FIRE ANALYSIS OF PARTLY DELAMINATED CURVED REINFORCED CONCRETE BEAM STRUCTURES

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Abstract

The topic of my research work and my PhD thesis is fire analysis of partly delaminated curved reinforced concrete beam structures. Extreme fire in tunnel can result in human casualties, material damage, pollution of environment and economic loss. To prevent such incidents fire safety engineering has become a significant part in the process of tunnel design and construction. The idea/goal of our research work is to use the knowledge obtained from the fire analysis of partly delaminated curved reinforced concrete beam structures to evaluate the behaviour of tunnels in fire conditions.

The proposed model is a new numerical model for nonlinear geometric and material analysis of partly delaminated curved reinforced concrete beam structures exposed to simultaneous mechanical and fire load. Firstly, the model will define stiffness, ductility and load bearing capability of partly delaminated curved reinforced concrete beam structures. Furthermore, the model will provide fair evaluation of significant parameters, which are used for defining criteria for concrete spalling. Based on the obtained results from the model we will be able to predict the behaviour of tunnels during fire.

The model can be divided into three basic steps. In the first step of the fire analysis the time dependant change of temperatures of the fire compartment surrounding the beam structure will be determined. Heat flux affecting the surface of the beam structure due to convective and radiative heat flows from the surrounding fire compartment will be accounted for in boundary conditions of the next step of the fire analysis (hygro-thermal calculation). The temperature of the fire compartment, i.e. in tunnel, can be calculated by using parametric temperature-time curves (hydro-carbon fire curve) or CFD methods. Parametric fire curves present simpler way of determining the temperatures in fire compartment, while CFD methods are more complex and require appropriate fire scenario. As tunnel is a vast fire compartment, where temperatures during fire are distributed unevenly, we assume CFD methods, i.e. FDS, will be nearly inevitable in the fire analysis.

In the second step of the fire analysis heat and mass transport model will be implemented due to heterogeneous structure of concrete. RC is heterogeneous material consisting of solid matrix, water and gaseous mixture of water vapour and dry air. The model allows us to determine heat and moisture transfer in concrete during fire and detect special processes within the material due to high temperatures, e.g. concrete spalling. The governing equations of the heat and mass transport model will be solved numerically using finite element method. FEM software will be developed in Matlab environment.

The third step of the fire analysis will evaluate the mechanical response (stress-strain state) of the partly delaminated curved reinforced concrete beam structures. The beam structure will be presented as two connected curved RC beams, where the contact between the beams will be defined by a nonlinear constitutive law with respect to longitudinal and transversal slip. Reissner's kinematically exact planar beam theory will be implemented in the mechanical

model. Governing equations are equilibrium, kinematic and constitutive equations. The principle of additivity will be considered in the mechanical model as well, meaning that the increment of total strain is the sum of strain increments due to temperature, stress and creep in concrete and steel plus transient strains in concrete. The basic equations of the mechanical model will be solved with finite element method involving a strain-based planar curved beam finite-element.

The main goal of our research is to connect the second and the third step of the fire analysis. Transfer of heat and moisture in RC due to high temperatures is significantly affected by the stress-strain state of two connected beams. On the other hand, longitudinal and transversal slips have a great impact on the stress-strain state of two connected beams. For better understanding and more accurate results of the fire analysis of partly delaminated curved reinforced concrete beam structures, interaction between hygro-thermal and mechanical model must be considered. We assume that the mathematically coupled model (hygro-thermal + mechanical) can be used for the evaluation of the behaviour of tunnels in fire and detecting special fire events such as concrete spalling.