Non-Linear Analysis of Concrete Filled Double Skin Circular Steel Column

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Abstract—This paper investigates the behaviour of CONCRETE FILLED DOUBLE SKIN TUBULAR (CFDST) Circular stub columns with steel tubes compressed under concentric axial loads. The CFDST member is a new type of composite construction, which consists of two concentric steel tubes with concrete sandwiched between them. Thus, CFDST columns have a series of advantages, such as high strength, high bending stiffness, good seismic and fire performance, and also having favorable construction ability. The finite element analysis of the CFDST circular column is conducted to validate the finite element model with existing experimental data. The results obtained from the finite element investigation are compared with the strength values predicted using existing formulations in the analytical investigation. A good correlation was found between the values obtained from existing formulations in the analytical investigation.

Keywords—Concrete Filled Double Skin Tubes; ANSYS;

I. INTRODUCTION
Composite steel–concrete construction is widely used in the construction of modern buildings and bridges, even in regions of high seismic risk. The composite construction ideally combines the advantages of both steel and concrete, namely the speed of construction, high strength, and lightweight of steel, and the inherent mass, stiffness, damping, and economy of concrete. A creative innovation of composite construction is known as concrete-filled double skin steel tubes. CFDST members have almost all the same advantages as traditional CFST members. They have better structural performance than those of bare steel or bare reinforced concrete. The steel hollow section acts as formwork as well as reinforcement for the concrete. Concrete eliminates or delays the local buckling of steel hollow section, and increases significantly the ductility of the section. CFST construction has proven to be economic in materials well as providing for rapid construction and thus additional cost savings. Moreover, they have lighter weight, higher bending stiffness, and better cyclic performance.

A concrete-filled double skin tube (CFDST) column with circular cross section (Fig. 1) consists of two concentric steel tubes with concrete filled between the two tubes. The CFDST columns also have excellent resistance to seismic [2-5] and are lighter and have more fire resistant than CFT columns [7]. The ultimate strength of a CFDST column is affected by the compressive strength of the concrete, the concrete confined pressure, the yield strength of the tubes, and the diameter-to-thickness ratios of the inner and outer tubes. It is known that the circular cross sections have the best confinement effect and offshore loading resistance [5,6]. Therefore, CFDST columns with circular cross section and subjected to axial compressive forces are studied. In this paper, nonlinear analyses are carried out using the finite element program ANSYS Workbench15 and verified against experimental data reported by Tao et al. [1] and Zhao et al. [3].

![CFDST Column](image)

Fig.4.1. Cross-section of a Circular Steel CFDST Column

II. FINITE ELEMENT MODELLING
A. General Information
For the simulation of circular concrete-filled double-skin steel tubes and the analysis of their behaviour, the finite element programme ANSYS Workbench 15 was used. The aim is to create models that would accurately predict the behaviour of this form of composite columns, therefore the materials with their characteristic stress–strain curves needed to be defined separately along with their interactions, the loading and boundary conditions of each sections a unit, and the most suitable mesh selected.

B. Material Properties
I. Steel
The Steel is assumed to have isotropic hardening behaviour, i.e., the yield surface changes uniformly in all directions so that yieldstresses increase or decrease in all stress directions when plasticstraining occurs. For the specimen of Tao et al. [1], the elastic Elastic modulus ($E_s$) and Poisson's ratio for steel are taken as 200,000 N/mm² and 0.3, respectively. The yield strength of the inner tube ($f_{ys}$) and outer tube ($f_{yo}$) is taken as 370.2 N/mm² and 275.9 N/mm². The Density of steel is considered as 79 k N/m³. A bilinear property of steel tube is used in the analysis.

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2. Concrete

The Poisson’s ratio of concrete under flexural stress ranges from 0.15 to 0.22, with a representative value of 0.19 or 0.20. In this study, Poisson’s ratio of concrete is assumed to be 0.20. For the specimen of Tao et al. [1], the Elastic modulus ($E_s$) is taken as 333,000 N/mm² and 0.3, respectively. The average cubestrength for the stub column specimens of Tao et al. [1] were taken as 47.4 N/mm². The Density of concrete is considered as 24 kN/m³.

3. Geometry

The Geometric property of CFDST circular stub column namely CC3a Tao et al. [1] having the length (L) and thickness of column (t) is taken as 540 mm and 3 mm. The outer diameter $D_o$ and inner diameter $D_i$ is considered as 180 mm and 88 mm respectively.

4. Element Mesh

All the parts composing the double-skin composite columns were modelled with a similar mesh size. Generally, the average mesh size used was 15 mm for the concrete, 10 mm for the outer tube, 10 mm for the inner tube.

5. Boundary Conditions

The loading conditions were applied using the boundary conditions of each cross-section. The bottom was fixed against all degrees of freedom. On the other hand, the node in the centre of the top was fixed against all types of rotation and against lateral displacements (x and y directions).

III. ANALYSIS AND DISCUSSION

Nonlinear analysis is done. Using ANSYS Workbench15, Static analysis of Circular CFDST column is analysed. Comparing the results with experimental data and to be validated through plotting graphs.

Fig. 4.4 shows that axial deformation is maximum at top of the column section and decreases with the increase in the distance of the column section from top and becomes zero at the bottom of the column section where column is fixed. Fig. 4.5 shows the Deformation curve.

The load–strain behaviour of the circular double-skin specimen, cc3a, was also observed. Fig. 4.5 shows the load–strain behaviour.

The comparison of the experimental observations with the modelled results was drawn using three parameters: the ultimate capacities, the axial load–strain curves and the final deformations of the specimen. Table 1 shows the recorded maximum strengths of the test specimens together with the attained ultimate resistances of the specimens modelled in ANSYS. Good agreement was noted generally, with the tested-to-finite element model strength ratios being close to unity.
TABLE 1. AXIAL LOAD CAPACITY

<table>
<thead>
<tr>
<th>Model</th>
<th>Experimental</th>
<th>Analytical</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC3a</td>
<td>1648kN</td>
<td>1700kN</td>
<td>3%</td>
</tr>
</tbody>
</table>

IV. CONCLUSION

A finite element analysis was conducted in order to examine the cross-sectional capacity and behaviour of the recently introduced composite double-skin columns subjected to concentric loading. Past experimental results were used to verify that the accuracy of the utilised method was sufficient. This was implemented by comparing the compressive resistance and axial load–strain curves.

REFERENCES