Analysis of Concrete Filled Steel Tubular Beams

Nimisha A. R., Abhilasha P. S.

Abstract - The Steel-concrete composite column can be an effective solution for any type of civil engineering construction instead of bare concrete or bare steel column because of having a good confinement effect between steel and concrete. Now a day's usage of concrete filled steel tube (CFST) is increased. Their usage as columns in high-rise and multi-story buildings, as beams in low-rise industrial buildings and as arch bridges has become extensive in many countries. But in India their usage is a new concept. This paper presents the finite element (FE) analysis and modelling of square concrete filled steel tube beams using the software package ANSYS 16.2. 3 different cross-sections of square CFST (72mm*72mm, 80mm*80mm, 100mm*100mm) were selected. Their modelling was done and a parametric study is also carried out using the verified FE models to study the effect of depth to thickness ratio (D/t), thickness of steel tube (t), compressive strength of infilled concrete, length of the steel tube (L), effect of shape of cross-section of steel tube was also studied.

Keywords: Concrete filled steel tube; CFST beams; Finite element analysis; ANSYS 16.2

1.INTRODUCTION

Several researchers presented different procedures in order to study the effect of both static and dynamic loading on different composite systems. Concrete filled steel tube (CFST) is a composite material which is composed of steel tube filled with concrete. The use of CFST columns and beams, in construction of buildings, has been increased exponentially in recent decades. As the available literatures lacks the numerical model for the flexural behavior of square and rectangular CFST, therefore, the main aim of this study is to investigate the flexural behavior of square CFST beams numerically by using the commercial Finite CFST's under pure bending. After FEA model verification, the numerical analysis is extended to perform the parametric study like compressive strength of concrete, D/t ratio, L/D ratio, length of element package ANSYS 16.2. This investigation contains the FEA modelling technique to analyze the flexural behavior, interaction of concrete and steel and load – deflection curves of dif- ferent types of concrete for square and rectangular specimen, cross-section of specimen and compressive strength of concrete on the performance of CFST beams under flexure load.

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2 .BRIEF DESCRIPTION OF SOFTWARE USED

Finite element method considers to be the best tool for analyzing the structures recently, many software's uses this method for analyzing and designing. The most popular and the easiest to learn is Ansys Workbench software, it combines the strength of our core product solvers with the project management tools necessary to manage the project workflow. In Ansys Workbench, analyses are built as systems, which can be combined into a project. The project is driven by a schematic workflow that manages the connections between the systems.

3. MATERIAL MODELLING

Elastic–plastic model is used to describe the constitutive behavior of steel. Bilinear properties for steel tube and multi-linear property of concrete are used. The modulus of elasticity of concrete is taken as 5000√fck according to IS 456:2000, where fck is characteristic strength of concrete.

Structural steel property : Density – 7850 kg/m^3, Poisson's ratio - 0.3, Elastic modulus - 2x105N/mm^2 Yield strength – 345 N/mm^2.

Concrete property: Density – 2400 kg/m^3, Poisson's ratio - 0.2, Elastic modulus - 27386 N/mm^2 Compressive Cube strength – 30 N/mm^2.

3.1. Boundary Conditions

The boundary conditions have to be applied correctly for the nodes lying on the planes of symmetry to reflect the actual behavior. The nodal displacements perpendicular to the plane of symmetry are restrained while the two remaining transitional degrees of freedom and free; the nodal rotation perpendicular to the plane of symmetry is free while the two remaining rotational degrees of freedom are restrained. Furthermore, at the support, the nodal displacement in the Y -direction is restrained while the two remaining transitional degrees of freedom are free (support located at 100mm from the end).

4 .DETAILS OF SPECIMENS CONSIDERED FOR THE ANALYSIS

In this paper 3 different square cross-section of CFST beams were selected (72mm*72mm, 80mm*80mm, 100mm*100mm). And FEM modelling of specimens were carried out using ANSYS 16.2 for these sections by taking a thickness of steel tube as 2mm, length as 1000mm, and steel yield strength of 345 MPa , concrete compressive strength of 30 MPa. Parametric studies were also carried out by varying steel tube thickness from 2mm to 3mm, 4mm, 5mm, 6mm, steel tube length 1000mm, 1200mm, 1500mm. 1700mm and fck values 40MPa, 50MPa, 60MPa. Load deformation and moment midspan deflection curves were plotted. Variation in load due to the influence of different D/t ratios and L/D ratio and fck values were noted. And also to check whether the deformation behavior will influence the CFST section, to that rectangular section of same cross-sections was also analyzed.

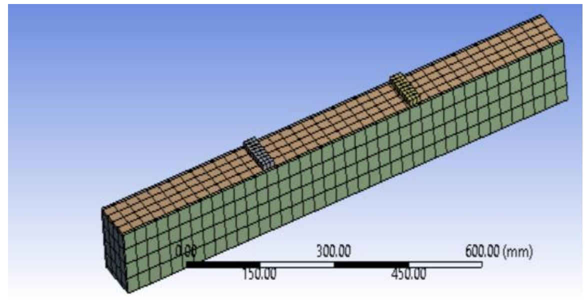


FIG. 1. FINITE ELEMENT MODELLING OF BEAM SPECIMEN

5. RESULTS AND DISCUSSIONS

5.1. Effect of D/t ratio

Effect of Depth to_Thickness raio (D/t) on the strengthening behavior of CFST was investigated on all the specimens by varying steel tube thickness by 3mm, 4mm, 5mm,6mm.and the results are shown in Fig 3. The decrease in D/t ratio with increase in thickness for a constant diameter represents the improvement in crosssection of steel tube and hence produces greater cap acity. And moment carrying capacity of CFST also found to increase while decreasing D/t ratio

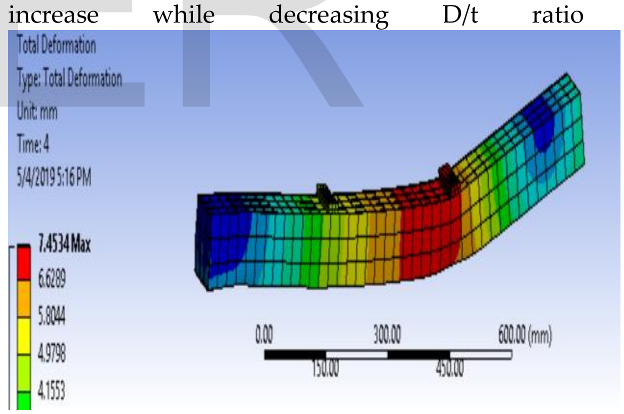
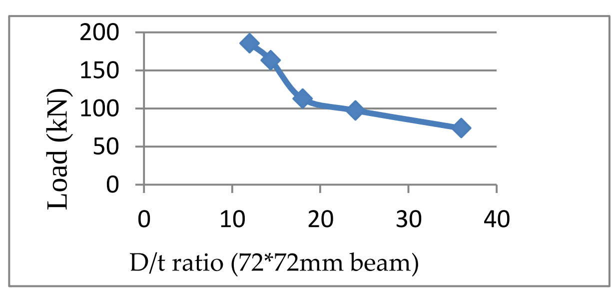
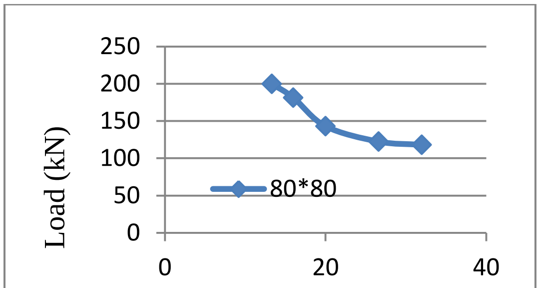
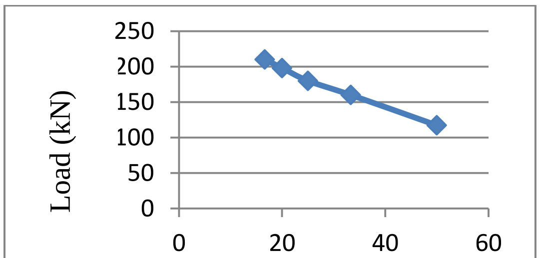


FIG.2. DEFORMATION BEHAVIOR OF 72*72*2 MM BEAM





(1) D/t ratio (80*80mm beam)

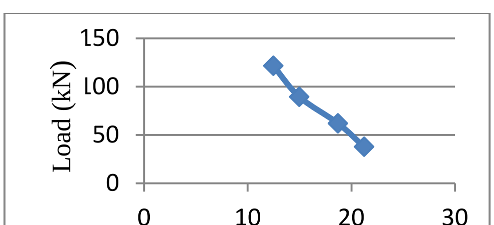


(3). D/t ratio
(100mm*100mm beam)

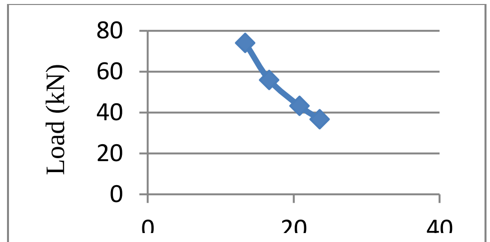
FIG.3.LOAD – D/T RATIO CURVES FOR DIFFERENT SPECIMENS (1). 72*72 BEAM, (2). 80*80 BEAM, (3).100*100 BEAM

5.2. Effect of L/D ratio

In order to to investigate effect of beam's length on the strengthening behavior, all the specimen's steel tube lengths were varied from 1000mm, 1200mm, 1500mm,1700mm and the results are shown in Fig 4. The increase in L/D ratio with increase in length of specimen for a constant diameter produces lesser capacity. And moment carrying capacity of CFST also found to decrease while increasing L/D ratio.



(1). L/D ratio (72*72mm) beam

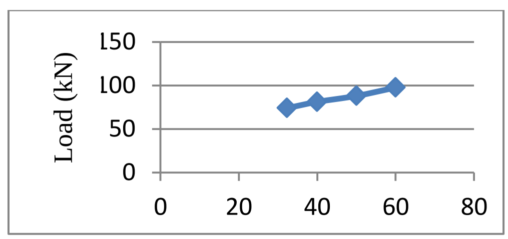


(2) L/D ratio (80*80mm beam)

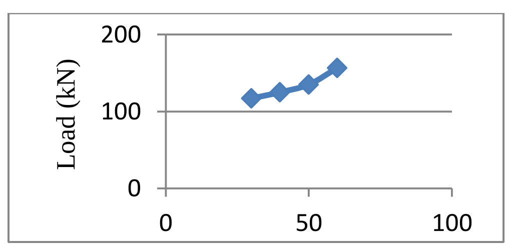
FIG.4.LOAD – L/D RATIO CURVES FOR DIFFERENT SPECIMENS (1). 72*72 BEAM, (2). 80*80 BEAM

5.3. Effect of compressive strength of concrete

The strength of concrete core determines the stiffness of CFST members. The increase in concrete core strength increases the strength of CFST sections to a larger extent, no matter of either D/t ratio or L/D ratio. The load carrying capacity of CFST beams increases with an increment in the concrete compressive strength. Fig 5 shows the effect of variation of grade of concrete on the load carrying capacity of different sections of square beams. The load carrying capacity increases linearly. Increasing the concrete compressive strength from 30MPa to 40MPa, 50MPa, & 60 MPa increases the ultimate load carrying capacity.



(1) Load vs fck for 72*72*2mm beam



(2).Load vs fck for 80*80*2 mmbeam

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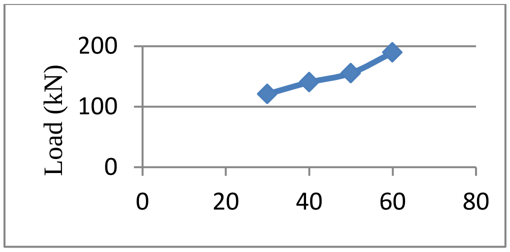
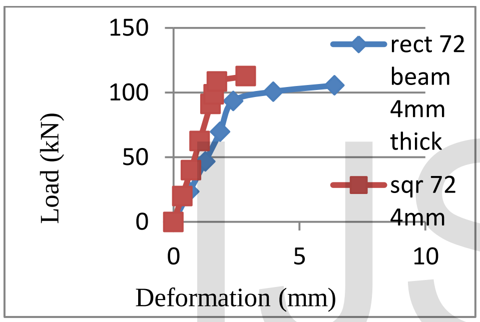


(3). Load vs fck for 100*100*2mm beam

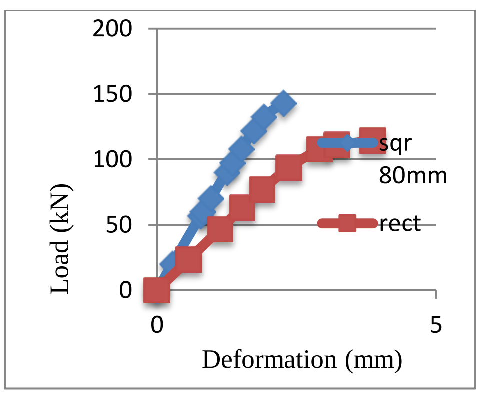
FIG.5.LOAD – FCK CURVES FOR DIFFERENT SPECIMENS (1). 72*72 BEAM, (2). 80*80 BEAM, (3).100*100 BEAM

5.4. Effect of shape of CFST section

The deformation of CFST section influences the shape of the section.



(1).72*72*4mm vs 96*48*4mm beam



(2). 80*80*4mm vs 96*48*4.505mm beam

FIG.6.LOAD – DEFORMATION CURVES FOR DIFFERENT SPECIMENS (1). 72*72*4 SQUARE BEAM VS 96*48*4MM RECTANGULAR BEAM (2). 80*80*4MM SQARE BEAM VS 96*48*4.505 RECTANGULAR BEAM.

To verify this effect besides square section rectangular sections were also analyze. Rectangular sections of dimensions 96mm*48mm*4mm and 96mm*48mm*4.505mm which equals the cross-sectional areas of 72mm*72mm*4mm & 80mm*80mm*4mm square sections were analyzed using ANSYS 16.2 . Load – deformation behavior of rectangular section corresponding to the square sections were plotted and shown in fig.6 below. From the results it was found that square shaped CFST sections have better confinement effect and load carrying capacity compared to rectangular sections. The deformation of square CFST section is better comparing with equal cross sectional rectangular section.

6. CONCLUSIONS

The finite element model for three different sections of concrete for different types of concrete, effects of D/t ratio, length to depth raio, effect of shape of section on the load-deflection curves and ultimate flexure load carrying capacity of CFST beams under flexure load were analysed. The results of finite element analysis on the applied boundary conditions and material properties are summarized as follows.

- Depth-to-thickness of steel tube has significant impact on the performance of the CFST beams.
- It is also observed that compressive strength of concrete and yield strength of steel used in CFST beams, have very marginal effect on the structural behaviour of CFST.
- The deformation of CFST section influences the shape of the section.
- It was found that square shaped CFST sections have better confinement effect and load carrying capacity compared to rectangular sections. The deformation of square CFST section is better compairing with equal cross sectional rectangular section.
- The FE results presented can be used for the verification of other nonlinear analysis techniques and to modify composite design codes for square CFST beams.

- The FE model developed can be used in the design and analysis of high strength concrete subjected to flexure load in practice.
- It can assist in generating the required data needed to develop design recommendations for CFST members with fewer limitations imposed.

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