ABSTRACT

A capsule-based self-healing cementitious material, capable of autonomically repairing its own cracks, can extend the service life of concrete structures and decrease the costs associate with repair and maintenance actions. However, the size, shell thickness, shell material and mechanical properties of the capsules still need to be optimised to ensure self-healing performance. Thus, the objective of this research was to explore the controlled microfluidic encapsulation to investigate the production of microcapsules for physically triggered self-healing in cementitious materials. A flow-focusing microfluidic device was used to produce double emulsions to be selectively photopolymerised to generate a core-shell structure. Subsequently, the physical triggering was assessed by embedding the produced microcapsules in cement paste, fracturing it and observing the cracked surface in the SEM. The results showed the production of microcapsules with 80-140 μm of diameter with excellent control over size and shell thickness. Using water-in-oil-in-water (w/o/w) double emulsion, microcapsules were synthesised containing water, colloidal silica solution and sodium silicate solution as core material. In addition, an oil-in-oil-in-water (o/o/w) double emulsion was used to encapsulate mineral oil and emulsified healing agents. The formation of the core-shell structure with aqueous and organic cores was characterised using optical microscopy and SEM. It was demonstrated that the water is not retained inside of the capsule, resulting in the formation of dimples and buckled capsules, particularly for shells thickness ~7 μm. On the other hand, TGA confirmed the retention of mineral oil for shells thickness of ~2 μm and the encapsulation efficiency was demonstrated to be 66%. When the capsules were added to the cement paste, four key factors were observed to prevent physical triggering: (i) thick shells, (ii) buckling of thinner shells due to the loss of water core, (iii) mechanical properties and (iv) poor interfacial bonding. As a result, a mechanical characterisation of the shell material was performed, indicating brittle fracture at room temperature, reduced Young's modulus when compared with cementitious matrix and stress at rupture of 15-36 MPa. In addition, an innovative methodology was proposed to functionalise the surface of the microcapsules with hydrophilic groups in order to increase the interfacial bonding between the cement paste and the microcapsules. Thus, microcapsules with low tensile strength, low shell thickness, organic core and good interfacial bonding were successfully synthesised and demonstrated to rupture upon crack formation. These results experimentally demonstrate the importance of reduced shell thickness, core retention and interfacial bonding as valuable guides during the design of microcapsules for physically triggered self-healing in cementitious materials.