Mixed-Mode Fracture of Cement Paste and Interface under Three-Point Bending Test: Numerical and Experimental Investigations

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Concrete is a quasi-brittle material with a high degree of heterogeneity. The presence of multiple phases in concrete (cement paste, sand, gravel, porosity, etc.) leads in a gradient of mechanical characteristics, notably around the aggregates, where an Interfacial Transition Zone (ITZ) is formed. This disparity in microstructure characteristics has a significant impact on the process of damage and cracking, making fracture propagation in concrete difficult to predict.

The cracks can occur at the interfaces of relatively heterogeneous materials like concrete due to debonding and subsequently spread through the cement paste, or vice versa [1]. These observations highlight the significance of conducting a local numerical investigation of crack propagation at the level of pure cement paste and at the interface between the cement paste and the aggregate, considering these two areas to be preliminary cracking zones. The CZM is one of the modeling methodologies used here for fracture mechanisms in heterogeneous materials [2]. This model allows us to define the fracture as a displacement jump between cohesive elements. The CZM model will be used to execute a numerical study of mixed mode fracture at the “local scale” of cementitious material [3,4].

For this purpose, two-dimensional simulations of three-point bending tests under variable load and geometry are modeled by employing CZMs. These tests are performed on parallelepipedal samples of dimension (10 x 10 x 30 mm^3).

A pre-notched cement pastes samples beam with eccentric load are tested. The eccentricity is defined as the distance between the point of load and the center of the sample. Four loading points equal to 0 mm (centered load), 2.5, 5, and 7.5 mm are studied. Composite specimens (cement paste linked to one siliceous aggregate) are also evaluated in bending with centered loading. Here, the composite specimen design is different: the interface angle between cement paste and aggregate varies between 30° and 90°.

This procedure enables the provision of a diverse set of crack trajectories and propagation modes, enhancing the calibration of numerical models by comparison with experimental results at this local scale.

As result, the numerical responses match the experimental results after identifications of the elastic and cohesive parameters based on experimental data. Therefore, the findings at this local scale demonstrate that when the mixed mode ratio increase, the fracture energy and material resistance increase too for the two sample types (cement paste and composite). Moreover, similar crack propagation, fracture path and mechanical responses are obtained in experimental and numerical model.

References

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