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# STUDY ON BEHAVIOUR OF CFST INCLINED COLUMN SUBJECTED TO VERTICAL LOAD USING ANSYS SOFTWARE

**KEYWORDS** ANSYS software, Concrete filled steel tubular columns, inclined column, codal provisions on CFST columns

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**ABSTRACT** *An analytical investigation has been carried out using ANSYS software to understand the behaviour of Concrete Filled Steel Tubular inclined column subjected to vertical load. The study is limited to understand the behaviour of inclined CFST columns fixed at bottom and hinged at top for 0º, 5º, 10º and 15º inclination only with same geometric and material properties. A brief review of literature and codal provisions have been presented and the ANSYS results have been compared with different codal provisions, in particular, EC4, ACI-318 and AISC-LRFD. It has been observed that the inclined columns withstands less vertical load and is 18%, 26% and 30% for the columns with 5º, 10º and 15º respectively as compared to an upright column.*

## INTRODUCTION

Concrete filled steel tubular (CFST) members utilize the advantages of both steel and concrete. They compromise of a steel hollow section of circular or rectangular shape filled with plain or reinforced concrete. They are widely used in high-rise buildings, multi-storey buildings, bridges, piles and offshore structures as columns and beam-columns, and as beams in low-rise industrial buildings where a robust and efficient structural system is required.

The structural behavior of concrete-filled tubes is complex because of the interaction between the steel tube and the in-fill concrete. The pioneer research effort on the structural behavior of CFST members was first made by Kloppel and Goder (1957) [1]; Salani and Sims (1964) [1]; Furlong (1967) [1]; Knowels and Park (1970) [2]. The researches mainly concentrated on the fundamental behaviour of short columns with the slenderness being largely stored. The design equations were also derived based on these researches. After a decade of relative tranquility, there has been resurgence in CFST research in recent years all over the world.

## REVIEW OF DESIGN CODES

Different methods for the design of composite columns exist in codes of practice. A composite column may be treated in some methods as a steel column strengthened by concrete, whereas other methods may consider it as a reinforced concrete column with special reinforcement.

The design codes are based on several different theories, which can produce different results, and the assistance provided in terms of application varies significantly. Existing code differences can be attributed to two main reasons: difference in design philosophy, and numerical quantification. Whereas the former covers the fundamental considerations, such as strain distribution and compatibility, the latter is a consequence of the use of a specific experimental data base to arrive at actual design expressions. Even when two codes use the same philosophy and the same experimental results, some discrepancies are to be expected in estimating the final section properties for a given load, or the capacity of a pre-defined section. This may be due to the differences in safety factors, allowable material properties, limiting dimensions, consideration of long-term loading, etc. It is therefore not surprising that various codes would yield a wide range of designs for the same conditions [3].

## ANALYTICAL STUDY

The design of a CFST column may be based on a rigorous analysis of structural behaviour which accounts both for the material non-linearity and for the geometric non-linearity. However, this analysis is intended only for special problems which might arise. The rigorous analysis is generally too complex for routine design.

For routine design, a simple design procedure should be used as provided in some of design codes, i.e. in particular Eurocode 4, AISC-LRFD and ACI-318.

### Geometric properties

The Concrete Filled Steel Tubular columns are circular in shape with the diameter of concrete core and steel tube being 340mm and 350mm respectively for both upright and inclined column making the thickness of steel tube equal to 10mm. The height of the column is 3000mm. The results are obtained for inclined columns by incrementing 5 degrees each at a time for the same geometric properties and boundary conditions i.e. 0º, 5º, 10º and 15º.

### Material properties

The Poisson's ratio of concrete under uniaxial compressive stress ranges from 0.15 to 0.22 with a representative value of 0.2 for uncracked concrete. In this study, the Poisson's ratio of concrete is taken as 0.2 and 0.3 for steel in elastic stage respectively.

The characteristic strength of concrete and steel is taken as 20N/mm$^2$ and 235N/mm$^2$ respectively. The modulus of elasticity and density of steel being 200kN/mm$^2$ and 7850kN/mm$^2$, the modulus of concrete is considered based on the characteristic strength of the concrete with modulus of elasticity of concrete 29kN/mm$^2$.

### Boundary conditions

The top surface of the column is so placed that rotation in y-direction is allowed restricting the rotation in x and z-direction i.e. Δx = Δz = 0 and the bottom surface of the column is restrained in all the directions i.e. Δx = Δy = Δz = 0. The loads are applied to the top surface of the CFST column which transfers the displacements equally to the steel tube and the concrete core.

## RESULTS AND DISCUSSION

### Load vs Deformation plots

Fig 1 and Fig 2 depicts load-deformation plots from the ANSYS results for upright and inclined columns with an increment of 5° and up to 15° for design load and failure load respectively. For a given load, the ANSYS predicts the deflection of the structure. Most of the columns subjected to compressive force follow Hooke's Law. That is, the further they are compressed, the harder they push back against whatever is compressing them. This behavior is best illustrated in the form of a load vs deflection graph. Therefore, if the maximum load to be applied is known, the maximum deflection can be worked out. Alternatively, if the maximum acceptable deflection for the structure is known, the maximum load which is acceptable can be worked out.

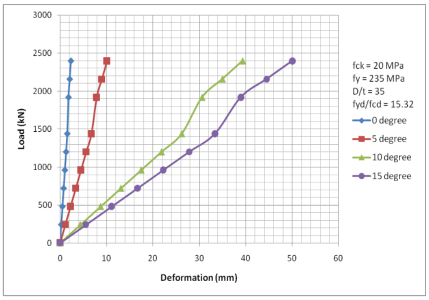

Fig 1: Load vs Deformation curves obtained for design load

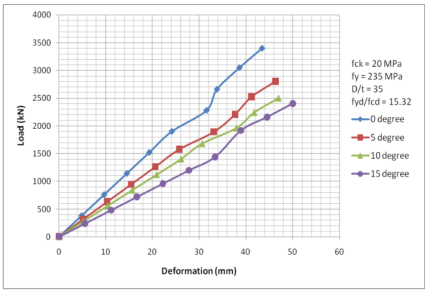

Fig 2: Load vs Deformation curves obtained for failure load

### Stress vs Strain Plots

Variations in stress and strain have been shown in Fig: 5 and Fig: 6 where the stresses obtained from ANSYS software are the Von Mises stresses. Von Mises stress is a geometrical combination of all the stresses (normal stress in the three directions, and all three shear stresses) acting at a particular location. Whenever an elastic body subjected to loads in its 3 dimension, the stresses will get developed along the principal axis of the body.

Von Mises postulated that, even though none of the principal stresses exceeds the yield stress of the material, it is possible for yielding of the same from the combination of stresses. Von Mises stress is useful for materials which classify as ductile. Instead, maximum principle stress (normal stress on the plane at which it is maximum) is used to predict failure.

It has been observed that increase in inclination of the column reduces stiffness. By examining the stress distribution, it has been observed that the failure occurred due to yielding of steel tube in the CFST column for an inclination of 15o w.r.t to vertical axis.

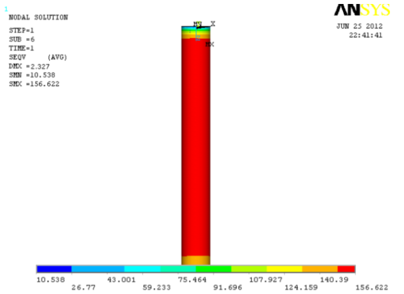

Fig 3: Von Mises Stress contours of an upright CFST column

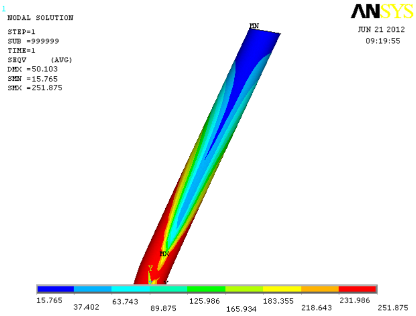

Fig 4: Von Mises Stress contours of an inclined CFST column

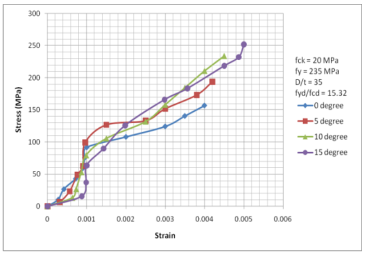

Fig 5: Stress vs Strain curves obtained for design load

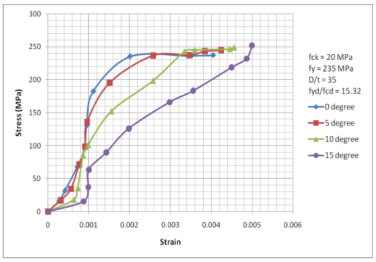

Fig 6: Stress vs Strain curves obtained for failure load

## CONCLUSIONS

- The results obtained by ANSYS are comparable with the results obtained by various codes and hence the software can be conveniently used for the analysis of CFST inclined columns.
- For an inclined column moment plays a primary and major role and the axial load is secondary. It has been observed that the moment increases by 50% with an increment in angle of inclination by 5o due to eccentricity.
- Comparison among codes have revealed that European code yields conservative results and is about 6.33% as compared to ACI and 7.14% more as compared to AISC code respectively. It has also been observed that the ANSYS software gives safer results compared to the EC4, ACI and AISC codes by 41, 32 and 51 percentages. However, several aspects like load factor, material safety factors etc have been considered in these codes. Also, the discrepancies found among various codes for analysis have been highlighted.The Von Mises stresses had higher value of 20%, 33% and 37% for 5°, 10° and 15° CFST inclined columns respectively

compared to that of an upright column subjected to the vertical load obtained using Eurocode 4.

- The axial strains obtained for upright columns were more by 5%, 11% and 20% for 5°, 10° and 15° CFST inclined columns respectively compared to that of an upright column subjected to the vertical load obtained using Eurocode 4.
- Analysis has revealed that about 21%, 80% and 95% increase in axial shortening for 5°, 10° and 15° CFST inclined columns respectively compared to that of an upright column subjected to the vertical load obtained using Eurocode 4.
- It has also been observed that the inclined column withstands less vertical load and is 18%, 26 % and 30% for 5°, 10° and 15° CFST inclined columns respectively compared to that of an upright column obtained from ANSYS software.
- At failure, the Von Mises stresses had higher value of 3%, 5% and 6% for 5°, 10° and 15° CFST inclined columns respectively compared to that of an upright column.
- At failure, the axial strains obtained for upright columns were more by 5%, 12% and 20% for 5°, 10° and 15° CFST inclined columns respectively compared to that of an upright column.
- There was 7%, 8% and 14% increase in axial shortening for 5°, 10° and 15° CFST inclined columns respectively compared to that of an upright column under failure load.
- No buckling due to flexure has been observed in the inclined columns even for an inclination of 15°. All the columns have failed in local buckling.
- As further recommendations, studies can be made on the following:
    - o Different shapes and dimension
    - o Variation in thickness and grade of concrete and steel
    - o Interaction between steel and concrete
    - o Study on connections between beams and columns
    - o Variation in angle w.r.t vertical axis
    - o Further investigations on experiment are necessary.

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