Numerical Analysis of the Influence of Surface Roughness on Shear Strength of Cracked Concrete

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ABSTRACT

Aggregate interlock is the mechanism via which normal and shear stresses are transferred across the lips of cracks in concrete [1]. The fractal property of cracking surfaces in concrete plays a significant role in shear transfer across surfaces. Because of the concrete constituents, it is expected that the distribution of aggregates will influence fracture surface properties. Ideally, one should statistically analyze the influence of micro-roughness (related to aggregates), meso-roughness (related to crack local shape) and macro-roughness (related to the crack global shape) on its associated shear strength. In this study, we focus on the influence of aggregate distribution on meso-scale roughness and subsequently, on shear strength of cracked concrete.

To that end, fracture surfaces are artificially generated using the Fourier algorithm as proposed by Hu and Tonder [2]. However, such artificially generated crack surfaces do not account for the distribution of aggregates. A novel method is proposed to generate fractal surfaces with random distribution of aggregates for a given packing density. A Fuller distribution curve [3] is employed to control the aggregate sizes. It is shown that the power spectrum of these artificially generated rough surfaces closely follows the power-law behavior observed for real fracture surfaces (Hurst exponent, $H \approx 0.8$). This allows us to assume that the crack path is known $a - priori$.

To quantify the contact stresses, a Finite Element based fracture-contact model is developed. The crack propagation along generated surface is numerically simulated under mixed-mode loading and the contact between surfaces is computationally resolved. The crack propagation is handled with cohesive elements, governed by an exponential cohesive law. The parameters for the cohesive law are calibrated for different interfaces, i.e. aggregate-aggregate, aggregate-mortar and mortar-mortar, based on the experiments by Trissa et. al. [4]. Contact constraints, including friction, are enforced through a Penalty formulation, with a node-to-segment contact detection. The evolution of contact area for the generated surfaces and its influence on distribution of contact stresses at the crack interface is studied through numerical simulations.

REFERENCES

[1] Walraven, J.C. *Fundamental Analysis of Aggregate Interlock*, J. Struct. Div. ASCE (1981) **107**:2245-2270 .

[2] Hu, Y.Z. and Tonder, K. *Simulation of 3-D Random Surface by 2-D Digital Filter and Fourier Analysis*, Int. J. Mach. Tools Manufact (1992) **32**:83-90.

[3] Fuller, W. and Thompson, S. *The laws of Proportioning Concrete*, transcations of the American Society of Civil Engineers (1907) **2**:67-143.

[4] Trissa, M., Ruiz, M.F. and Muttoni, A. *Interfaces Stresses in Cracked Concrete: Testing for Review of its Fundamentals*, Proceedings of the 12^{th} fib PhD Symposium in Civil Engineering, Prague (2018)