Mesomechanical analysis of concrete under loading that generates rotation of cracking

L. Puiggrós*, C.M. López*, M. Rodríguez*, I. Carol*

* Department of Geotechnical Engineering and Geo-Sciences
Universidad Politécnica de Cataluña
Jordi Girona 1, Edif. D2, E-08034 Barcelona, Spain
e-mail: luispuiggros@gmail.com, carlos.maria.lopez@upc.edu,
mariana.rodriguez@upc.edu,ignacio.carol@upc.edu

ABSTRACT

During the last decade, the group of Mechanics of Materials UPC (School of Civil Engineering), has developed and applied a methodology for the meso-mechanical analysis of heterogeneous materials, particularly concrete[1,2]. The material meso-structure (2D or 3D) is discretized using irregular polygons or polyhedra representing the aggregate pieces, which are surrounded by a matrix representing the behavior of mortar and smaller aggregates. The possibility of cracking is included using zero-thickness interface elements equipped with fracture-based constitutive models [3], which are inserted in between aggregates and mortar, and across the mortar, in order to generate all potential fracture mechanisms. In previous publications, the approach has been described in detail, together with examples of application to concrete specimens subject to a number of mechanical and environmental loading scenarios.

However, there are particularly complex loading situations for which experiments are not technically feasible or too expensive. One common example is the rotation of principal stresses after first cracking, which may lead to crack closure and opening of secondary cracks with different orientation. This type of loading scenario prompted the theoretical test proposed by Willam et al. (1987)[4], in which strain is prescribed to the material in two steps: a first uniaxial tension step is then followed by a second step with increasing biaxial strain under continuous axial rotation. The Willam Test has been often used in the literature to test and compare anisotropic constitutive models, although the comparison is purely numerical since no experimental results are currently available.

In this paper, the Willam Test is reproduced numerically using the meso-mechanical model described above. A numerical sample of material is subject on its boundaries to the average strains of the test, leading to complex cracking patterns and evolution. An inner control perimeter in the simple is used to evaluate the average stress tensor components and the rotation of principal axes. The trends observed basically confirm previous results obtained with continuum-based anisotropic constitutive models.

REFERENCES

[1] CM. López, I. Carol, A. Aguado. "Meso-structural study of concrete fracture using interface element. I: numerical model and tensile behaviour". *Materials and Structures*, Vol. 41, Nº 3, 583-599 (2008).

[2] A. Caballero, CM. López, I. Carol. "3D meso-structural analysis of concrete specimens under uniaxial tension". *Comput. Methods Appl. Mech. Engrg.*, 195, 7182-7195 (2006).

[3] I. Carol, P. Prat, CM. López. "A normal/shear cracking model. Application to discrete crack analysis". *ASCE J. Engrg. Mech.*, **123** (8), 765-773 (1997).

[4] K. Willam, E. Pramono, S. Sture. "Fundamental issues of smeared crack models". *International conference on fracture concrete and rock*, Houston, Texas, June 17-19 (1987).