Alternative Implementation of a Porous Media Model for Simulating Drying of Heated Concrete

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Abstract

In a previous publication [1], a porous media model for simulating the pressure development in heated concrete has been presented, which is based on the classical formulation given in [2]. However this formulation has some drawbacks, which are addressed in a new implementation. The original formulation is only valid as long as liquid water is present and as long as the temperature stays below the critical temperature (374°C). These restrictions are dictated by two implementational details. First, the vapor saturation pressure, which is used to eliminate the pressure variable, is only defined within these limits. Second, the capillary pressure, which is used as primary variable, has no physical meaning outside of these restrictions. The classical formulation uses some workarounds to produce plausible results outside of the valid domain.

In this paper we use a different approach, already implemented for gypsum [3]. Instead of strictly enforcing the equilibrium vapor pressure, the evaporation is modelled as a vapor source, which reestablishes the thermodynamic equilibrium. The same idea is also used in some drying models in the COMSOL Application Library and is called non-equilibrium formulation. In a more general sense it can also be considered as a penalty formulation. This formulation needs one more dependent variable than the classical formulation, but has the advantage that evaporation can be stopped when the source is exhausted, because all water is evaporated. Since this will always be the case before the temperature has reached the critical temperature, neither the vapor saturation pressure nor the capillary pressure are needed outside of their domain of definition. Instead of the capillary pressure, the implementation uses the liquid saturation as primary variable.

The method is implemented directly from the differential equations, using only the weak form interface. Although some physics modules could be used, the weak form implementation seems to be more practical when experimenting with different formulations. In this way, it was possible to obtain the new formulation by applying only a few modifications to the existing previous implementation, even though there were some fundamental changes in the mathematical formulation.

The model is able to reproduce temperatures and pressures measured in a heating test presented in the literature. Since the pressure peaks occur below the critical temperature, the new implementation gives results very similar to the classical model. However, the physical background is much more appealing.

References

[1] B. Weber, D. Dauti, and S. Dal Pont, COMSOL Implementation of a Porous Media Model for Simulating Pressure Development in Heated Concrete, 2016 COMSOL Conference, Munich.
[2] D. Gawin, F. Pesavento, and B. Schrefler, Modelling of hygro-thermal behaviour and damage of concrete at temperature above the critical point of water, International Journal for Numerical and Analytical Methods in Geomechanics, 26, 537-562 (2002).
[3] B. Weber, Heat transfer mechanisms and models for a gypsum board exposed to fire, International Journal of Heat and Mass Transfer, 55(5-6), 1661-1678 (2012).

Figures used in the abstract

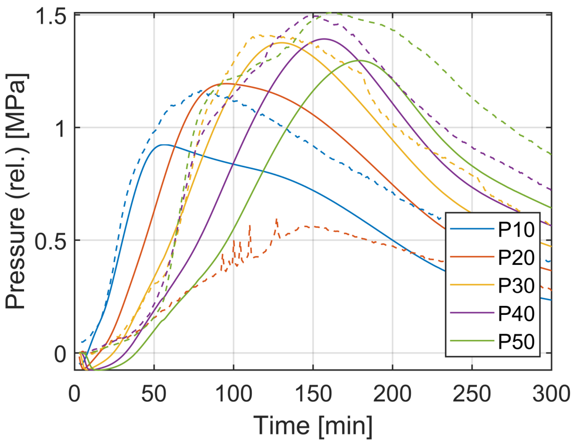

Figure 1: Comparison of simulated and measured pore pressures.