BYG508 Master's Thesis

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Title:

Modelling heat diffusion in concrete structures during a tunnel fire, to investigate structural safety

Summary

In this study, the heat diffusion in concrete structures during a tunnel fire is investigated. The fire curves investigated in this study is the ISO 834, EUREKA, HC, and RWS fire curve, illustrated in figure 1.

Different approaches have been simulated in the software ANSYS, and temperature profiles have been established and compared.

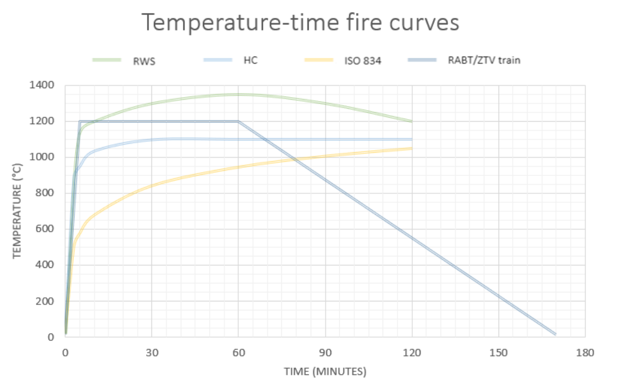

Figure 1 Fire curves

The 1D-model based on elements with properties for conduction, convection, and radiation corresponded well with the temperature profiles presented in Eurocode 2, which indicates that the model is adequate for comparison. The different fire curves seem to influence the heat diffusion by the maximum achieved temperature, the steepness of the curve, the duration of the fire, and the cooling stage.

Introduction/Case

Bane NOR have experienced that even though they recommend the use of the EUREKA fire curve when dimensioning concrete load-bearing tunnels for fire, some consultants have used the ISO 834 fire curve with an extended fire duration. Bane NOR wants to know if this approach is adequate when considering the heat diffusion within the concrete.

Research question

"How do different fire loads influence the heat diffusion in load-bearing concrete tunnels?"

- What is known from the literature concerning heat diffusion in concrete exposed to fire curves?
- How should fire be modelled in the software ANSYS?
- How do the different fire curves [ISO 834, EUREKA, HC and RWS] influence the heat diffusion in the concrete?

Method

The methods for this master's thesis have been a literature study and conducting meetings with experts. Available literature has been investigated, tutorials online have been watched, and a course in fire engineering have been attended.

Results and discussion

Because available research is based on different parameters and framework for the analyses, the results are inadequate for comparison, both to eachother and to the performed analyses. Different models in ANSYS was considered but because the student's version of ANSYS has limitations regarding the number of nodes/elements the 3D-model was not selected for further investigation. The 1D-model is built upon elements that consider all three forms of heat transfer; conduction, convection, and radiation. The model is based on parameters from the Eurocode and proved adequate for comparison.

The ISO 834 fire curve has temperature profiles presented in the Eurocode 2. The results from the analyses in ANSYS corresponds well with these temperature profiles. A selection of the results can be seen in table 1 below.

Table 1 Comparison of heat diffusion ISO 824

Distance from surface	Eurocode 60 minutes	1D ANSYS 60 minutes
0 mm	890°C	900°C
60 mm	180°C	190°C

It emerged from this study that the RWS fire curve achieved the highest heat diffusion in the concrete, as assumed in advance. It also emerged that the ISO 834 fire curve with a fire duration of 240 minutes gave higher temperatures in the concrete than the EUREKA 120 fire curve. A selection of results from the comparison can be seen in table 2 below.

Table 2 Comparison of heat diffusion

Distance from surface	ISO 834 240 minutes	EUREKA 120 120 minutes
20 mm	870°C	835°C
60 mm	505°C	400°C

Conclusion

From the literature study, it emerges that there is little available research on heat diffusion for the fire curves and that the available research does not use the same parameters or framework for the analysis. Together this makes the research inadequate for comparison. The importance of including all three stages of heat transfer when modeling fire occurred during the literature study and through the modelling in ANSYS. The 1D-model based on elements with properties for radiation, convection, and conduction corresponded well with the temperature profiles presented in the Eurocode 2, which indicates that this was an adequate model for fire simulations.

What emerges from this study is that the different fire curves influence the heat diffusion by the maximum achieved temperature, the steepness of the curve, the duration of the fire, and the cooling stage. The EUREKA fire curve is the only curve with a cooling stage and is very dependent on how long the holding stage is. When comparing the EUREKA 120 fire curve to the ISO 834 fire curve with a fire duration of 240 minutes, the results from the analyses implies that the heat diffusion in the concrete would be higher for the ISO 834 fire curve.

The influence of concrete spalling during a fire is neglected in these fire simulations. It is important to remember that if spalling should occur, this will influence the heat diffusion remarkably.