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Effect of Thermal Loading on CFST Element using Abaqus Software

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Abstract - Concrete filled steel tube, or CFSTs, are composite material made up of steel and concrete that have proven to be a useful substitute for traditional steel constructions. They enhance the behavior of steel structures by increasing their stiffness, durability, and load capacity under conditions of thermal loading. An appealing alternative to civil engineering construction is tubular columns filled with concrete. The ABNT NBR 14323:2013 and Eurocode 4 provide straightforward examples of how to construct composite columns that withstand fire. Furthermore, Eurocode 4 specifies a particular process for columns with concrete covered section profiles with regard to determining the temperature field in cross section. The work aims to provide a streamlined process for ascertaining the temperature reported in steel columns filled with concrete, which may be applied to columns including different section tubes.

Key Words**:** Cement, concrete, steel, Stiffness, templates

1.INTRODUCTION

The members that enable the employment of both the advantages of steel and concrete are concrete filled steel tubes, or CFST. This is comprised of a circular or rectangular hollow steel section filled with either unreinforced or reinforced concrete. The column's excellent structural performance is further enhanced by the material distribution in the cross section. The outside surface is where the steel is located, and this is where bending and friction function best. Since the material is the farthest from the core, this also results in the highest stiffness. Thus, the largest contribution to the moment of inertia is produced in conjunction with the steel's significantly bigger elasticity modulus. The axial compression resistance is primarily contributed by the concrete foundation. The hollow tubes are created precisely so they can bear the floor load up to three or four storey heights. The concrete is emptied into the tubes from the bottom after the top floors are finished. For quick pumping, the tubes are continuous at ground level. High-performance concrete and modern pumping plants enable easily accessible three or four floors of pumping.

2. CFST columns

Concrete that fills the steel hollow section grants the columns outstanding fire resistance without needing additional protection. In the initial moments of fire exposure, the steel tube heats up at a faster rate than the concrete core, enabling it to support more weight than the core can. The concrete core, which has lower thermal conductivity compared to steel, takes in the heat. After approximately 20 to 30 minutes, the temperature of steel begins to decrease due to its high temperature, while the concrete's temperature rises very slowly. At this point, the concrete infill slowly begins to bear the load. As the temperature in the core increases, the strength of the concrete diminishes, ultimately leading to buckling or compression that results in failure.

3.Objectives:

- To create an analytical model and research the thermal-structural behavior of CFST columns under typical thermal loading conditions.
- To examine and use the experimental method for figuring out the basic t-d-T behavior of structural members in order to ascertain the basic behavior of CFT members.

4. Analytical approach

To predict the thermal and structural responses of CFSST columns under standard fire test conditions, a sequentially interconnected analytical method was employed. This method features three successive analytical steps, where the outcomes of each stage contribute to the subsequent phase of the analysis. The steps taken were as follows:

Step 1- Axial Loading

Prior to applying heat loading, a column specimen needs to experience some compression loading.

Step 2- Thermal load

The outer surfaces of the steel tube were subjected to thermal load, or steel temperature, in according to the ISO 834 fire curve.

Step 3- Heat transfer analysis

Standard fire experiment was conducted on CFST columns to anticipate their thermal and structural behavior using a tri step, sequentially coupled analytical technique. The method is a three-stage sequential analysis where carried out to the findings from each step are used to start the next part of the investigation. The procedure had gone like this:

Step 4-Stress analysis

To ascertain the column's structural response to axial and thermal loading, a nonlinear stress analysis was carried out. To perform stress analysis, we require the nodal T-t curves that are created step 2 and the initial geometric imperfection of the column.

5. Structural behaviour of CFST element under thermal loading:

A few of the constructed concept equations are employed in additional analysis.

Design equations from Eurocode (1994-1-2):

Two distinct methods for assessing the compressive load-bearing capacity of a CFT column subjected to fire conditions are outlined in the Eurocode (199-4-2).

1.Thermal elongation

The thermal elongation of concrete $(\Delta l/l)_c$ may be determined from the following equations.

Siliceous aggregates:

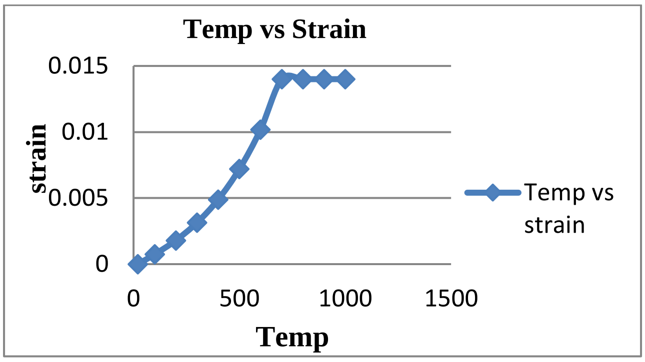
$(\Delta l/l)_C$ $=-1.8*10^{-4}+9*10^{-6}*\theta d+2*3*10^{-11}*\theta d^3$

$(\Delta l/l)_C$ $= 14*10^{-3}$

Calcareous aggregates:

$(\Delta l/l)_C$ $=-1.2*10^{-4}+6*10^{-6}*\theta d+1*4*10^{-11}*\theta d^3$

$(\Delta l/l)_C$ $= 12*10^{-3}$



Graph 1: Temperature Vs Strain

2.Specific heat

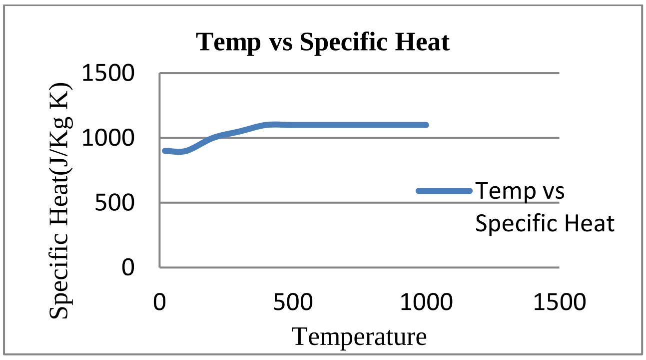
The specific heat is determined from the following equations:

Cc =900 (J/kgK) for 20ºC ≤ θd ≤ 100ºC

Cc =900+(θd - 100) (J/kgK) for 100ºC ≤ θd ≤ 200ºC

Cc =1000+(θd - 200) (J/kgK) for 200ºC ≤ θd ≤ 400ºC

Cc = 1100 (J/kgK) for 400ºC ≤ θd ≤ 1200º



Graph 2: Temperature Vs Specific Heat

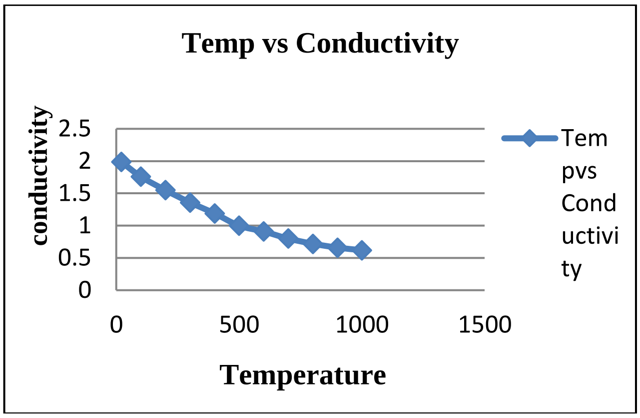
3.Thermal conductivity

Upper limit of normal weight concrete are:

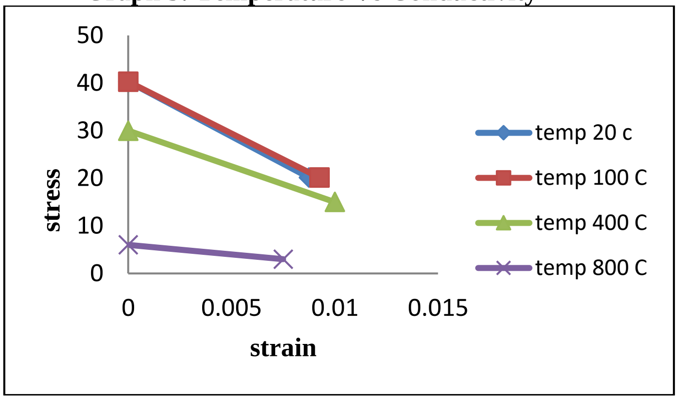
$\lambda_c = 2 - 0.2451\cdot(\theta d/100) + 0.0107\cdot(\theta d/100)^2$ (W/mK)

Lower limit of normal weight concrete are:

$\lambda c = 1{,}36 - 0.136\cdot(\theta d/100) + 0.0057\cdot(\theta d/100)^2$ (W/mK) for 20° C ≤ θd ≤ 1200° C.



Graph 3: Temperature Vs Conductivity



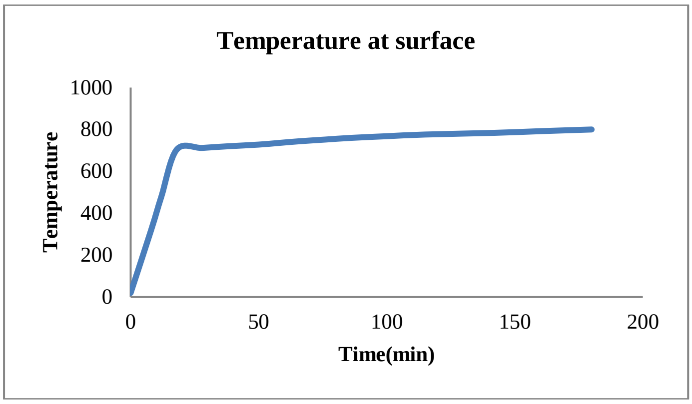
Graph 3: Plastic stress strain of strength 40 MPa at elevated temperature.

6. Validation for the columns exposed to thermal load

To maintain the ends firm, assuming that the steel and concrete are perfectly bonded: With the assumption of complete bonding and rigidity at the ends, a three-dimensional numerical model was built. In order to conduct the experiments, the columns were heated in a furnace designed specifically to test laden columns.

The table displays a list of these columns.

Specimen No	CS01	CS02
Sectional Dimensions (mm)	200*1830*3	200*1830*3
Boundary Condition	F-F	F-F
F_Y (MPa)	292.9	292.9
Es ($*10^5$) (MPa) for 20°C ≤ θd ≤ 1200°C	2.01	2.01
F_{ck} (MPa)	40.3	40.3
Test Load (KN)	500	770
R Test (min)	200	120
R Predicted (min)	178	90



Graph 4: Time Vc Temperature

The above graph represents the variation of temperature with time, as in previous graph it is shown that how temperature and conductivity are co related in the graph no 3. the columns were heated in a furnace designed specifically to test laden columns.

SUMMARY

This work uses computational analysis to examine the fire behavior of a concrete-filled tubular column that has an axial charge. A three-dimensional finite element model was developed to predict the axially loaded CFST columns' structural behavior. The accuracy of the numerical model was verified through comparison with the experimental data available in the literature. Testing and modeling were done to determine how accurate square and circular CFT columns are at estimating column capacity. The following presents a number of the parametric study and numerical model findings.

1. The values of the results at room temperature are higher than the experimental values. For the round columns, the computational model and the practical testing at room temperature agreed quite well. As a result, the capabilities are overstated.

2. It is discovered that CFT columns experience hoop stresses as a result of this radial direction temperature change, which are not seen at high temperatures in conventional steel columns.

3. Because of these stresses, the tensile strength of the concrete determines the column's total capacity to support a compressive load at a high temperature.

4. CFT Column The conduct contact between the zero-bond strength steel and concrete is pleasant and aligns with the experimentally distorted shape. One crucial factor in forecasting is the interaction between the concrete and steel.

5. In situations where there is a strong and uniform bond between the steel and the concrete, local steel tube buckling is prevented.

6. The coefficient of friction between the steel and concrete surfaces has no effect on the activity of the column fire. To develop a generic equation of design for the prediction of CFT column fire behavior, parametric tests are carried out. The results gained are compared to the capabilities of the experimental design. The capacities of the Eurocode columns are more than the anticipated column capacities.

7. Core concrete keeps the steel tube from buckling inward, and because it removes concrete moisture from the steel tube, it occasionally acts as nonbrittle material.
   Regardless of the terminal friction between the rigid end plate and compressive CFST, the overall load deflection behavior and deformed shape of the CFST column remain unchanged.

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CONCLUSIONS

- The FE model shows that the load level significantly affects the fire resistance of the CFSST columns.
- Analytical testing indicates that in the later phases of fire exposure, the core concrete carries the majority of the axial load.

CFSST and CST columns have different fire efficiency under the same fire conditions because carbon steel and stainless steel have different mechanical and thermal properties. A CFSST column is often more fire resistant than a CFST column.

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