Meshfree modelling of dynamic mixed-mode fracture in fibre-reinforced concrete

†Rena C. Yu*, Pedro Navas, and Gonzalo Ruiz

School of Civil Engineering, University of Castilla-La Mancha, Spain.

*Presenting author: rena@uclm.es

Abstract

This work is concerned with the numerical study of dynamic mixed-mode fracture in fiber reinforced concrete (FRC). A recently developed eigensoftening algorithm [1] to deal with the fracture of quasi-brittle materials is employed in a meshfree framework. In particular, the optimal transportation meshfree method, an updated Lagrangian numerical scheme that combines concepts from optimal transportation theory with a material-point sampling and the local max-ent meshfree approximation, is used. Such a scheme is chosen for its numerous advantages such as the exact mass transport, the satisfaction of the continuity equation, exact linear and angular momentum conservation. Since the deformation and velocity fields are interpolated from nodal values using shape functions based on the principle of maximum entropy, the Kronecker-delta property at the boundary makes it possible for the direct imposition of essential boundary conditions. The eigensoftening approach to fracture was engineered for the gradual dissipation of the fracture energy in quasi-brittle materials such as concrete. In other words, the material softens in a progressive manner until its complete failure (i.e. the formation of a stress-free crack). This is equivalent to the crack band model, since energy dissipation is through the softened (or failed) volume. In the meantime, the analogy to cohesive approaches is straightforward through the definition of a damage variable.

Three-point bending tests on notched beams reinforced with steel fibers carried out through a drop weight device at two loading velocities are modelled herein. Since the notch was placed with an offset from the middle section, mixed-mode crack formation was facilitated. Three types of concrete with the same matrix reinforced with different amounts of steel fibers were used for these beams. All mechanical and fracture properties were measured through independent tests. Assuming a linear softening stress-equivalent crack opening relation, the numerical methodology is first validated against experimental results on plain concrete. Subsequently, it is applied to study the dynamic fracture of fiber reinforced concrete with a bilinear softening relation. The numerical simulations reproduced remarkably well the experimental results such as load-line displacements, crack patterns and reaction forces. The parametric studies show that the total energy dissipation plays an important role on the peak reaction load, whereas the transitional point between the two branches has a significant influence on the crack patterns.

Keywords: **Dynamic Fracture, mixed-mode, eigensoftening, meshfree method**

References

[1] Navas, P., Yu, R.C., Li, B. and Ruiz, G. (2018). Modeling the dynamic fracture in concrete: an eigensoftening meshfree approach, *International Journal of Impact Engineering* **118**, 9–20.