International Journal of Solids and Structures 48 (2011) 1945–1961

Contents lists available at ScienceDirect

International Journal of Solids and Structures

journal homepage: www.elsevier.com/locate/ijsolstr

What physical phenomena can be neglected when modelling concrete at high temperature? A comparative study. Part 2: Comparison between models

Dariusz Gawin [a], Francesco Pesavento [b,*], Bernhard A. Schrefler [b]

[a] Department of Building Physics and Building Materials, Technical University of Łódź, Al. Politechniki 6, 93-590 Łódź, Poland

[b] Department of Structural and Transportation Engineering, University of Padua, via Marzolo 9, 35131 Padova, Italy

ARTICLE INFO

Article history:
Received 21 October 2009
Received in revised form 17 February 2011
Available online 9 March 2011

Keywords:
High temperature degradation of concrete
Numerical model
Hydro-thermo-chemo-mechanical phenomena

ABSTRACT

The paper deals with modelling of hygro-thermal performance and thermo-chemical degradation of concrete exposed to high temperature. Several possible simplifications in modelling of heat and mass transport phenomena in heated concrete are considered and their effect on the results of numerical simulations is analyzed.

In part I of the companion paper, the physical phenomena, and heat and mass flux and sources in a concrete element were studied, both during slow and fast heating process, to examine the relative importance of different flux components. Then, the mathematical model of concrete at high temperature, developed by Authors in the last 10 years, was briefly presented and for the first time all the constitutive relationships of the model are summarized and discussed in detail. Finally, the method of numerical solution of the model equations was thoroughly presented.

In this part of the paper a brief literature review of the existing mathematical models of concrete at high temperature and a summary of their main features and physical assumptions is presented first. Then, extensive numerical study is performed with several simplified models, neglecting a chosen physical phenomenon or flux component, to evaluate a difference between the results obtained with the simplified models and with the reference model. The study concerns hygric, thermal and degradation performance of 1-D and 2-D axisymmetric concrete elements during fast and slow heating. The analysis will allow us to indicate which simplifications in modeling of concrete at high temperature are practically and physically possible, without generating excessive differences of the results with respect to the full reference model.

1. Introduction

In the first part of this paper (Gawin et al., 2011) we have recalled the most complete model for analysing concrete at high temperatures available in literature. We have added the Klinkenberg effect i.e. the influence of gas pressure on gas permeability, previously neglected and have given for the first time the complete set of necessary constitutive relations. We have also shown the numerical solution of the governing equations. With this model we have then analysed a test case under fast and slow heating rate, showing the important physical phenomena heated concrete undergoes. Some of them can be evidenced only through numerical modelling because they would be extremely difficult to measure.

We remind that this model has been extensively validated with respect to experiments within several European Projects (HITECO – "*High Temperature Concrete*", MAECENAS – "*Modelling of Ageing in Concrete Nuclear Power Plant Structures*", UPTUN – "*Upgrading Existing Tunnels*").

Now the stage is set to examine critically the other models for concrete at high temperatures which have appeared in literature, evidence the simplifications which they contain compared to the model of part 1 taken as reference and discuss the effects of these simplifications. The main reason for this comparison is to find out if such simplifications give acceptable results because the reference model is still computationally expensive especially in 3D situations which are sometimes necessary to be considered and because it requires many parameters to be determined. This comparison is carried out by solving the same example as in the first paper with fast and slow heating rate, introducing one by one the simplification, as well as their combinations. The two heating rates are considered because the reasons for temperature increase may be manifold. Just to mention a concrete structure under fire (e.g. a tunnel vault) or a containment vessel for a nuclear power plant which in his lifetime can undergo several thermal cycles with much slower heating rate. The effects of the different heating rates are important as already pointed out in the first paper. Finally an

* Corresponding author.
E-mail addresses: gawindar@p.lodz.pl (D. Gawin), pesa@caronte.dic.unipd.it, pesa@dic.unipd.it (F. Pesavento), bas@caronte.dic.unipd.it (B.A. Schrefler).

0020-7683/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.ijsolstr.2011.03.003