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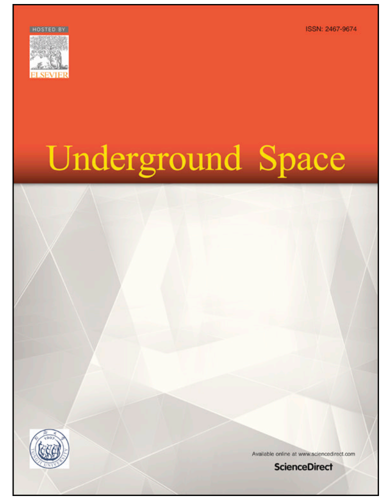

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Interaction between matrix crack and circular capsule under uniaxial tension in encapsulation-based self-healing concrete

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Abstract This paper investigates the fracture process of a capsule when subjected to uniaxial tension in encapsulation-based self-healing concrete. A circular capsule embedded in the mortar matrix is considered along with different ratios of core-shell thickness. To represent potential cracks, zero thickness cohesive elements are pre-inserted throughout element boundaries. The effects of fracture strength around the interfacial transition zone of the capsule are analyzed. The crack nucleation, propagation, and fracture mode of capsule are also discussed. The numerical results indicate that increasing the strength of the interfacial transition zone around the capsule can increase the load-carrying capacity of self-healing concrete. Moreover, given a similar fracture strength around the interface of the capsule, the fracture probability of capsule in encapsulation-based self-healing concrete is strongly dependent on the core–shell thickness ratio.

Keywords: Fracture; Cohesive elements; Capsule; Interfacial transition zone; Thickness

1 Introduction

Microcapsule-based self-healing materials have currently gained great popularity in the civil engineering discipline (Yang et al., 2011; Maes et al., 2014; Dong et al.,2015). These capsules are embedded in the cementitious matrix during concrete mixing. When a crack appears, the embedded capsules, which are placed along the path of incoming cracks, are fractured, and then release of healing agents in the vicinity of damage. This microcapsule-based method, in which capsules are well dispersed in the mortar matrix, is claimed to have the highest performance in healing cracks at different areas in the material (Gruyaert et al., 2016).

In the past decade, many researchers have developed various methods to simulate the fracture behavior in both brittle and quasi-brittle materials (Rabczuk, 2013). These include the meshfree method (Rabczuk and Belytschko, 2004; Rabczuk and Belytschko, 2007a; Rabczuk and Zi, 2007b), cohesive zone (Areias and Rabczuk, 2008; Nguyen et al., 2017), XFEM-based (Chen et al., 2012; Nguyen-Vinh H et al.,2012; Zhang et al.,2016; Vu-Bac et al., 2011), phase-field (Amiri et al., 2014a, 2014b), FEM-based (Areias et al., 2013a, 2013b, 2014), remeshing (Areias et al., 2016a), screened Poisson (Areias et al., 2016a), and peridynamics (Ren et al., 2016, 2017). Hamdia et al. (2015, 2016) proposed an artificial neural network combined with Bayesian technique to predict the fracture energy of polymer nanocomposites. Talebi et al. (2014, 2015) investigated fracture with a concurrent multiscale method. The multiscale method for studying the fracture behavior was also investigated by Budarapu et al. (2014a, 2014b). A crack propagation study using a phantom node was developed by Budarapu et al. (2014a). The ghost atom is used not only to convert between coarse and fine scale, but also to serve as boundary of finer scale. An equivalent continuum model from an atomic level to coarse scale was also investigated (Budarapu et al., 2014b). Instead of the phantom node, Yang et al. (2015) proposed an extension of the adaptive meshless method into a partition of unity in the coarse scale. A coarse-grained (CG) approach to study the interaction between polymer chains and nanotubes was introduced by Arash et al. (2015, 2016). They used this method to predict the macroscopic behavior of carbon nanotubes (CNT). Gui et al. (2016) used a cohesive zone combined with continuum-discrete models to simulate the fracture process in rock dynamic tests. To predict the behavior of rocks, elastic and inelastic displacements were used in the cohesive model. However, the aforementioned methods were mostly presented in finite element procedures, and not in the actual application of microcapsule-based self-healing systems.
Recently, some researchers have started to study encapsulation-based self-healing systems in cementitious materials