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CRACK-CENTERED ENRICHMENT FOR DEBONDING IN TWO-PHASE COMPOSITE APPLIED TO TEXTILE REINFORCED CONCRETE

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ABSTRACT

Textile reinforced concrete (TRC) is a composite material combining the advantages of fiber reinforced concrete and steel reinforced concrete. Textile reinforcement made of glass, carbon or aramid are embedded as fabrics in a cementitious matrix.The heterogeneity of both the matrix and the reinforcement occuring on similar length scales of the material structure demands for an improved accuracy to capture the relevant damage mechanisms. The eXtended Finite Element Method (XFEM) is utilized by augmenting the finite elements with special functions reflecting the discontinuities both in the matrix displacement and in the slip between the matrix and the reinforcement. The approach is presented on the 1D example of a tension bar and a 2D analysis of shear zones with a detailed approximation of the local deformation fields in the crack bridge.

The XFEM provides an efficient tool for introducing discontinuities and material interfaces into an originally smooth discretization [1] independent of the initial mesh. In the approach presented here, we extend the discontinuity enrichment by an explicit representation of the debonding between the matrix and reinforcement. The variational framework is established using a two layered body occupying the domain Ω with the boundary Γ. The resolution of the material components into separate layers is introduced adaptively together with the propagation of cracks. One layer represents the matrix cracked matrix, the other layer represents the reinforcement.

In particular, once a crack gets introduced into the matrix using the XFEM enrichment the discretization in the vicinity of the crack gets adapted such that slip between the two layers can be reflected. The interface behavior is governed by a general debonding law. For example, assuming a purely frictional bond (constant shear flow $\tau(s)$ for arbitrary value of slip s) and one-dimensional problem, analytical solution of the debonding can be found leading to a smooth approximation of the separated displacement field shown in Fig. 2 for 1D case.

In a general case of an arbitrary bond law and for two-dimensional problems a numerical approach has to be chosen. Then, the crack-centered enrichment is realized using fine scale enrichment for the

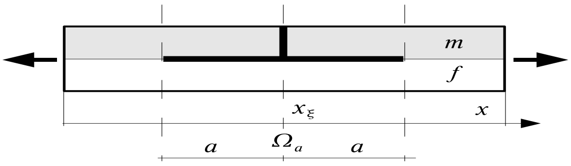

Figure 1: Crack bridge geometry.

debonding over the range $x \in \Omega_a$ (Figure 1). The starting point for the development of the general discretization is the variational expression for the local debonding problem in the vicinity of the crack bridge over an unknown debonded length a is varied with respect to the virtual local fields $\delta\tilde{u}_m$, $\delta\tilde{u}_f$:

$$\begin{aligned} (\delta\tilde{u}_m, [E_m u_{,xx} + E_m \tilde{u}_{m,xx} + \tau])_{\Omega_a} &= 0 \\ (\delta\tilde{u}_f, [E_f u_{,xx} + E_f \tilde{u}_{f,xx} - \tau])_{\Omega_a} &= 0 \end{aligned} \quad (1)$$

where $(-,-)_{\Omega_a}$ denotes integration over the range $x_\xi \pm a$. The displacements of the matrix and reinforcement are decomposed into the common part u and the respective deviations $\tilde{u}_m$ and $\tilde{u}_f$. This decomposition may be regarded as multi-scale resolution and the further elaboration is done within the multiscale variational framework.

The applications of this approach are motivated by the need for high-quality resolution of the shear zones in the simulation of bending speciments and connection details. These cases exhibit relatively coarse crack pattern. The hot spots of reinforcement damage are encountered in the vicinity of dominating cracks. Therefore, the quantification of the crack opening and crack sliding displacement is of crutial importance to assess the state of the damage in the bond. The presentation will provide a comparison between the local, crack-centered enrichement and global bond disretization on the example of experimentally traced shear zones of TRC bending specimens.

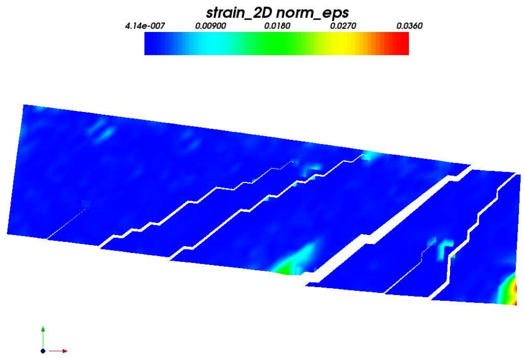

Figure 2: Distribution of slip magnitude.

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