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Numerical Simulation of Concrete Tunnels Subjected to Fire

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ABSTRACT

Concrete behaviour at high temperature represents a complex phenomenon that in general case requires a coupled hygro-thermo-chemo-mechanical model. An example of an advanced hygro-thermo-mechanical model is presented in Gawin, D. et. al. 2003. This paper presents a modification of the combined fracture-plastic model developed by the authors and initially presented in Cervenka. J. et. al. 1998. The extended model is applied for the analysis of structures subjected to fire, where the material properties of concrete as well as reinforcement are strongly dependent on temperature. The objective is to develop a model that can be applied to large-scale analyses of engineering problems at a reasonable computational cost. The presented work is an extension of a previously published thermally dependent model by Cervenka J. et. al. 2006. The transport part of the model is extended to include the effect of water vapour transport and the development of high pore pressure when the concrete is heated. The paper presents new results and an application to a real tunnel scenario. The temperature and pore pressure distribution inside a heated structure is calculated by a separate non-linear transient thermal analysis. The obtained temperature and pressure fields are then applied in a mechanical analysis, which takes into account the thermally induced strains as well as the material degradation induced by high temperatures.

The model was developed during the European research project UPTUN and then extended during a research project 103/07/1660 supported by Czech Grant Agency. The model behaviour is tested on uni-axial tensile and compression tests as well as on experimental data of a real scale fire experiment of a tunnel suspended ceiling. At the end of the paper the model is applied to investigate the effects of fire resistant shotcrete protection during a Virgolo tunnel fire test.

The temperature dependent mechanical model is implemented in program ATENA, which was used to analyse the examples presented in this paper.

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