Numerical Analysis of Mathematical Model of Heat and Moister Transport in Concrete at High Temperatures

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Since the second half of the 1990s there is a renewed interest in the modelling of concrete at high temperature. Heat and mass transfer in concrete structures subject to high temperatures are of great interest in nuclear engineering applications and in safety evaluation against fire in civil engineering. Increased recurrence of tunnel fires in Europe, often connected with losses of life, always with destruction of the concrete structures and causing heavy economical losses, have evidenced the dramatic need for an upgrading of existing tunnels and introduction of new standards. Again the need for a new modelling capacity for concretes under such extreme conditions has been evidenced. Fire resistance is a key requirement for the concrete that goes into tunnel construction – a fact nowhere more clearly demonstrated than in the recent accidents in the Montblanc and Gotthard tunnels, where large pieces of concrete spalled off the roof of the tunnels at temperatures of over 1000°C. The devastating Montblanc accident of March 24, 1999, dramatically shows the immediate impact of this kind of fire on the stability of concrete structures.

In this paper, we present a nonlinear mathematical model for numerical analysis of the behaviour of concrete subject to transient heating according to the standard ISO fire curve. This example allows us to analyse and better understand physical phenomena taking place in heated concrete.

The governing equations of the present model are the dry air conservation equation, water species (liquid - vapour) conservation equation and energy conservation equation (general nonlinear heat equation).

For the model closure the initial and boundary conditions are needed. The convective (Neumann's) and radiative (Cauchy's mixed) boundary conditions for heat and moisture exchange are of importance.

The behaviour of concrete at high temperature is dependent on its composite structure, on the physical and chemical composition of the cement paste, which is a highly porous, hygroscopic material. The solid skeleton of the paste itself is composed of various chemical compounds and chemically bound water. In the whole temperature range, the gas phase is a mixture of dry air and water vapour. Therefore, the moist concrete is modelled as a multiphase material.

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