Concrete cover separation analysis in FRP-plated RC beams via an inter-element cohesive fracture approach

***Umberto De Maio[1], †Fabrizio Greco[1], Lorenzo Leonetti[1], Paolo Nevone Blasi[1] and Paolo Lonetti[1]**

[1]Department of Civil Engineering, University of Calabria, Italy.

*Presenting author: umberto.demaio@unical.it
†Corresponding author: fabrizio.greco@unical.it

Abstract

The technique of bonding fibre reinforced polymer (FRP) sheets/plates to the tension face of reinforced concrete (RC) beams is widely used in building and civil engineering for strengthening or retrofitting existing structures. However, the use of this technique exposes the reinforced beams to new and exceptional modes of failure. They become vulnerable to various debonding failures, in particular plate-end interfacial debonding or concrete cover separation [1–3]. In this work, a novel finite element model to predict cover separation failures in RC beams under quasi-static loading conditions is presented [4], based on an inter-element fracture approach, here regarded as more appealing compared to sophisticated intra-element approaches, such as X-FEM methods [5]. The numerical procedure to simulate the fracture behaviour of reinforced beams is based on the intrinsic cohesive zone formulation, according to which nonlinear interface elements, equipped with a softening constitutive law, are inserted among all the finite elements of the computational domain [6]. A mixed-mode coupled criterion, accounting for an equivalent critical displacement, is adopted to predict damage onset, whereas, the subsequent debonding propagation is studied by using an energy criterion able to take into account different fracture energies for modes I and II. The main cohesive parameters have been calibrated to reduce the mesh dependency issues typical of cohesive zone models [7]. The reinforcing bars are modelled using truss elements with isotropic hardening and a simple bi-linear bond-slip law for investigated the bond behaviour between reinforcement bars and concrete is adopted. In order to verify this model, the results obtained in this study are compared with experimental results found in the literature that showing concrete cover separation as the dominant failure mode. The load-displacement curve predictions and the crack pattern are in close agreement with the results taken for comparison.

Keywords: **Discrete fracture; Cohesive Zone Model; Cover Separation Failure; Reinforced Concrete Beam; FRP composites.**

References

[1] Greco, F., Lonetti, P. and Nevone Blasi, P. (2007) An analytical investigation of debonding problems in beams strengthened using composite plates, *Engineering Fracture Mechanics* **74**, 346–372.
[2] Bruno, D., Greco, F. and Lonetti, P. (2013) A fracture-ALE formulation to predict dynamic debonding in FRP strengthened concrete beams, *Composites: Part B* **46**, 46–60.
[3] Bruno, D., Greco, F., Lo Feudo, S. and Nevone Blasi, P. (2016) Multi-layer modeling of edge debonding in strengthened beams using interface stresses and fracture energies, *Engineering Structures* **109**, 26–42.
[4] Gao, B., Kim, J.K. and Leung, C.K.Y. (2004) Experimental study on RC beams with FRP strips bonded with rubber modified resins, *Composites Science and Technology* **64**, 2557–2564.
[5] Meschke, G. and Dumstorff, P. (2007) Energy-based modeling of cohesive and cohesionless cracks via X-FEM, *Computer Methods in Applied Mechanics and Engineering* **196**, 2338–2357.

[6] Tijssens, M.G.A., Sluys, B.L.J. and van der Giessen, E. (2000) Numerical simulation of quasi-brittle fracture using damaging cohesive surfaces, *European Journal of Mechanics - A/Solids* **19**, 761–779.
[7] Turon, A., Dávila, C.G., Camanho, P.P. and Costa, J. (2007) An engineering solution for mesh size effects in the simulation of delamination using cohesive zone models, *Engineering Fracture Mechanics* **74**, 1665–1682.