Epoxy-based alginate shell particles as functional self-triggered additives for self-healing concrete

Yegor Morozov, Centro de Quimica Estructural, Instituto Superior Técnico, University of Lisbon, Portugal

Yanwen Guo, Microbelcaps S.A., Liège, Belgium

Slim Zgoulli, Microbelcaps S.A., Liège, Belgium

Maria Araújo, Magnel Laboratory for Concrete Research, Faculty of Engineering and Architecture, Department of Structural Engineering, Ghent University, Belgium

Kim Van Tittelboom, Magnel Laboratory for Concrete Research, Faculty of Engineering and Architecture, Department of Structural Engineering, Ghent University, Belgium

Nele De Belie, Magnel Laboratory for Concrete Research, Faculty of Engineering and Architecture, Department of Structural Engineering, Ghent University, Belgium

Emmanuel Cailleux, Belgian Building Research Institute, Brussels, Belgium

S.V. Lamaka, Magnesium Innovation Centre, Institute of Materials Research, Helmholtz-Zentrum Geesthacht, Germany

M.F. Montemor, Centro de Quimica Estructural, Instituto Superior Técnico, University of Lisbon, Portugal

Reinforced concrete is the most common construction material due to its low cost and superior characteristics. It is durable, when adequately designed and produced for the environment in which it has to serve. Nevertheless, there are conditions in which the performance of concrete is impaired by degradation phenomena that cause cracking. Cracks drastically increase permeability, undermining the barrier properties of the concrete cover, inducing steel reinforcement corrosion that promotes further deterioration. Therefore, regular rehabilitation of the structures is unavoidable to extend the life-expectancy of structures. However, these are laborious and expensive operations for large-scale infrastructures and for those in continuous use or in remote locations. Therefore, sustainable repair methodologies are of greatest demand, including self-protecting, self-repairing, fault-tolerant concrete.

Many cementitious materials show intrinsic autogenous healing, which can be further improved by engineered additives. There are many approaches, which include bio-concrete and self-healing through encapsulated polymers in particular, however the

development of "smart" encapsulation methodologies and respective materials is another challenging frontier.

The nature of a shell material determines the uniformity of the healing agents' distribution, its storage and controlled release, preventing unnecessary exposure to aggressive environment and premature reaction, which makes its development equally important to that of the healing agents. An ideal solution would be if self-healing additives could act to external stimuli to release a healing agent in a controlled manner upon demand. The changes that can be employed to trigger the release include: a) mechanical stress to break the shell of a particle; b) increase of the humidity, naturally occurring as water enters the crack, to dissolve a shell; c) variations in the chemical composition in the vicinity of cracks that results in shell disintegration. However, additives must be stable during concrete mix preparation and placing.

Concrete is a buffered system, and pH can drop due to the carbonation process, which is expected to occur inside cracks at much higher rates reaching values of 9 and lower. The composition of the interstitial solution is affected too. In this regard, the focus of the current study is the development of chemically triggered self-repair concrete additives. There are several ways to introduce such functionality, but the use of polyelectrolyte complexes is seen to be a very promising approach.

A concept of autonomous healing by epoxy-based alginate shell particles has been developed and tested. The reversible formation of a calcium alginate complex was used to incorporate an epoxy into a xerogel shell, ensuring its controlled release. The developed additives are spherical particles of 1.8 mm in diameter, and are built up of fine droplets of epoxy resin, which accounts for 90% by weight. The tests conducted in various solutions proved the excellent stability of the particles in grout extract and lime water, and demonstrated their lability in carbonated water-rich environments – the conditions commonly encountered inside concrete cracks. Such behaviour is attributed to the dissolution of the shell in calcium poor solutions, accompanied by the release of the healing agent that can be predicted by modelled concrete carbonation.

Acknowledgement: The authors would like to acknowledge FCT (Portugal) VLAIO (former IWT)-Flanders (Belgium) and DGO6-Wallonia (Belgium) for funding M-ERA.NET/0004/2012 CAPDESIGN project; and FCT (Portugal) for funding CQE