Crack-centered enrichment including debonding for 2D modeling of cementitious composites

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The paper is focused on the modeling of a two-phase composites with cracking and debonding between the zones. It has been motivated by the need to efficiently reflect the zones with several dominating cracks (e.g. shear zones, constructional details), where standard finite element discretization fails to capture strain localization effects in the vicinity of the crack bridge. Therefore, an improved approximation with high quality kinematics is desired. In order to achieve that, the displacement field \( u \) is adaptively resolved in the localization zones into two fields \( u_f, u_m \) representing the displacement of the reinforcement and concrete matrix, respectively. The kinematic extension is applied locally in the vicinity of the crack bridge using the combination of the extended finite element method (XFEM [1]) together with multi-scale variational framework originally introduced by Hughes [2]. The applied mathematical framework delivers a coupled kinematic enrichment for a crack bridge in two-phase media, combining the strong discontinuity in the phase 1 (matrix) with the weak discontinuity in the phase 2 (reinforcement).

The formulated framework is applicable both for analytical and numerical local resolution of the displacement fields. An enrichment can be constructed using either an analytical solution of the debonding problem or numerical small-scale model. For general problems with overlapping debonding zones, the numerical resolution is used. The enriched discretization delivers high-quality approximation of the crack opening and sliding displacements and of the slip between the matrix and reinforcement with a relatively low number of degrees of freedom. On the other hand, due to the focus on adaptive changes, the complexity of the implementation is increased and calls for special treatment in the code design. The implementation uses a hierarchical grid for adaptive adjustments of the discretization. Its interface supports the transition from the original element formulation to the refined/enriched one.

The explicit reflection of the debonding within the crack enrichment provides the possibility to use arbitrary non-linear bond models for the interaction between the matrix and reinforcement. Further, the explicit resolution of the debonding zones within the mesh is used to handle the case of merging debonding zones by simply joining the enrichment fields at the corresponding level of the hierarchical grid. The approach will be presented on 2D examples with elementary crack configurations visualizing the development of the debonding zones starting from the crack bridge. The paper will discuss the versatility, robustness and efficiency of the formulation.

References
