"Drawing with a crack in concrete": a hybrid test to control mixed-mode crack propagation

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Thanks to its good mechanical properties and relatively low cost the use of cement-based materials is widespread in standard civil engineering applications such as bridges or hydraulic dams, and due to the continuum improvement in it's quality, concrete is also used for more complex structures such as off-shore platforms, storage tanks for liquid gases and finally nuclear containment buildings. In the latter case the knowledge of the concrete behavior, in terms of crack initiation and propagation features, is crucial when analyzing the severely regulated leakage between the interior (i.e., the nuclear reactor) and the exterior (i.e., the in-between containment walls space). Therefore there is a need for material models to accurately predict the crack path and force-displacement history [1].

To experimentally validate concrete damage and fracture models, identify their parameters and better characterize the concrete behaviour during mixed-mode crack propagation, multiaxial tests are developed. Inspired by former works of Nooru-Mohamed (1992) [2] and Winkler (2001) [3] we perform rich and discriminating tests by using state of the art techniques, where the experimental boundary conditions are directly measured during crack propagation. The loadings are applied using a hexapod testing machine controlled by a 3D displacement system [4] and the cracking state is analysed via digital image correlation.

With the proposed experimental setup several loading histories are analysed: proportional multiaxial loading histories and non-proportional ones, with and without crack closure and friction. The experimental results are confronted with numerical simulations performed with nonlocal (i.e., gradient) damage models [5], [6], [7] and with a linear elastic fracture model coupled with the X-FEM framework [8] [9]. The present work underlines the importance of using accurate boundary conditions, estimated from full field measurements [10], to perform numerical simulations that reproduce the experimental results. Moreover it is shown that crack reorientation and crack branching is vital to create discriminant crack propagation tests.

Based on the recent experimental results a new kind of hybrid test is also presented. Obtained by solving inversed problem, i.e. given prescribed crack path the corresponding boundary conditions are found, this new discriminating concrete fracture test is able to fully investigate its complex mechanical behaviour within a single run.

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