concrete infill are being commonly used as structural members, because filling the steel section with concrete increases both its strength and ductility without increasing the section size. Researchers found that the CFST column system has many advantages compared with the ordinary steel or the reinforced concrete system due to its high-strength, stiffness, ductility, and better seismic resistance. Since steel confines the concrete, the use of formwork can be discarded. The concrete and steel are combined in such a fashion that the advantages of both the materials are utilized effectively in composite column .The potential economical advantages of concrete-filled steel columns (CFST) in tall buildings could lead to significant savings of steel usage in comparison with pure steel buildings. The structural behavior of CFST members was mainly affected by the difference between the Poisson's ratios of the steel tube and concrete core. In the initial level of loading, the Poisson's ratio for the concrete is decrease than that of steel. Thus, the steel tube has no confining effect at the concrete core.

1.1 Fiber Reinforced Polymer(FRP)

Fiber reinforced polymer is composed of fibers embedded in a resin matrix, and is characterized by its high strength-to weight ratio, high corrosion resistance, and ease of installation. It is well known that FRPs have limited fire resistance because of the low glass transition temperature of their epoxy resins. FRP material in itself is a composite that consists of fibers, which are chosen from a wide range of materials such as carbon, aramid and glass, which reinforce the polymer matrix. Some of the materials used for the polymer matrix are polyester thermosetting plastic, epoxy and phenol formaldehyde resins. The FRP material composes of mainly four elements. First, the reinforcing fibers are used to carry and withstand all the applied loads and stresses. Second, the resins are added to allow for load transformation among the fibers in addition to gluing these fibers together and shielding environmental effects. Third, the modifiers are additives to enhance the polymers performance and to increase its lifetime. Fourth, the fillers replace the unneeded resin in the composition and to control the final product's shrinkage as well as increase its cracking resistance.

The basalt fiber is now being a popular choice for the material scientists and research fellows for the replacement of carbon fiber and steel due to its high stiffness, low cost and low elongation at break. Basalt is a material made from extremely fine fibers of basalt which constitute the minerals include plagioclase, pyroxene, and olivine. Basalt of high acidity (over 46% silica content) and low iron content is considered desirable for fiber production .Compared to carbon and aramid fiber ,it has higher oxidation resistance ,higher radiation resistance, higher shear strength.

1.2Buckling Analysis

FEA is widely accepted in almost all engineering disciplines. The method is often used as an alternative to the experimental test method set out in many standards. The technique is based on the premise that an approximate solution to any complex engineering problem can be reached by subdividing the structure/component into smaller more manageable (finite) elements. In the present study ,nonlinear three dimensional finite element analysis software ANSYS.17 is used for analysis of research model.

Linear (eigenvalue) buckling analysis: predicts the theoretical buckling load of an ideal linear elastic structure. In linear buckling analysis, the structural eigenvalues for the given system loading are computed. It is also called as classical Euler buckling analysis. It is a fast analysis. The buckled mode shapes can be used as initial geometric imperfection for a nonlinear buckling analysis.

Nonlinear buckling analysis: Gives lower buckling loads than linear analysis. A nonlinear buckling analysis employs a nonlinear static analysis with gradually increasing loads to seek the load level at which a structure becomes unstable. Using a nonlinear buckling analysis, we can include features such as initial imperfections, plastic behavior, contact, large-deformation response, and other nonlinear behavior. Imperfections and nonlinear behavior prevent most real world structures from achieving their theoretical elastic buckling strength.

1.3 Objectives Of The Study

- To study the nonlinear structural behavior of CFST columns with FRP wrapping under axial loads by using finite element anaysis in ANSYS 17.0.
- Comparison of CFST columns without wrapping and with Basalt Fiber Reinforced Polymer (BFRP) wrapping in strengthening of CFST long columns by buckling analysis.
- Compare the load carrying capacity of CFST control specimen with BFRP wrapped CFST columns.
- Study the effect on maximum deflection and ultimate load on three different wrapping space (20 ,30& 40mm).And two orientation(0° & 45°) .
- Compare the results of BFRP, and find out which spacing and orientation is better in strengthening.

2. FINITE ELEMENT MODELLING

2.1 Engineering Data

The material properties of concrete, steel and BFRP are explained here.The grade of concrete used to fill the steel tube is M35.

Table -2.1: Material properties of concrete

Linear Isotropic	
Modulus of Elasticity (Mpa)	29580
Poisson ratio	0.18

Table-2.2: Material properties of steel

Linear Isotropic	
Modulus of Elasticity (MPa)	$2*10^5$
Poisson ratio	0.3
Bilinear Isotropic	
Yield stress of steel	250
Tangent modulus (MPa)	1450

BFRP composites are orthotropic material. Hence their properties are not the same in all directions. Table 2.3 shows material properties of BFRP.

Table-2.3: Material properties of BFRP

Elastic modulus of elasticity in x direction MPa	Ex	37700
Elastic modulus of elasticity in y direction MPa	Ey	5237
Elastic modulus of elasticity in z direction MPa	Ez	5237
Poisson's ratio in x direction	PRXY	0.2
Poisson's ratio in y direction	PRYZ	.21
Poisson's ratio in z direction	PRXZ	.21
Shear modulus in x direction MPa	Gxy	2050
Shear modulus in y direction MPa	Gyz	3630
Shear modulus in z direction MPa	Gxz	3630

2.2 Geometry

All CFST columns were 2600mm long, with 200mmx200mm cross section and thickness of steel tube is 5mm.

2.3 Modelling

A total of 7 CFST columns are modelled. In this one CFST column is modelled as control specimen,i,e column without

FRP .The remaining six are strengthened with Basalt Fiber Reinforced Polymer(BFRP) sheets in different wrapping space includes 20mm ,30mm and 40mm and orientation angle, 0° and 45°.The BFRP sheets are bonded externally in 100mm width above the CFST column. Table 2.4 shows designation of total models.

Table-2.4: Designation of CFST columns

No:	Specimen	Designation
1	Control CFST column	CTRL
2	CFST column with BFRP sheets wrapped at 20mm spacing in 0° orientation	CFST-B1-20-0°
3	CFST column with BFRP sheets wrapped at 30mm spacing in 0° orientation	CFST-B1-30-0°
4	CFST column with BFRP sheets wrapped at 40mm spacing in 0° orientation	CFST-B1-40-0°
5	CFST column with BFRP sheets wrapped at 20mm spacing in 45° orientation	CFST-B1-20-45°
6	CFST column with BFRP sheets wrapped at 30mm spacing in 45° orientation	CFST-B1-30-45°
7	CFST column with BFRP sheets wrapped at 40mm spacing in 45° orientation	CFST-B1-40-45°

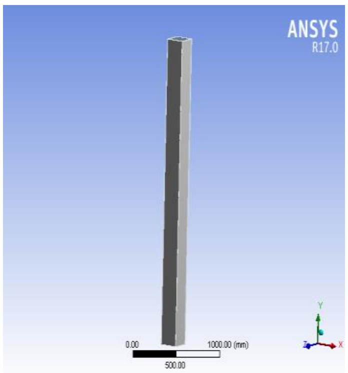


Fig-2.1: control CFST

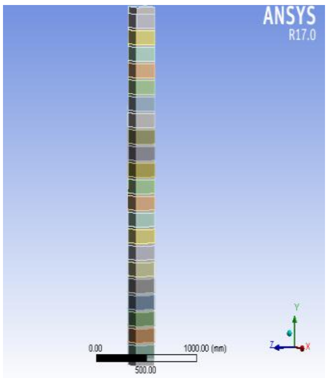


Fig -2.2:Model of CFST-B1-20-0°

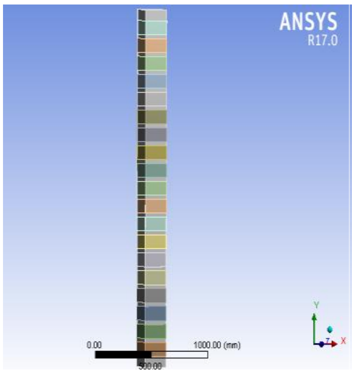


Fig -2.3: CFST-B1-30-0°

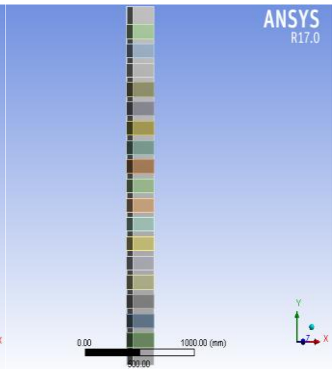


Fig -2.4: CFST-B1-20-0°

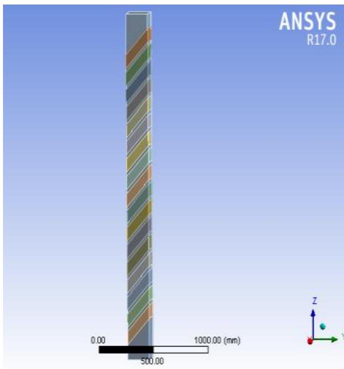


Fig -2.5: CFST-B1-20-45°

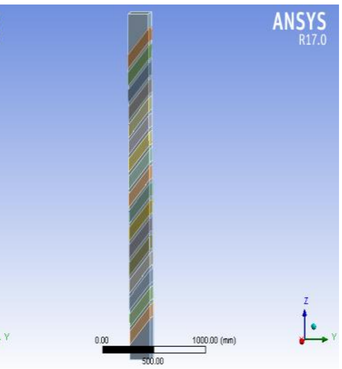


Fig -2.6: CFST-B1-30-45°

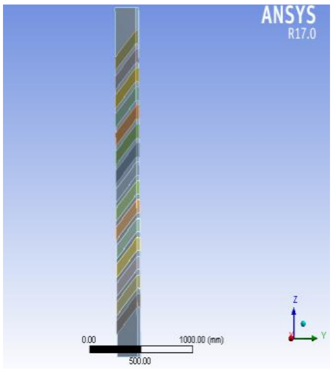


Fig -2.7: CFST-B1-40-45°

2.4 Meshing

The model is divided into number of Finite elements called mesh. Here a mesh size of 25mm is provided for all the CFST columns.Fig2.8 show meshed CFST column.

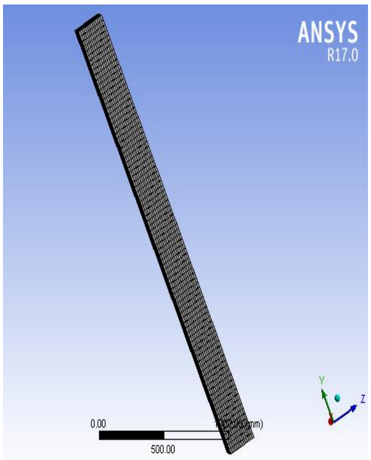


Fig-2.8: Meshed CFST column

2.5 Setup

The supports are modeled to create both pinned-pinned end condition in which one end is hinged and the other end is roller.Axail load is applied at top of he CFST column.

3.ANALYSIS

In this problem static structural non linear buckling analysis is considered.Static structural analysis gives different types of stress,strain and deformation of that particular element.Axial load and supports are assigned to the column and the defomation ,equivalent von-mises stress and force reaction are obtained from ANSYS Workbench.

4.RESULTS AND DISCUSSION

One CFST column is taken as control specimen without FRP wrapping.The buckling load,deflection and equivalent stress sre shown in fig -4.1,fig-4.2,fig4.3 respectively.

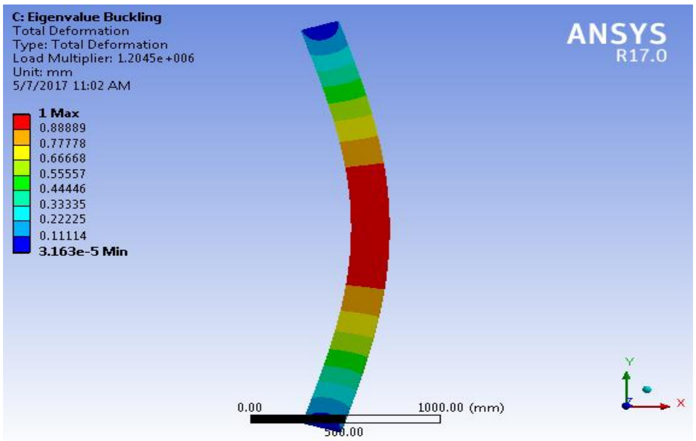


Fig-4.1 : Buckling load

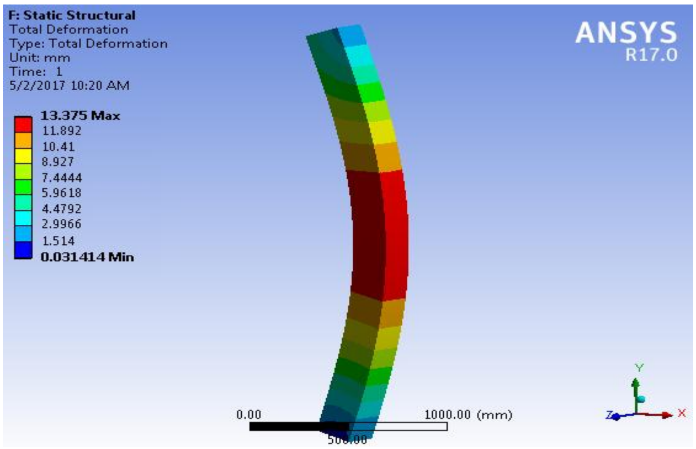


Fig -4.2 :Deformation Diagram

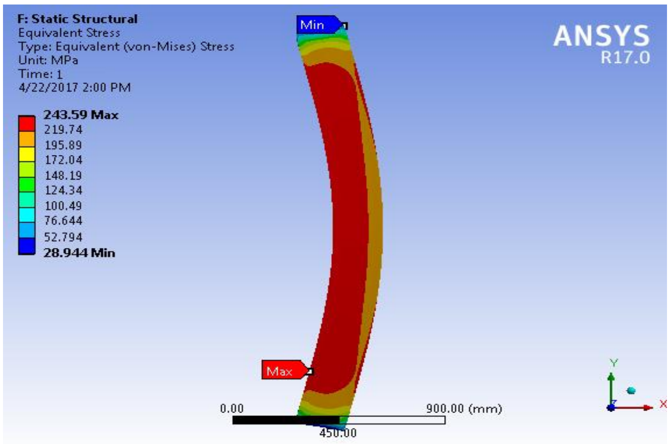
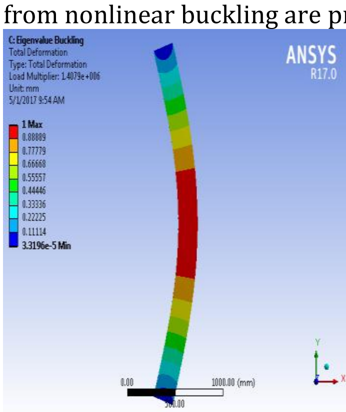


Fig-4.3 :Equivalent stress

Buckling analysis to find the effect of CFST column with BFRP wrapping.

4.1 CFST column with BFRP sheets wrapped in 20mm spacing at 0° oreintation-CFST-B1-20-0°.Ultimate load and mode shape from linear buckling analysis and deformation from nonlinear buckling are presented below



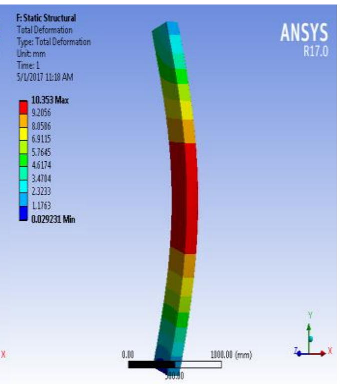


Fig-4.4: Buckling load **fig-4.5:**Deformation

4.2 CFST column with BFRP sheets wrapped in 30mm spacing at 0° oreintation-CFST-B1-30-0°. Ultimate load and mode shape from linear buckling analysis and deformation from non linear buckling presented below

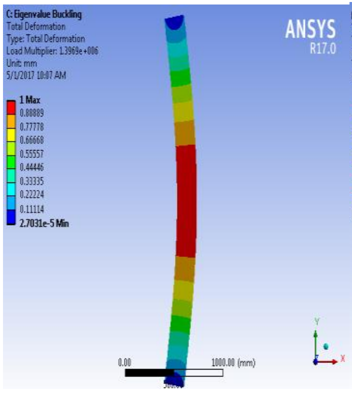


Fig-4.6: Buckling load

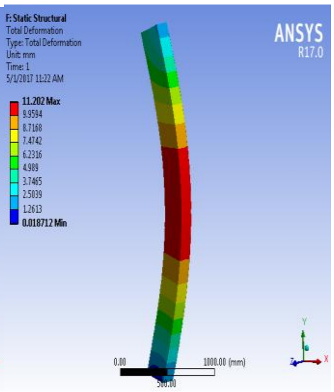


fig-4.7: Deformation

4.3 CFST column with BFRP sheets wrapped in 40mm spacing at 0° oreintation-CFST-B1-40-0°. Ultimate load and mode shape from linear buckling analysis and deformation from non linear buckling presented below

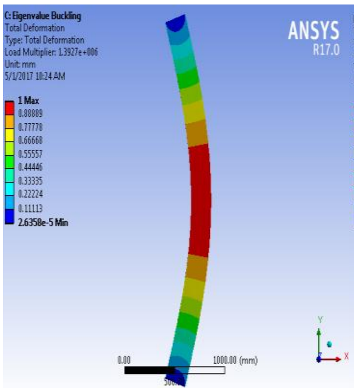


Fig-4.8: Buckling load

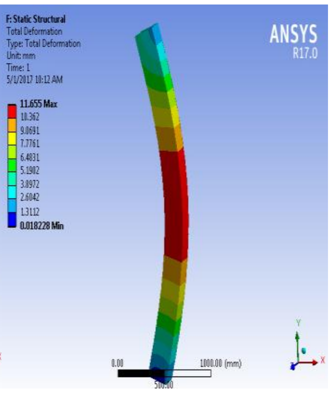


fig-4.9: Deformation

4.4 CFST column with BFRP sheets wrapped in 20mm spacing at 45° oreintation-CFST-B1-20-45°. Ultimate load and mode shape from linear buckling analysis and deformation presented below

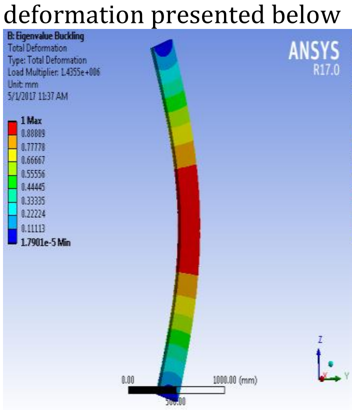


Fig-4.10: Buckling load

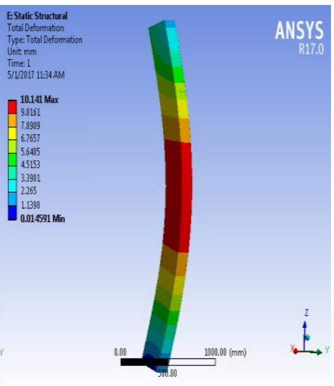


fig-4.11: Deformation

4.5 CFST column with BFRP sheets wrapped in 30mm spacing at 45° oreintation-CFST-B1-30-45°. Ultimate load and mode shape from linear buckling analysis and deformation fron nonlinear buckling analysis are presented below

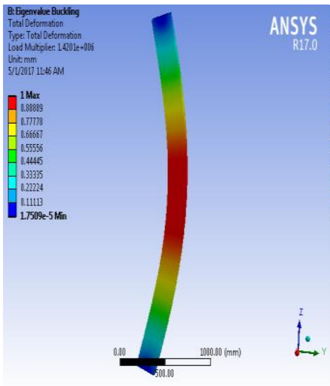


Fig-4.12: Buckling load

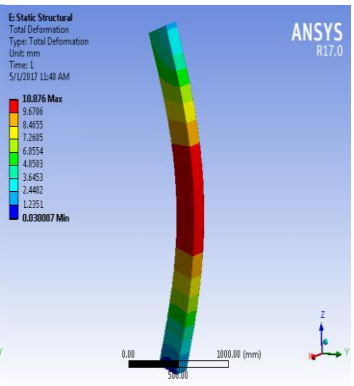


fig-4.13: Deformation

4.6 CFST column with BFRP sheets wrapped in 40mm spacing at 45° oreintation-CFST-B1-40-45°. Ultimate load and mode shape from linear buckling analysis and deformation from nonlinear buckling anlyasis are presented below

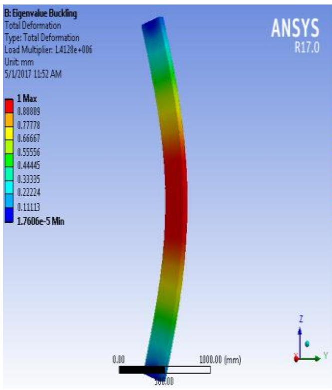


Fig-4.14: Buckling load

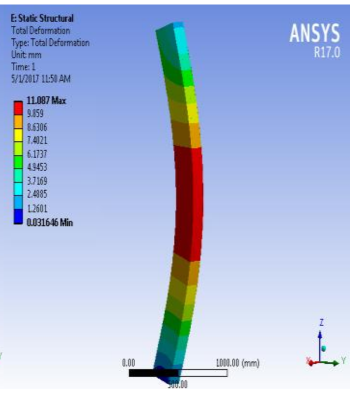


fig-4.15: Deformation

Table -4.1: Results

Designation Of Column	Linear Buckling	Nonlinear buckling		
	Ultimate load (KN)	Ultimate load (KN)	Deflection (mm)	% increase in load
CTRL	1204	1156	13.375	-
CFST-B1-20-0°	1407	1325	10.353	14.6
CFST-B1-30-0°	1396	1308	11.202	13.4
CFST-B1-40-0°	1392	1298	11.655	12.2
CFST-B1-20-45°	1435	1354	10.141	17.12
CFST-B1-30-45°	1420	1342	10.876	16.08
CFST-B1-40-45°	1412	1332	11.087	15.2

Table 4.1 show results of basalt fibre reinforced wrapping in 20mm,30mm, 40mm spacing in 0° and 45° orientation. And comparison is made with CFST column without wrapping.

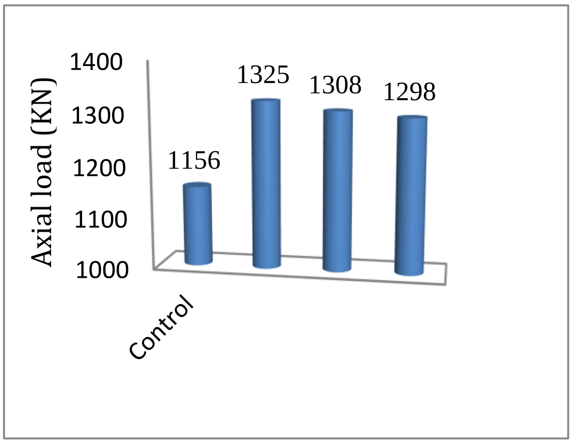


Chart-4.1: Comparison of Axial load of control and BFRP wrapped columns in 0° orientation

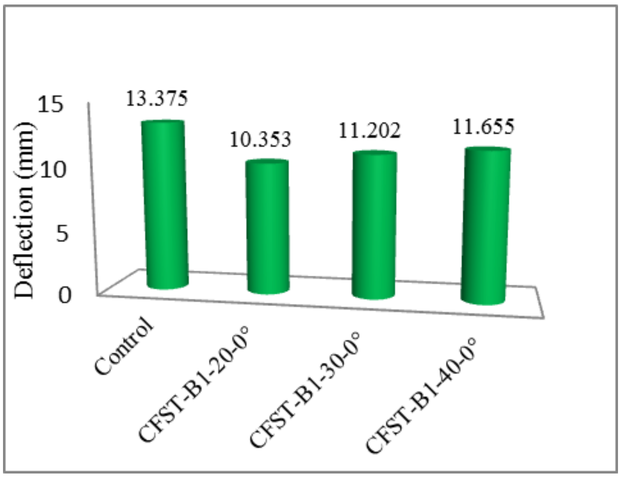


Chart-4.2: Comparison of deflection of control and BFRP wrapped columns in 0° orientation

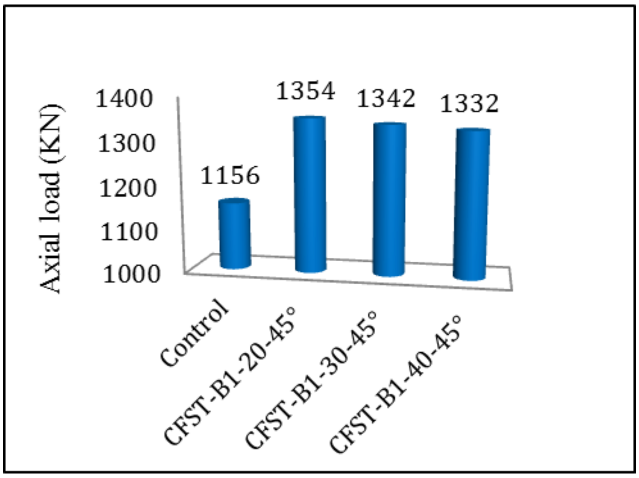


Chart-4.3: Comparison of Axial load of control and BFRP wrapped columns in 45° orientation

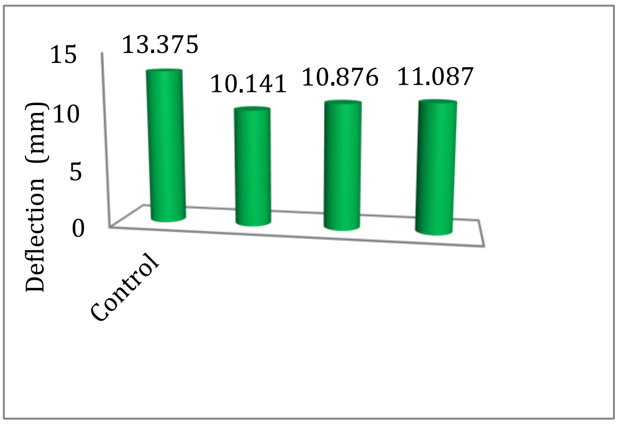


Chart-4.4: Comparison of deflection of control and BFRP wrapped columns in 45 orientation

Table 4.1 summarizes the ultimate load carrying capacity,deflection and % increase in load carrying capacity.From the table 4.1 it is found that compared to control CFST column ,the increase in load carrying capacity of columns CFST-B1-20-0°, CFST-B1-30-0°, CFST-B1-40-0°, CFST-B1-20-45°, CFST-B1-30-45°, and CFST-B1-40-45° are 14.6%, 13.4%, 12.2%, 17.12%,16.08%,15.2%,respectively. By increasing the spacing of wrapping load carrying capacity decreases,because the unwrapped is more and sufficient confining pressure was not provided by the FRP composites. From charts 4.2 & 4.4 it is clear that 20mm spacing shows decrease in deflection value compared with 30mm and 40mm in BFRP wrapping.And the control CFST specimen without FRP shows higher deflection. Comparing with control CFST about 22.5% decrease in deformation showed by CFST column with BFRP wrapped in 20mm spacing (CFST-B1-20-0°)and 24.17% reduction in deflection in the case of CFST column wrapped in 20mm spacing at 45° orientation.

5. CONCLUSIONS

The main conclusions obtained from the analysis are summarized below:

1. The ultimate load carrying capacity is higher for CFST column wrapped with BFRP than the CFST control without wrapping.
2. By increasing the spacing of wrapping ,ultimate load capacity decreases.ie,20mm spacing gives better results than 30mm and 40mm.
3. FRP sheets wrapped in 45°are better in strengthening than 0°.
4. 20mm spacing of BFRP sheet wrapping reduces the deflection by 22.5% in case of CFST-B1-20-0° and 24.17% in case of CFST-B1-20-45°.
5. BFRP sheets with 20mm spacing increases the load carrying capacity by 14.6% in case of CFST-B1-20-0°and 17.12% for CFST-B1-20-45°.
6. BFRP sheets wrapped in 20mm spacing at 45° orientation is the most desirable type of strengthening method of CFST column.

ACKNOWLEDGEMENT

I am thankful to my guide, Asst. Professor, Pinky Merin Philip in Civil Engineering Department for her constant encouragement and through guidance. I also thank my parents, friends and above all the god almighty for making this work complete.

REFERENCES

[1] Campione, G., et al. "Behavior in compression of concrete cylinders externally wrapped with basalt fibers." Composites Part B: Engineering 69 (2015): 576-586.

[2] Lai, M. H., and J. C. M. Ho. "Effect of continuous spirals on uni-axial strength and ductility of CFST columns." Journal of Constructional Steel Research 104 (2015): 235-249

[3]Patil, Bhushan H., and P. M. Mohite. "Parametric Study of Square Concrete Filled Steel Tube Columns Subjected To Concentric Loading." International Journal of engineering Research and Applications 1.4 (2014): 109-112.

[4]Li, G. C., et al. "Nonlinear Finite Element Analysis On Long Columns Of High-Strength Concrete-Filled Square Steel Tube With Inner CFRP Circular Tube Under Axial Load." Advanced Steel Construction 9.2 (2013): 124-138.

[5]Prabhu, G. Ganesh, and M. C. Sundarraja. "Behaviour of concrete filled steel tubular (CFST) short columns externally reinforced using CFRP strips composite." Construction and Building Materials 47 (2013): 1362-1371.

[6]Tao, Zhong, et al. "Nonlinear analysis of concrete-filled square stainless steel stub columns under axial compression." Journal of Constructional Steel Research 67.11 (2011): 1719-1732.