Study of the effects of fire on the stability of the structure of underground parkings

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***Abstract* – This master thesis provides an insight on the effects of fire on the structural stability of underground parkings.**

***Keywords* – fire, underground parking, punching shear, FEM, concrete, flat slabs**

I. Introduction

This master thesis studies the fire resistance of flat slabs in a rather secluded area such as an underground parking. To examine the structural stability, a number of software packages is combined.

The factors influencing punching shear during a fire are:

- temperature induced losses of strength and stiffness;
- restraint of the thermal expansion of the slabs: moment redistribution, increased load on column;
- restraint of the thermal expansion of the column;
- explosion (not studied in this thesis)

The studied geometry of the underground parking is based on Bamonte & Felicetti [1].

Information of the changing properties at elevated temperatures is necessary for the calculation of the structure during a fire. The losses of strength and stiffness are determined in EN 1992-1-2 [2].

The temperature development in terms of time and place can be determined by simulating a car fire. Simulating a car fire is executed with ANSYS Fluent.

The resulting temperature curve can be used afterwards for the thermo-mechanical calculations in Diana.

II. The Fluent software

A. General Information

In ANSYS Fluent 12.0.16 the temperature is modeled in function of time and place, where all partial differential equations in all points of the compartment are solved numerically.

B. Used turbulence models

The used turbulence model for this master thesis is the standard k-ε model and the realizable k-ε model with 'standard wall functions'.

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C. Simulations in Fluent

A heat release rate of 4 MW is taken for the fire load of the burning car. This heat release rate is introduced as a volumetric source term. A radiation model is not used, the energy is only released by convection.

During the simulation, attention is given to two situations: 1) a burning car in the corner (cfr. the first car in Bamonte & Felicetti) and 2) a burning car in the middle of the underground parking.

While determining the temperature development in the underground parking, the attention is primarily going to the temperature development close to the ceiling and at the position of the columns. This way the temperature increase of the slab and columns can be determined.

D. Results

Figure 1 shows the temperature results of a horizontal section through the car park at the heights of 1m, 2m and 2.8m for the case with a burning car in the middle. The used turbulence model here is a realizable k-ε model.

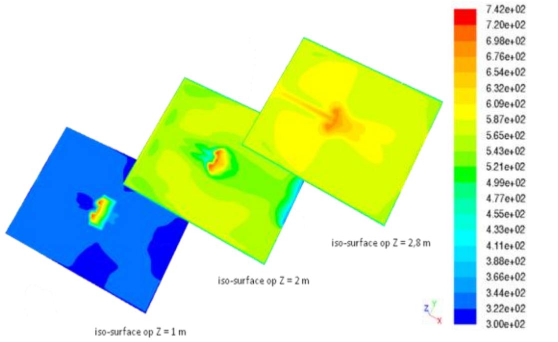

Figure 1: Temperature development at a height of 1m, 2m and 2.8m for a burning car in the middle with a realizable k-ε model

Figure 2 shows a graph of the temperature development at the different columns in function of the height. These are the temperature profiles that correspond to Figure 1.

The temperature is constant between 2-2.8m from the floor and reaches about 300°C. The temperature near the ceiling is lower due to absorption of the above structure.

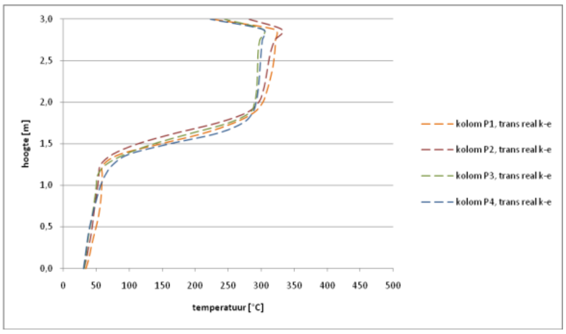

Figure 2: Temperature development in function of height for 4 different columns.

III. The Diana Software

A. General information

The Diana program is a finite element program, developed at TNO Delft. This program makes it possible to combine a thermal and structural analysis.

B. Slabs

The geometry of the 3D model of the slab is based on the paper from Bamonte & Felicetti.

A Heatflow-Stress staggered 3D analysis is used for the 3D calculations.

Figure 3 shows the load in function of the time for columns P1 and P2 for a thermo-mechanical calculation with a constant Youngs modulus (dotted line). Varying the Youngs modulus as function of temperature is also shown in figure 4 (full line).

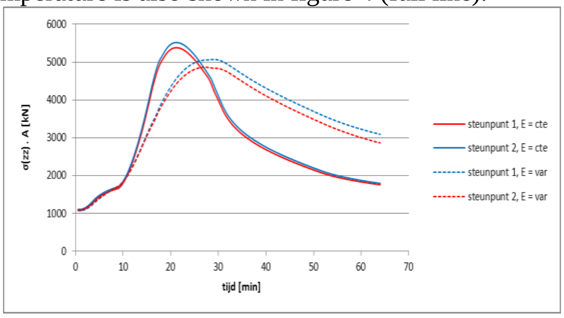

Figure 3: $N_{therm.\ slab}$ in function of time

C. Columns

The total force on a column during fire consists of the sum of the force by the dead and live load and the formation of additional forces by thermal restraint of the expansions of both the column and the slab.

$$N = N_{load} + N_{therm.\ column} + N_{therm.\ slab}$$

where

$$N_{therm.\ column} = E.\alpha.\Delta T.A$$

Curves that describe the strain in function of the temperature can be used for the determination of $N_{therm.\ column}$. These can be found from three different authors, namely Anderberg [3], Schneider [4] and Annerel [5].

Figure 4 shows this additional load $N_{therm.\ column}$ for the different authors and different load levels during heating following the ISO 834 curve.

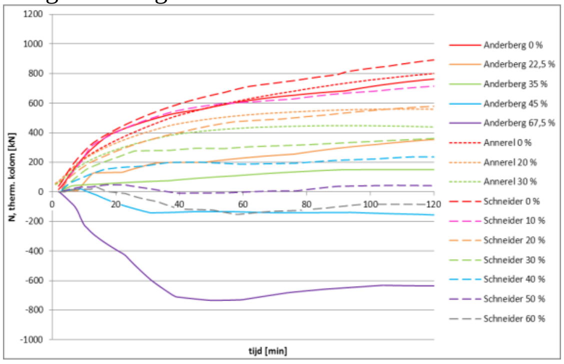

Figure 4: $N_{therm.\ column}$ during heating following the ISO 834 curve

IV. Conclusions

Using Fluent gives resulting temperatures that appear to be higher than the temperatures from the two zone model used in Bamonte & Felicetti [1].

This increased thermal load causes additional loads $N_{them,\ slab}$ and $N_{therm,\ column}$ that result in flat slabs that are highly sensitive to punching shear failures in case of a fire.

Acknowledgements

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