The 8th European Congress on Computational Methods in Applied Sciences and Engineering
ECCOMAS Congress 2022
5-9 June 2022, Oslo, Norway

Surface roughness and shear resistance in cracked concrete

M. Pundir[2], **G. Anciaux**[1]

[1] Computational Solid Mechanics Laboratory, IIC, ENAC
École polytechnique fédérale de Lausanne (EPFL)
[2] Department of Civil, Environment and Geomatic Engineering
ETH Zürich

Keywords: *Roughness, Concrete, Elasto-plastic contact, Boundary-element method*

In concrete structures, opened cracks contribute significantly to the transfer of shear and normal stresses through the contact forces acting on fractured surfaces. Such contact forces are due to protruding asperities, engaged by interlocking and friction during *mixed-mode* displacements.

The presented work first presents *micro*-CT and digital microscope measures of concrete surfaces which were previously sheared until failure. This allows to link the features of cracked concrete surfaces with the distribution of aggregates - induced by the *cumulative density function* and the *radial distribution function* - and with a small scale roughness coming from much smaller grains (mortar and broken aggregates) which can be acknowledged with statistical indicators such as the *Hurst* exponent and the *root-mean-square* of surface slopes. This experimental data lead to an accurate numerical surface generator which superposes of a fractal-like roughness with a set of protruding aggregates.

Then, the role played by such a roughness on shear resistance is investigated numerically, thanks to a contact solver based on a boundary integral approach. With an extremely fine description of cracked surfaces (four million discretization points), we demonstrate that roughness impacts drastically the shear resistance. The small scale roughness induces a non-monotonic evolution of the true contact area, which first increases before decaying as a power-law, which is intimately linked with the fine scale roughness self-affinity[2].

A remarkable outcome of our approach is a better agreement with the seminal experimental results of Jacobsen et al. [1]. We finally propose a semi-empirical traction-separation law for cracked concrete which accounts for micro-scale roughness and aggregate distribution. This law is directly usable in finite element simulations employing a cohesive element modeling of cracks, and naturally includes roughness-induced interlocking effect.

References

[1] J. S. Jacobsen, P. N. Poulsen, and J. F. Olesen. “Characterization of mixed mode crack opening in concrete”. In: *Mater. Struct.* 45 (2012), pp. 107–122.

[2] B. N. J. Persson, O. Albohr, U. Tartaglino, A. I. Volokitin, and E. Tosatti. “On the nature of surface roughness with application to contact mechanics, sealing, rubber friction and adhesion”. In: *Journal of Physics: Condensed matter* 17.1 (2005), pp. 1–62.