

Numerical Study on Behaviour of Concrete Filled Tubes (CFT) under Static Load

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ABSTRACT: Concrete Filled Tubular columns (CFT) are gaining importance day by day due to several attractive advantages it offer under various environments as compared to normal RC columns. Concrete Filled Steel Tubular columns (CFST) are the most commonly used type of CFT column. Due to the corrosive nature of steel tube, its application is limited in water prone areas. In such situations Concrete Filled FRP Tubes (CFFT) gained its importance due to its excellent corrosion resistance properties. The project focuses on the study of behaviour of CFT columns under static lateral .A comparative study on load deformation behaviour of CFST and CFFT is made. CFFT columns using Carbon Fiber Reinforced Polymer (CFRP) and Glass Fiber Reinforced Polymer (GFRP) is used. Analysis of the deformation behaviour is carried out under ANSYS workbench 16.2 software. The results shows that CFFT column offers best performance under both the given loading condition.

KEYWORDS: Concrete filled tubes (CFT), Concrete filled steel tubes (CFST), Concrete filled FRP tubes (CFFT), Fiber reinforced polymer (FRP), Glass fiber reinforced polymer (GFRP), Carbon fiber reinforced polymer (CFRP), Reinforced concrete (RC)

I. INTRODUCTION

Composite construction can be considered as a great choice of maintaining a proper balance between the advantages it offers and the cost. A wide variety of composite columns are available nowadays, but the concrete filled steel tubular (CFST) sections are the most commonly used one now a days. CFST column consist of a outer periphery steel tube which is filled with concrete a core. Concrete core provides stiffness as well as compressive strength to the tubular column and also reduces the inward local buckling. At the same time, the steel tube acts as longitudinal and lateral reinforcement for the concrete core helping it to resist tension, bending moment and shear and providing confinement for the concrete. CFST system utilizes the compressive strength of the concrete and the steel tube lies in the outer periphery contributes a large portion of the stiffness as well as tensile strength, in addition to that it also provides necessary confinement to the core concrete, which increases the compressive strength of the member.

Major advantages of concrete filled steel tubes includes, limited cross section, high strength, better fire resistance, better stiffness, fair seismic resistance, high ductility, energy absorption etc. The outer tube also act as a good permanent formwork during filling of concrete, which prevents the need of a additional formwork system. The inward buckling of steel tube which is seen in the case of hollow steel tube is eliminated in the case of a CFST system. CFST member also has many applications such as columns supporting platforms in offshore structures, roofs of oil storage tanks, bridges and open-air overhead travelling cranes, piles in foundation etc.

Even though CFST members have many advantages there are certain disadvantages for the same i.e. For a number of reasons, the infrastructure related with concrete filled tubes become unsatisfactory and also ageing of metallic structures are often reported as a serious issue. The metallic structures become deteriorated due to many factors and the

International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 6, Issue 5, May 2017

main factor is corrosion. As a result of various deficiencies related to CFST members like inadequate factors of safety, usage of weak or inferior materials, poor workmanship etc, the design strength of structures may not be achieved. In such a situation the usage of FRP composite alternatives gained its importance. Fibre-reinforced composite materials have wide applications in civil engineering due to their high, high corrosion resistance, high strength to weight ratio etc. In the new era of construction, these polymer composite materials act as a confining material for concrete column in concrete filled FRP. The lateral confinement in columns increases the properties such as ductility, compressive strength and energy absorption capacity of the concrete. The major advantage of this CFST member includes, it provide a better waterproofing and insulate the exposed concrete columns and protecting reinforcing bars form corrosion, improves lifespan of concrete columns without the need of additional reinforcing re-bars and enhancing the compressive strength, flexural and shear strengths of concrete columns and short construction period through pre-cast product.

Yong ye [1] conducted study on both square and circular CFST specimens under combined axial and lateral shear load. results showed that failure modes of CFST member mainly depend up on their shear span to depth ratio. The shear capacity increases linearly with increase of axial compression ratio. Qasim S. Khan [2] examined the behaviour of GFRP and CFRP confined concrete specimens of varying thickness and they noted the reasons for deformation behaviour and concluded that rupture of fibers and crushing of concrete are the main reasons for failure. Stress- strain behaviour of both specimen showed similar characteristics. Darshika k.Shah [3] made a study on the behaviour of square and circular CFST columns to understand the load deformation characteristics of both circular and square specimens under static loading by means of a finite element analysis based on ANSYS software. Circular specimens exhibited much less deformation compared to square specimen. X Yang[4] conducted study on behaviour of both CFST and CFST under lateral and axial load, they found that the load resistance of both the type of columns were higher than that of RC column, but CFST column showed better load bearing, ductility and energy dissipation capacity compared to CFST column.

The main objective of this project is to study the behaviour of Concrete Filled Tubular (CFT) columns under static lateral load by using ANSYS 16.2 software. The project aims at a comparative study on load deformation behaviour of both CFST and CFST column under same static lateral load. For load deformation analysis specimens having inner concrete grade M40 and outer tube thickness of 2 mm is chosen. To make a comparative study on load deformation behaviour, the steel tube is replaced by GFRP and CFRP composites of same thickness. The material properties and geometry implemented in [1] was validated by ANSYS software and the results were in good agreement with each other. So that the same geometry is applied for the project model.

II. GEOMETRY AND MATERIAL PROPERTY

The geometry of the column was modelled using ANSYS 16.2 Finite Element Analysis software. Geometry of Concrete Filled Steel Tube (CFST) column is given below:

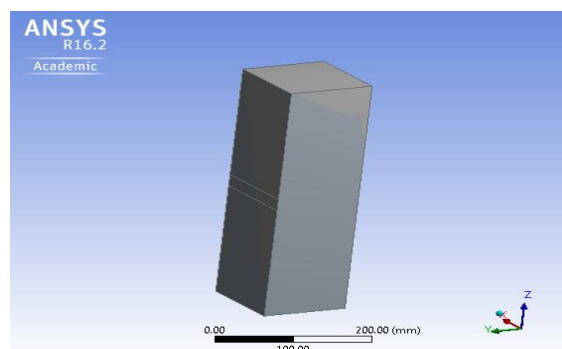


Fig1.Geometry of Concrete Filled Steel Tube (CFST) column

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Fig 1 represents the geometry of CFST column chosen for the study. The outer steel tube is of mild steel having a thickness of 2 mm. As a part of the comparative study, the outer steel tube is replaced by CFRP composite Epoxy Carbon UD prepreg and GFRP composite Epoxy E- glass UD. Tables below shows the material properties of various specimens

Table1. Material properties of Concrete Filled Steel Tube specimen

Properties	Steel	Concrete
Density (Kg/m ³)	7850	2400
Young's modulus (Pa)	2×10^{11}	3×10^{10}
Bulk modulus (Pa)	1.67×10^{11}	1.667×10^{10}
Shear modulus (Pa)	7.692×10^{10}	1.25×10^{10}
Poissons ratio	0.3	0.2

Table2. Material properties of Concrete Filled CFRP specimen

Properties	Steel	Concrete
Density (t/mm ³)	1.54×10^{-9}	2400
Young's modulus (MPa)	2.09×10^5	3×10^{10}
Shear modulus (MPa)	5500	1.25×10^{10}
Poissons ratio	0.27	0.2

Table3. Material properties of Concrete Filled GFRP specimen

Properties	Steel	Concrete
Density (t/mm ³)	2×10^{-9}	2400
Young's modulus (MPa)	45000	3×10^{10}
Shear modulus (MPa)	5000	1.25×10^{10}
Poissons ratio	0.3	0.2

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III. LOAD DEFORMATION ANALYSIS

Load deformation analysis of Concrete Filled Steel Tube columns and Concrete Filled FRP columns was done by ANSYS 16.2 software. The load applied was static lateral load of 250 kN in all the three specimens and the end conditions were fixed. All the specimens were of length 390 mm and cross section 120 x 120 mm.

3-1 Load deformation analysis of CFST column

The figure below shows the maximum deformation of CFST column subjected to static lateral load of 250 kN

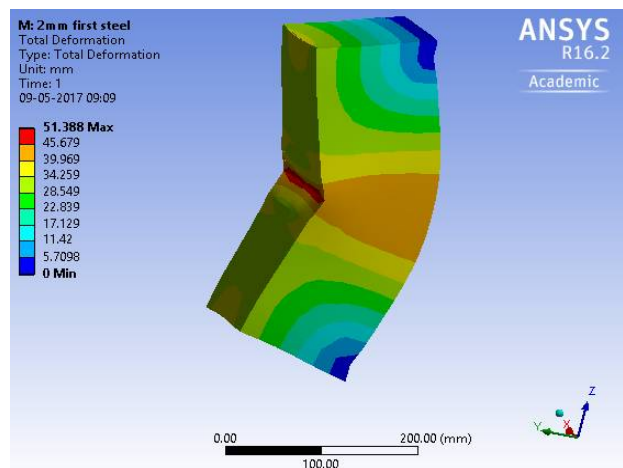


Fig 5. Deformed geometry of CFST column under applied load

3-2 Load deformation analysis of Concrete filled CFRP column

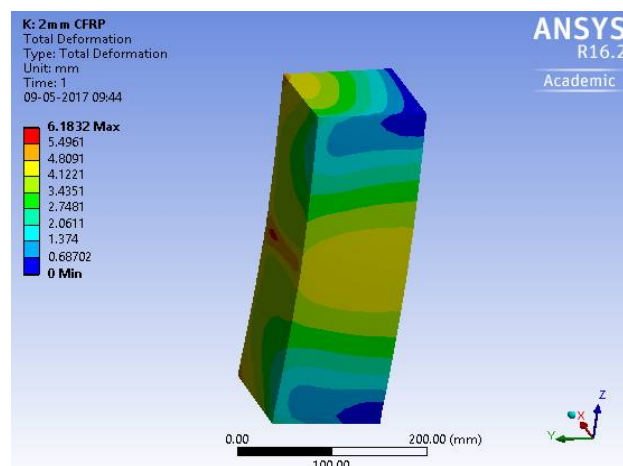


Fig 6. Deformed geometry of Concrete Filled CFRP column under applied load

3-3 Load deformation analysis of Concrete filled GFRP column

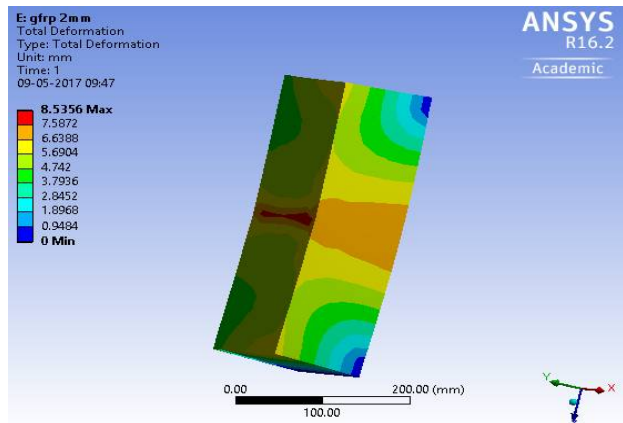


Fig 6. Deformed geometry of Concrete Filled GFRP column under applied load

IV. RESULTS FROM LOAD DEFORMATION ANALYSIS

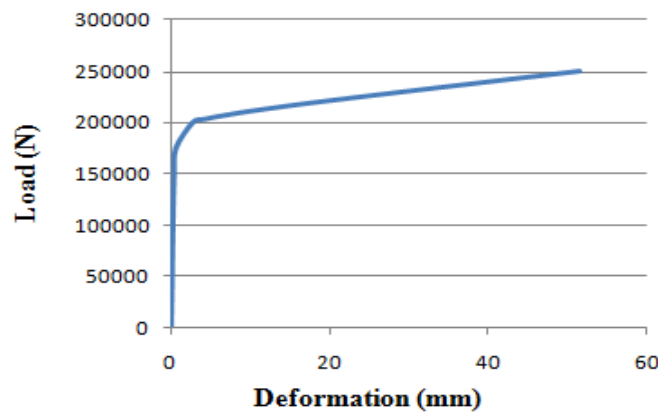


Fig 7. Load deformation curve of CFST column

Figure 7 gives the load deformation curve of CFST column under applied load of 250 kN. The maximum value of deformation obtained is 51.388m. From the graph it is clear that the deformation is increasing with increasing load. The specimen showed linear elastic behaviour up to a load of nearly 180 kN. After this load the specimen started yielding and began to show plastic behaviour. The deformation of the CFST column is very large for the applied load which resulted in the total failure of the specimen.

Steel shows more ductile behaviour, which means it is able to withstand large deformations prior to failure. Ductile materials possess small Young's modulus and ultimate stress as compared to brittle materials. From the load deformation curve of the CFST column it is well clear that the yielding point is at 200 kN. After this point the specimen showed a complete ductile behaviour. But the deformation corresponding to the applied load is very large. Being ductile in nature the specimen exhibited large strain and yielding before failure.

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Figure 8 represents the load deformation curve of Concrete Filled FRP tubes.

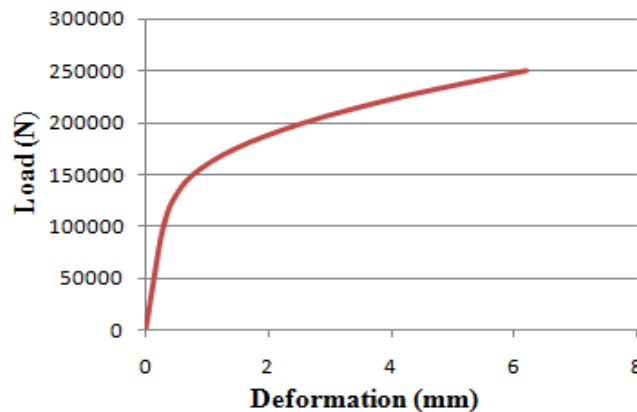


Fig 8. Load deformation curve of Concrete filled CFRP column

The maximum deformation corresponding to the applied load of 250 kN is 6.18 mm. The specimen exhibited linear elastic behaviour up to 120 kN and started yielding at 150 kN load. After the yielding point the specimen began to show plastic behaviour. The decreased value of deformation is due to high modulus of elasticity of CFRP.

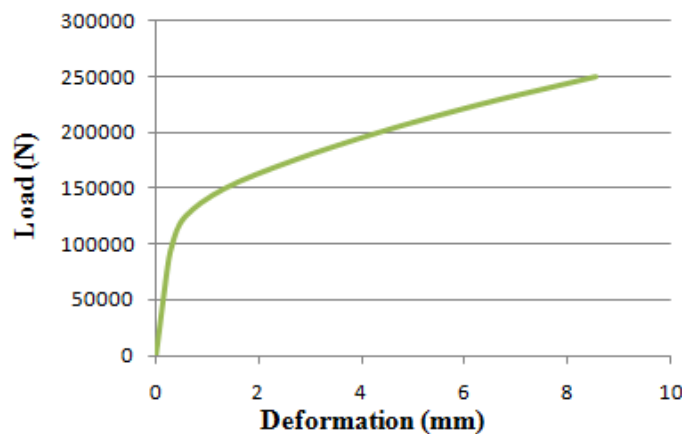


Fig 9. Load deformation curve of Concrete filled GFRP column

Figure 9 represents the load deformation curve of GFRP confined column. The maximum value of deformation corresponding to applied load is 8.556 mm. The specimen showed linear elastic behaviour up to a load of 120 kN. The specimen started yielding at a much lower load of 120 kN. The specimen showed a brittle failure. Being brittle in nature, the specimen exhibited only less strain and yielding prior to deformation. The rate of deformation is less due to better material properties of GFRP composite.

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Figure 10 gives a comparative study on load deformation behaviour of CFST and FRP composite columns under the applied static load of 250 kN.

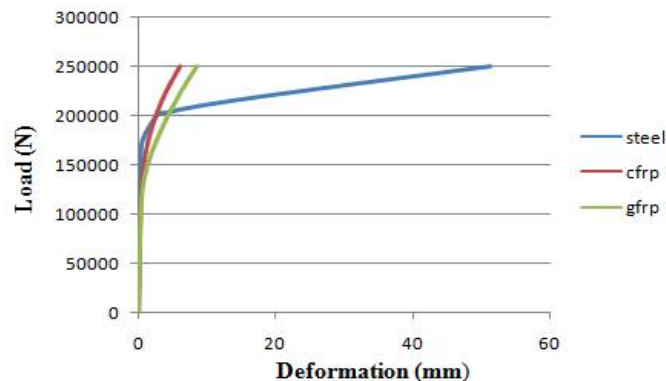


Fig 10. Comparison of load deformation behaviour of CFST and FRP composite columns

From the figure it is clear that steel tube specimen exhibited greater deformation as compared to FRP composite columns. CFST column started yielding at a load of 180 kN, At the same time FRP composite specimens started yielding at a much earlier load as compared to steel tube column. Which means the load carrying capacity of CFST column is larger compared to FRP composite columns. But the rate of deformation is very large in the case of CFST column. Concrete Filled CFRP column shows a minimum deformation of 6.18 mm and Concrete filled GFRP column showed a minimum deformation of 8.52 mm. Both these deformations are very less as compared to the deformation of CFST column.

V.CONCLUSIONS

The behaviour of CFST column and FRP composite columns under static loading showed great variations. Under static loading, CFST specimen resulted in maximum deformation compared to FRP confined columns. Carbon fiber confined columns showed the least deformation value. This reduced deformation of CFRP confined column is due to its improved material properties, i.e. the elastic modulus and tensile strength of CFRP is much more higher than that of steel. Being ductile in nature steel shows maximum deformation prior to complete failure as compared to FRP composites. Being ductile in nature steel tubular column shows more plastic behaviour and shows maximum deformation prior to failure. For the applied load of 250 kN CFRP and GFRP confined columns shows less deformation as compared to CFST column. Being brittle in nature GFRP does not shows much deformation prior to failure.

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