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LATTICE MODELLING OF AUTONOMIC HEALING PROCESSES IN CEMENTITIOUS MATERIALS

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ABSTRACT

Considerable focus has been given recently to the specific creation of composite materials with manufactured 'autonomic' healing abilities. Their self healing capacity is reliant on the transport and curing of some form of healing agent, whose release is initiated by the damage (cracking) process. Significant self healing research has been completed within polymeric materials by White et al[1], and the concept has been explored experimentally within cementitious materials[2-4].

This paper presents preliminary results of a new approach for modelling the self healing process within cementitious materials. The numerical results are compared with data obtained from a series of self healing experiments which have recently been conducted at Cardiff University[5], using a cyanoacrylate healing agent. These involved testing lightly reinforced mortar beams in which 4 open ended capillary tubes were embedded, as illustrated in Figure 1 below. The tubes were filled with glue immediately prior to testing. The testing regime involved loading the beams until a crack of 0.3mm had occurred, unloading, and reloading after a period of 24 hours.

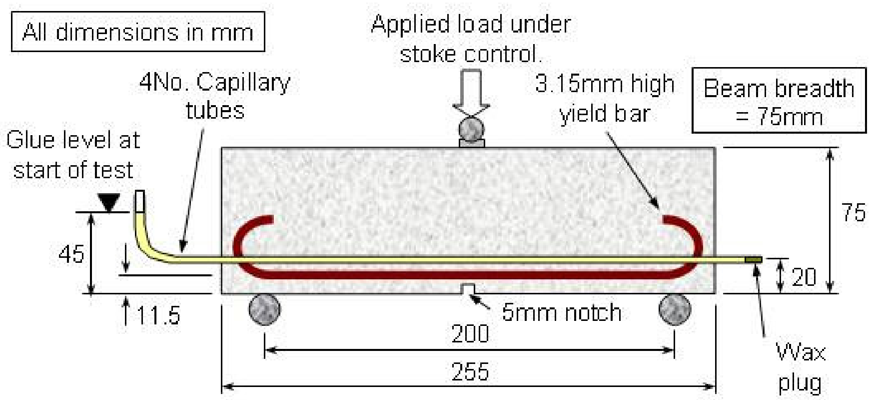

Figure1. Experimental arrangement for self healing beams

The modelling approach adopted is based on a lattice model which uses discrete beam elements to represent the continuum. Mortar is treated as a two phase material which has a statistical variation of beam strengths. This method has been shown to capture the softening branch of fracture tests on quasi-brittle materials, despite assuming a simple elastic-brittle constitutive relationship for the beam elements[6]. Cracks are modelled discretely in this approach and thus crack openings are determined automatically.

The breakage of the capillary tubes is assumed to be governed by a crack width criterion. Once the capillary tubes have fractured, it is assumed that the flow of the glue is controlled by the varying aperture of the crack at that location. The approach followed is based on capillary flow through non-uniform sections[7] and is essentially similar to that employed by Roels et al.[8] for modelling moisture flow in discrete cracks in building materials. This involves using a 1D moving front model in which both capillary and gravity forces are considered. The governing equations are Darcy's equation of flow and mass continuity, with a sink term included in the latter to model the flow of glue into the fracture process zone surrounding the macro-crack.

Glue setting is modelled using a time dependent function, with strength developing over time. Comparisons are made between numerical results and data obtained from the experiments. These suggest that the model is able to capture many of the primary characteristics of the experimental behaviour.

REFERENCES

[1] S. R. White, N. R. Sottos, P. H. Geubelle, J. S. Moore, M. R. Kessler, S. R. Sriram, E. N. Brown, and S. Viswanathan, "Autonomic healing of polymer composites," *Nature*, vol. **409**, pp. 794-797, (2001).

[2] C. Dry, "Matrix cracking repair and filling using active and passive modes for smart timed release of chemicals from fibres into cement matrices". *Smart Materials and Structures,* vol. **3**(2), pp. 118-123, (1994).

[3] V. C. Li, Y. M. Lim, and Y. W. Chan, "Feasibility study of a passive smart self-healing cementitious composite." *Composites Part B: Engineering*, vol. **29**(B), pp. 819-827, (1998).

[4] H. Mihashi, Y. Kaneko, T. Nishiwaki, and K. Otsuka, "Fundamental study on development of intelligent concrete characterized by self-healing capability for strength." *Transactions of the Japan Concrete Institute*, vol. **22**, pp. 441-450, (2000).

[5] C. Joseph and A. D. Jefferson, "Issues relating to the autonomic healing of cementitious materials". *1st international conference on self-healing materials*. Noordwijk, Holland, (2007).

[6] C. Joseph, and A.D. Jefferson, "Stochastic regularisation of lattice modelling for the failure of quasi-brittle materials", Proceedings of Fracture Mechanics of Concrete and Concrete Structures 6, 17th – 22nd June, 2007.

[7] W-B. Young, "Analysis of capillary flows in non-uniform cross-sectional capillaries". Colloids and Surfaces A. Physicochem. Eng Aspects, vol. **234** pp. 123-128, (2004).

[8] S. Roels, K. Vandersteen and J. Carmeliet "Measuring and simulating moisture uptake in a fractured porous medium". *Advances in Water Resources,* vol. **26,** pp. 237-246, (2003).