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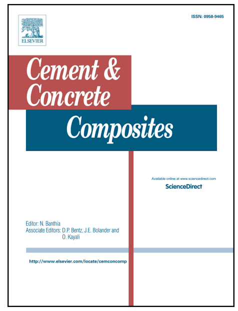

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Integral procedure to assess crack filling and mechanical contribution of polymer-based healing agent in encapsulation-based self-healing concrete

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Abstract

This work presents an experimental and numerical study to analyze the crack filling process in encapsulation-based self-healing concrete. A specimen consisting of two small concrete blocks has been designed containing capsules filled with a polyurethane-based healing agent. This design enables to control the capsule breakage and release of healing agent. Two setups are studied: (i) a two-capsule system, where one capsule contains the pre-polymer fluid and the other contains a water-based accelerator component, and (ii) a single capsule system with only the pre-polymer fluid. The amount of healing agent released in the crack is visualized using micro Computed Tomography scanning. Tensile mechanical tests are performed to evaluate the strength contribution of the cured healing agent. A computational fluid dynamics model has been developed to understand how the healing agent spreads in the crack as a function of the crack width.

Keywords: self-healing materials, capsules, agent leakage, capillary force, strength recovery, tensile test

1. Introduction

Concrete structures are constantly undergoing different kinds of loads during their service life, which produce continuous damage in the form of new cracks that add up to already existing defects originating from the fabrication process. An encapsulation-based self-healing concrete is based on small healing agent-filled capsules embedded in the matrix. When an internal crack reaches a capsule, the stresses undergone by the capsule lead to its sudden breakage, and the fluid inside is released. This liberation, or "leakage" from now on, has to take place immediately after the crack has broken the capsule. Then, the curing reaction of the healing agent seals the crack. The chemical nature of the agent can be quite varied [1–4], however, this paper focuses on a polyurethane-based healing agent encapsulated in a glass capsule. Regarding the internal process of cracking, the brittle nature of a sufficiently thin-walled glass capsule matches well with the local brittleness of the concrete matrix. Also, this healing strategy uses the capillarity as the driving force in charge of the leakage of the agent in the crack. The idea behind using a healing agent based on a polyurethane resin relies on the crack sealing process by means of a volume increase by foaming that might definitely fill the space created by the crack. This reaction is triggered by the humidity in the material. Therefore, two key processes play a decisive role to ensure a successful healing: on the one hand, the healing agent still in its fluid phase must spread efficiently in the crack by capillarity, and on the other hand, the reaction process taking place in the agent must produce enough foam to guarantee a tight filling of the damaged area. To speed up the process, some authors have decided to include capsules in pairs [3, 5, 6]. In these studies, the authors place two closely attached capsules, one containing the healing agent and the other containing a water-based accelerator. The effectiveness of this system relies on several assumptions. First, once a crack reaches the capsules both should break simultaneously.

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