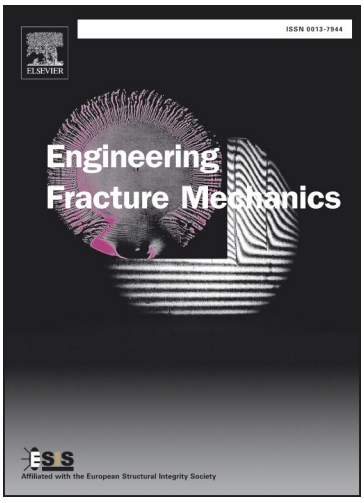

Combined experimental and numerical study on micro-cube indentation splitting test of cement paste

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Combined experimental and numerical study on micro-cube indentation splitting test of cement paste

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Highlights

- Produce and apply indentation splitting test on the micro cement paste cubes.
- Determine the nominal splitting tensile strength of the tested micro cubes.
- Analyse the nominal splitting tensile strength using Weibull statistics.
- Simulate the fracture process of the micro-cube by microstructure-informed lattice model.
- Validate the simulation results using the experiment obtained load-displacement curve and crack pattern.

Abstract

The aim of this paper is to investigate the fracture performance of cement paste at micro scale by both experimental and numerical methods. Micro cubic specimens with length of 100 µm were fabricated by precision cutting, grinding and micro-dicing, and tested by splitting with a wedge tip mounted on a nano-indenter. A nominal splitting tensile strength was derived from the maximum load of the recorded load-displacement diagram to represent the global fracture performance of the fractured micro-cube. To achieve this, an analogy was made between the micro-cube indentation splitting test and the standard Brazilian splitting test. To cope with the inherent heterogeneity of this material at micro scale, for cement paste with each water/cement (w/c) ratio (0.3 ,0.4 and 0.5), more than hundred micro-cube specimens were fabricated, tested and analysed using Weibull statistics. The analysis shows that the splitting tensile strength of cement paste on the micro scale is much higher than on the macroscopic scale but lower than tensile strength of distinct hydrated cement phases measured on micro or nano scale. Furthermore, higher and less scattered values of splitting tensile strength were observed for the specimens with lower w/c ratio. In parallel with the experiments, a micro-structure informed lattice fracture model was adopted to simulate the fracture process of the micro-cube under indentation splitting. The simulated results were compared with the experimental one and have a good consistency in terms of the load-displacement curve and fracture pattern. With the method presented in this paper the framework for validation of the modelling results at micro scale is created.

Keywords: Micromechanics; Splitting tensile strength; Micro-cube splitting; Lattice modelling; Cement paste.

1 Introduction

Concrete is a material with heterogeneities at length scales ranging from sub-nanometres to metres, and its mechanical properties are affected by various factors at all composite scales [1]. To cope with its multi-scale nature, multi-scale strategies are commonly applied [2-6]. At the µm scale the internal structure of hardened cement paste is the most important structural feature, comprising various phases, i.e. the hydration products (inner hydration product, outer hydration product and calcium hydroxide) [7], anhydrous cement particles and capillary pores. At higher (cm) scale, cement paste is homogenized together with the aggregates and the interfacial transition zone between these two phases, while at lower scale distinct hydration products containing nano pores and capillary pores are regarded