8th. World Congress on Computational Mechanics (WCCM8)
5th. European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 – July 5, 2008
Venice, Italy

# POLYPROPYLENE FIBRES AND EXPLOSIVE SPALLING IN TUNNEL CONSTRUCTIONS

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**Key Words:** *Polypropylene fibres, explosive spalling, fire, concrete; modelling, porosity, permeability.*

## ABSTRACT

Polypropylene (pp) fibres contribute to the reduction of pore pressures in concrete during heating, and hence the reduction of the probability of explosive spalling. Pressure reduction depends upon (a) the molecular structure of pp fibres during heating in relation to the microstructure of the concrete; (b) the mechanical properties of the fibres as functions of temperature; and (c) the type, dosage and dimensional characteristics of the fibres. The application to preserve tunnel concrete linings from fire effects is straightforward. This work forms part of an international research programme called NewCon carried out under the Eureka umbrella involving six organisations in four European countries. The NewCon research project was initiated in 2003 under the Eureka international umbrella to investigate the critical issues that require addressing through a comprehensive integrated research and development programme involving six organisations in four European countries. These are Imperial College (UK), Padua University (Italy), TNO (NL), FSD (UK), ADFIL (UK) and CETu (France). The NewCon project [1] adopts a holistic approach through small- and large-scale testing supported by hydro-thermo-mechanical numerical modelling. The key objectives are to:

- carry out comprehensive research and development into the influence of polypropylene fibres upon explosive spalling of concrete in fire for tunnel and other applications;
- investigate at the practical, experimental, and theoretical levels the role of a range of polypropylene fibres that represent those generally used in the industry at large;
- define the 'domain' within which polypropylene fibres are effective in combating explosive spalling in concrete when exposed to fire;
- resolve a number of key uncertainties about the fibres themselves and their use in concrete under service and fire conditions;

- arrive at a better understanding of the operative mechanisms underlying this phenomenon;
- present recommendations, guidelines, multidimensional design tools to assist in the practical implementation of this technology.

This entailed the following investigations:

- Micro-structural analysis (CETu)
- Fibres analysis (Imperial College and ADFIL)
- Toxicity analysis (FSD)
- Materials properties testing (Imperial College)
- Large-scale spalling tests on cylinders (TNO)
- Large-scale spalling tests on slabs (CETu)
- Numerical modelling (Padua University)

Results of the study of the mechanisms by which pp fibres influence explosive spalling are given in references [2-5].
The data produced is input into the thermo-hydro-mechanical numerical model NEWCON for the prediction of concrete spalling with and without the presence of pp fibres [6-10]. The model itself is validated against the large-scale test results and incorporates new developments about additional permeability and porosity due to pp fibres. Details concerning porosity effects were presented in [11], while in this paper the modelling aspects related to the permeability contribution due to pp fibres are included.

## REFERENCES


[1] Khoury, G.A. - "NewCon project. Concrete Engineering International", *Tunnels and Tunnelling*, Spring 2006. pp. 6-11.

[2] Khoury, G.A. and Willoughby, B. - "Polypropylene fibres in heated concrete. Part 1: Molecular structure and materials behaviour", *Magazine of Concrete Research*, 2008, (in press).

[3] Khoury, G.A. - "Polypropylene fibres in heated concrete. Part 2: Pressure relief mechanisms and modelling criteria", *Magazine of Concrete Research*, 2008, (in press).

[4] Sauer, J. A. and Pae, K. D. - "Mechanical properties of high polymers", in *Introduction to Polymer Science and Technology*, eds., H. S. Kaufman and J. J. Falcetta, Wiley-Interscience, New York, 1977.

[5] Khoury, G.A. - "Concrete spalling assessment methodologies and polypropylene fibre toxicity analysis in tunnel fires", *Structural Concrete*, March 2008 (in press).

[6] Khoury, G.A., Majorana, C.E., Pesavento, F., Schrefler, B.A. - "Modeling of heated concrete", *Magazine of Concrete Research*, Thomas Telford Ltd, London, U.K., vol. 54, no. 2, April 2002, pp. 77-101.

[7] Schrefler, B.A., Gawin, D., Khoury, G.A., Majorana, C.E. - "Thermo - hydro - mechanical modeling of high performance concrete at high temperatures", *Engineering Computations*, MCB University Press, Bradford, U.K., vol. 19, no. 7, 2002, pp. 787-819.

[8] Salomoni, V.A., Mazzucco, G., Majorana, C.E. – "Mechanical and durability behaviour of growing concrete structures", *Engineering Computations*, vol. 24, no. 5, 2007, pp. 536-561.

[9] Salomoni, V., Majorana, C., Giannuzzi, G., Miliozzi, A. - "Thermal - fluid flow within innovative heat storage concrete systems for solar power plants", *International Journal for Numerical Methods in Heat and Fluid Flow*, 2008, (in press).

[10] Majorana, C.E., Salomoni, V.A., Khoury, G. - "Stress-strain modelling of concrete under high temperature conditions", Special Lecture, *Proc. 11th International Conference on Civil, Structural and Environmental Engineering Computing*, St. Julians, Malta, 18-21 September 2007.

[11] Khoury, G., Majorana, C.E. - "Polypropylene Fibres and Explosive Spalling". *Fire design of concrete structures, from material modelling to structural performance, FIB Workshop*, Coimbra, Portugal, 8-9 November 2007.