

# NUMERICAL INVESTIGATION OF THE LOCALIZED FAILURE OF CFRP RETROFITTED REINFORCED CONCRETE JOINTS WITH EMBEDDED ANCHORS

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**Key Words:** Reinforced Concrete, Seismic Retrofit, FRP, Enriched Finite Elements, Pull-out.

Due to their lightweight, mechanical and durability properties, Fibre Reinforced Polymers (FRP) have shown to be well-suited for the enhancement of Reinforced Concrete (RC) structures to prevent seismic risk. In the case of externally bonded laminates, their effectiveness relies upon the local mechanical interaction between the strengthening phase and the underlying material. Such technology is therefore associated with high stress gradients at the material interface and their estimate must be carefully addressed by numerical analysis [1]. In a finite element framework, due to the lower computational cost, implicit modeling [2-3] appears to be an appealing choice for large scale simulations even though its accuracy may not be satisfying in case of non-standard reinforcement arrangements. Such is the case of FRP retrofitted RC structural members where the aforementioned localized mechanisms reveal to be even more important than for standard steel reinforcement layouts, as it has been assessed by extensive experimental campaigns [4]. In the present work, the simulation of strengthened RC joints provided with embedded FRP anchors is considered by means of an enriched implicit finite element model inspired by the Strong Discontinuity Approach (SDA) [5]. With the aim of improving the description of the interaction between concrete and anchors, an element-wise kinematic enhancement is added to the usual finite element approximation. Additional equilibrium equations are therefore derived at the interface in the fulfilment of the reinforcement static boundary conditions. Real-life case studies are simulated by comparing different strengthening configurations and material properties under 2D modeling assumptions. It is shown that the proposed approach both improves the representation of debonding behaviours and allows to reduce the computational effort with respect to standard modeling strategies.

## REFERENCES

- [1] M.R. Ben Romdhane and F.J. Ulm. Computational mechanics of the steel-concrete interface. *International journal for numerical and analytical methods in geomechanics*, Vol. **26**, pp. 99-120, 2002.
- [2] X. Martinez, S. Oller, F. Rastellini and A.H. Barbat. A numerical procedure simulating RC structures reinforced with FRP using the serial/parallel mixing theory. *Computers & Structures*, Vol. **86**, pp. 1604-1618, 2008.
- [3] A. Sciegaj, F. Larsson, K. Lundgren, F. Nilenius and K. Runesson. A multiscale model for reinforced concrete with macroscopic variation of reinforcement slip. *Computational Mechanics*, Vol. **63**, pp. 139-158, 2019.
- [4] F. Ceroni, M. Pecce, S. Matthys, and L. Taerwe, Debonding strength and anchorage devices for reinforced concrete elements strengthened with FRP sheets. *Composites Part B: Engineering*, Vol. **39**, pp. 429-441, 2008.
- [5] F. Riccardi, C. Giry, F. Gatuingt. Enhanced finite element formulation incorporating stress jumps and interface behavior in structures with embedded linear inclusions. *International Journal for Numerical Methods in Engineering*, pp. 1–26, 2020.