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Micro-bending for multi-scale fracture characterization of cement-based materials and ceramics

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Abstract

Exponential advances in technologies have brought upon researchers, and engineers alike, tools to further explore theory and gain more knowledge in the various fields of science. As for material engineering, developments of data-acquisition devices and numerical methods have broadened the horizons on ways to test material properties – allowing the development of new procedures and methodologies. Pursuing such novel approaches could allow the development of more efficient and accurate mechanical properties testing procedures to be used in future regulatory standards.

The last few years have seen the development of several testing techniques at the micro-scale to characterize the mechanical properties of multi-scale materials. One of such novel methods are micro-cantilever bending tests to assess elastic, visco-elastic, as well as nonlinear mechanical properties – i.e., fracture energy and toughness (K_C) – of materials. Micro-cantilever tests allow for a variety of test configurations including scaled chevron-notch geometry (Fig. 1) allowing for the controlled crack-growth prior to reaching the critical failure load. Chevron notches are convenient at such length scales since they allow for ex-situ measurements of crack length as a function of bending compliance – avoiding the need to directly measure crack length, which could be a challenge at such scale. The test approach provides access to crack resistance curve (R-curve) behavior for quasi-brittle materials on the micro-scale (Fig. 2) and opens the door to investigate more sophisticated and advanced topics, i.e., creep crack growth. Moreover, the technique complemented with visualization and scanning tools, such as Scanning Electron Microscopy (SEM) and Microtomography (McT), allows for a proper and extensive analysis of the crack growth phenomena.

The motivation of this work revolves around expanding currently available knowledge on multiscale characterization of cement-based materials with the focus on fracture testing at the micro- and mesoscale through the novel micro-bending technique. This test opens the door to understanding fracture, toughening mechanisms and evolution of these properties with regards to processing variables like degree of hydration. The micro-bending fracture test will allow us to look into the development of novel cement organic-inorganic systems with minimum bulk material preparation, high statistical reliability, as well as ease of testing.

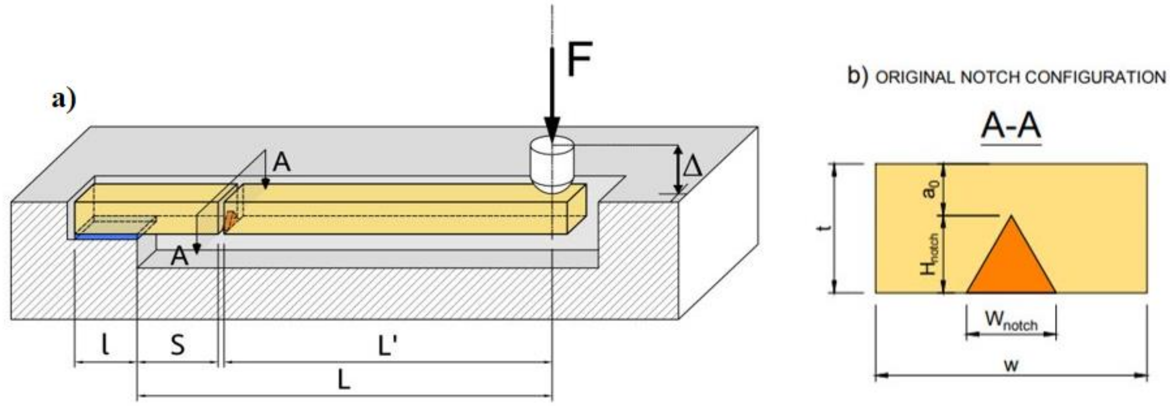

Fig.1 – Perspective of the micro-bending fracture set-up [L ~ 8 mm] (a) and cross-sectional view of the machined notch [H_{notch} ~ 200 μm] (b) along cut A-A.

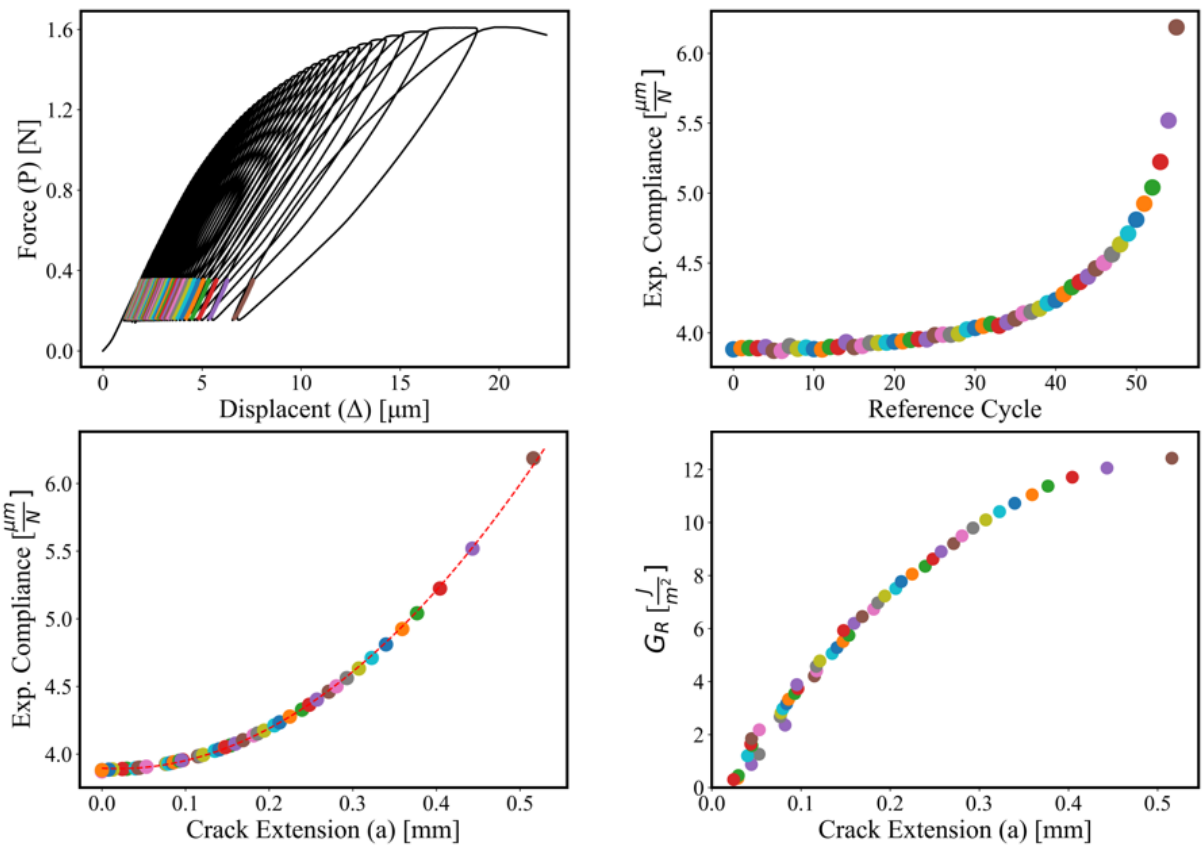

Fig.2 – Micro-bending fracture test (a-d), P-Δ diagram obtained through the use of the MTS protocol (a), along with the unloading compliances from each cycle (b), the ex-situ inferred crack-length at every cycle (c) and the crack-resistance curve (d) for the Lava Stone ceramic.