

SUSTAINABLE SELF-HEALING CEMENTITIOUS COMPOSITES

R.J. Lark¹, A.D. Jefferson¹, D. Gardner¹, B. Isaacs¹ and S. Dunn¹

¹Cardiff School of Engineering, Cardiff University, Newport Rd, Cardiff. CF24 3AA. UK.
Email: lark@cardiff.ac.uk

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ABSTRACT

The resilience of building and civil engineering structures is typically associated with the design of individual elements such that they have sufficient capacity or potential to react in an appropriate manner to adverse events. Traditionally this has been achieved by using ‘robust’ design procedures that focus on defining safety factors for individual adverse events and providing redundancy. As such, construction materials are designed to meet a prescribed specification; material degradation is viewed as inevitable and mitigation necessitates expensive maintenance regimes. More recently, based on a better understanding and knowledge of biological systems, materials that have the ability to adapt and respond to their environment have been developed. This fundamental change in material design philosophy therefore has the potential to facilitate the creation of a wide range of ‘smart’ materials and intelligent structures, including both autogenous and autonomic self-healing materials and adaptable, self-repairing structures, which can truly respond to their environment. In such a way resilience can be embedded within the materials and components of these structures and rather than being defined by individual events they can evolve over their lifespan.

This paper discusses the development of cementitious composites derived from sustainable components, which can deliver both this resilience and ultimately provide a material that has an enhanced strength and ductility.

Cementitious composites, such as concrete and mortar are among the most widely used materials in construction and, whilst in many respects they have served the construction industry well, they nearly always contain cracks, and it is these cracks that so often lead to the durability problems, which have necessitated significant expenditure on remediation. To address this problem a novel approach, explored at Cardiff, is to embed shape memory plastic (SMP) tendons into the cementitious matrix with the aim of creating a material system which can either close cracks or prevent them from occurring [1]. Materials in which the shrinkage stress level is sufficient to provide this inbuilt mechanism for closing cracks have now been identified [2, 3] and work is currently under way to further develop Variants II and III (Fig. 1).

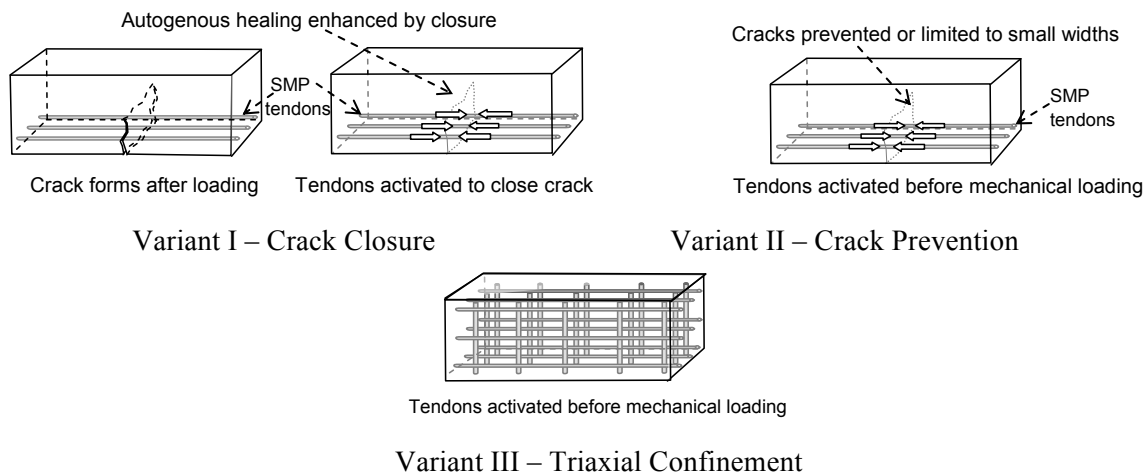


Figure 1: Concept of proposed material system

For Variant III the issues still to be explored are the ability of, initially, 2D and, subject to availability, 3D grids to fully or partially confine the cementitious matrix; the benefits of which should be an enhancement of both its strength and ductility. Particular issues to be investigated are the degree to which such grids can prevent cracking, the effect of confinement on the overall ductility of the matrix and the long-term losses due to creep and shrinkage in the cementitious matrix and relaxation of the SMP.

To achieve crack closure tendon shrinkage stresses of the order of 10MPa are required, whereas for partial confinement they will need to be an order of magnitude greater. However, the polyethylene terephthalate (PET) that has been used to-date have been reported as having shrinkage stresses as high as 80MPa when yarns drawn at 85°C are heated to 88°C [4]. The fact that PETs are widely used in bottles and other packaging also means that it may be possible to use recycled polymers in this application.

To further improve the sustainability of such composites it is also envisaged that they may include natural, geopolymer binders and manufactured aggregates. The work done to-date has focussed on how autogenous healing can be enhanced by the mix design and curing regime that is adopted [3]. However it is also well known that cement replacement materials and alternative binders can both decrease the amount of cement required and improve the rheology and hence refine the pore structure of the cementitious matrix [5]. Likewise, studies have shown that the use of recycled aggregates and, in particular, manufactured sands can improve the interfacial transition zone in hardened concrete and hence limit cracking, and also reduce permeability and hence improve durability due to the fines blocking the capillary pores within the hardened concrete [6]. Work at Cardiff is therefore ongoing to characterise these alternative materials and to identify how they might be used to further enhance the sustainability and self healing properties of the cementitious composites under consideration and preliminary results will be presented in the full paper.

It is anticipated that these developments will yield a truly sustainable and adaptable cementitious composite, which also has the potential to respond intelligently to its environment. The natural efficiency and sustainability of the proposed material system, together with its broad range of applicability, makes the work that is described both technically and commercially significant.

REFERENCES

- [1] A.D. Jefferson, C. Joseph, R.J. Lark, B. Isaacs, S. Dunn and B. Weager, A new system for crack closure in cementitious materials using shrinkable polymers, *Cement and Concrete Research*, **40**, 2010, pp. 795-801.
- [2] S. Dunn, A.D. Jefferson, R.J. Lark and B. Isaacs, Investigation into the shrinkage behaviour of polyethylene terephthalate (PET) for a new cementitious-shrinkable polymer material system, *Journal of Applied Polymer Science*, **120**, 2010, pp. 2516-2526.
- [3] B. Isaacs, R.J. Lark, A.D. Jefferson, C. Joseph, and S.C. Dunn, Crack healing using a shrinkable polymer cementitious material system. Submitted to *Cement and Concrete Composites*, September 2010.
- [4] S.D. Long and I.M. Ward, Shrinkage force studies of oriented polyethylene terephthalate, *Journal of Applied Polymer Science*, **42**, Issue 7, 1991, pp. 1921-1929.
- [5] V.M. Mulhotra, Mineral Admixtures, *Concrete Construction Engineering Handbook*. Taylor & Francis Group, New York. 2nd Edition, 2008.
- [6] B. Li, J. Wang and M. Zhou, Effect of limestone fines content in manufactured sand on durability of low and high strength concretes. *Construction and Building Materials*, **23**, 2009, pp. 2846-2850.