Parameter calibration of a fibre-reinforced concrete fracture model by means of co-simulation between OOFEM and Scipy

F. Suárez[1*]

[1] Department of Mechanical and Mining Engineering, University of Jaén, Escuela Politécnica Superior de Linares, Campus Científico-Tecnológico de Linares, 23071, Jaén, Spain, fsuarez@ujaen.es

The use of fibre-reinforced concrete (FRC) is not new, but has experienced a big impulse in recent years. The increasing interest in FRC has produced a remarkable number of experimental studies to identify how diverse aspects of their production affect their properties, both in fresh state and hardened. Together with these experimental studies, several approaches have been proposed for numerically reproducing fracture in FRC. It is worth mentioning the use of cohesive fracture by using a trilinear softening diagram [1] that allows reproducing the behaviour of this material taking into account different FRC mixes (with different fibre length and proportion), different loading scenarios [2] and capturing the size effect [3]. Moreover, the trilinear softening diagram is defined with crack opening and stress values that are related with physical parameters of the FRC mix (concrete strength, fibre length, polymer elastic modulus or the fibre proportion, for instance).

The trilinear softening diagram is defined by six values (f_t, f_k, f_r, w_k, w_r and w_f), that correspond to stresses (f_i) and crack opening values (w_i) that must be calibrated to fit the experimental results. Since this process includes a relatively high number of parameters to adjust, it implies carrying out a trial and error process that may lead to a high number of models to be run (typically, around 25 would be a fair estimation).

The trilinear softening diagram has been successfully used with an embedded fracture model in the past. In this study, the trilinear softening diagram is adapted and implemented in a smeared crack model of the free finite element code OOFEM [4] and the calibration process of the parameters that define the trilinear softening diagram is carried out by means of an algorithm that makes use of an optimization package of Scipy [5]. To illustrate the performance of this algorithm, an experimental reference of a three-point bending test is used and, by providing the experimental load-displacement diagram and an initial set of parameter values, the algorithm is able to provide a set that minimizes the deviation of the numerical model with respect to the experimental curve. Error is computed as the difference between the experimental and the numerical results at selected points of the load-displacement diagram.

References

[1] Alberti M, Enfedaque A, Gálvez J, Reyes E. Numerical modelling of the fracture of polyolefin fibre reinforced concrete by using a cohesive fracture approach. Composites Part B: Engineering. 2017;111:200–210.

[2] Suárez F, Gálvez J, Enfedaque A, Alberti M. Modelling fracture on polyolefin fibre reinforced concrete specimens subjected to mixed-mode loading. Engineering Fracture Mechanics. 2019;211:244–253.

[3] Suárez F, Gálvez JC, Alberti MG, Enfedaque A. Fracture and Size Effect of PFRC Specimens Simulated by Using a Trilinear Softening Diagram: A Predictive Approach. Materials. 2021;14(14). Available from: https://www.mdpi.com/1996-1944/14/14/3795.

[4] Patzák B. OOFEM—an object-oriented simulation tool for advanced modeling of materials and structures. Acta Polytechnica. 2012;52(6).

[5] Virtanen P, Gommers R, Oliphant TE, Haberland M, Reddy T, Cournapeau D, et al. SciPy 1.0: Fundamental Algorithms for Scientific Computing in Python. Nature Methods. 2020;17:261–272.