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Nonlinear Analysis of Fire Resistance of Composite Steel-Concrete Tube Column

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Abstract: Generally, three different approaches can be applied for analysis of a fire safety: A time factor, bearing capacity factor, and the temperature factor. Three types of columns (a steel tube filled with concrete; an encased steel cross-shaped profile; reinforced-concrete column of a circular cross-section) were investigated using the transient temperature analysis. Heat transfer in composite columns as well as the effects of boundary conditions represented by normalized temperature curve, were monitored during a period of two and a half hour [1, 2].

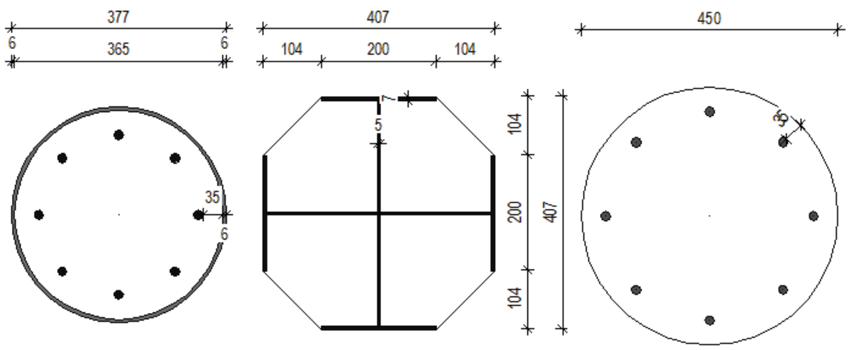

Fig. 1: Analyzed columns: C1- steel tube filled with concrete, C2- encased steel cross-shaped profile, C3 - reinforced-concrete column

Introduction

The fire process can be divided into four basic phases: Ignition, Growth, Fully developed and Decay. Overall ignition occurs, when the temperature between 400 to 600°C is exceeded, while the heat from floor releases by the highest rate, i.e. 20kW/m^{2}s. There remains only a small chance to survive for persons who failed to escape the fire site. The temperature before the overall ignition is rather low and the fire is localized in its epicenter. The action of a fire-fighting crew as well the evacuation of humans is possible. Casualties indicated in international statistical indexes, range from 0,0004 to 0,04%. Economic losses range from 1,6 to 5,9% from the Gross National Product. 85 % of fire casualties occur during fires of residential buildings [3]. Considering the above mentioned factors, one can see that fire safety is an important part that has to be involved in the building structures design.

Temperature analysis

For a proper investigation of the fire resistance of a structure, it is necessary to determine the time-temperature curve. The temperature changes dynamically and it is given by a normalized temperature curve [4].

Basic equation of the non-stationary heat conduction can be written in following form $\mathbf{C\dot{T}+KT=Q}$, where $\mathbf{K}$ - matrix of thermal conductivity, $\mathbf{T}$ - vector temperatures in nodes, $\mathbf{Q}$ - vector of heat flow, $\mathbf{C}$ - matrix of thermal accumulations, $\mathbf{\dot{T}}$- time derivation of vector $\mathbf{T}$.

Boundary conditions and calculation

Numerical simulation of heat transfer in the structure was analyzed using the ANSYS software with use of elements for the thermodynamic analysis. Two-zone model was used for the calculation. Two different normalized temperature curves were defined. Models were divided in their middles into two parts lengthwise. Each model was loaded by lower temperature in its bottom part and by higher temperature in its upper part. Two model situations were investigated: Model Situation 1 – Fire load acts on the whole diameter of a column; Model Situation 2 – Fire load acts on the half of diameter. Boundary conditions valid for the model were specified using applicable elements. Altogether six situations were modeled, two for each column. The results obtained for each Model Situation were strongly affected by quality of mesh.

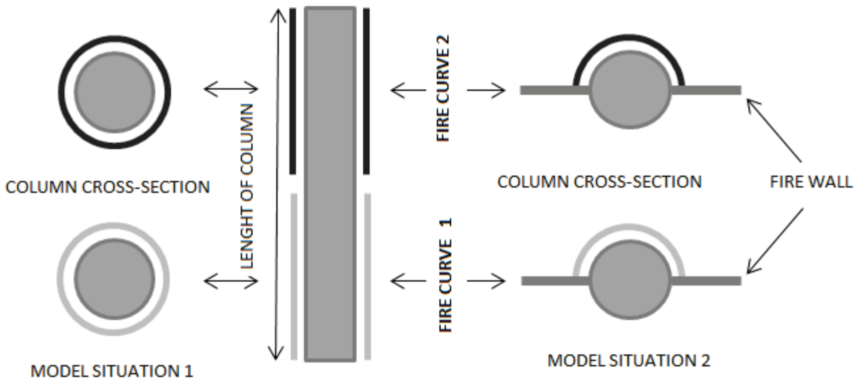

Fig. 2: Fire scenario for the transient analysis

Summary

The investigations have proved a considerable drawback of an encased steel cross-shaped column: the steel which is unprotected on the surface, continually progresses into the core what enforces the degradation of the concrete strength considerably. In this type of column in time 2 hours, the area of concrete which is not damaged by heat effects, is by approx. 30% smaller compared to a steel tube filled with concrete. The maximum temperature difference in this type of column under the uniform load occurs in time approx. 1 hour, namely in the concrete part of profile. Here, in the undisturbed core the temperature is only 28 ºC, while the temperature of damaged concrete on column's edge is 786ºC. In Model Situation 2 the maximal temperature difference is in time approx. 80 minutes in the value of 950ºC.

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