# From anisotropic damage to multiple cracks by coupling a microplane model and a strong discontinuity formulation in the Embedded Finite Element Method

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**ABSTRACT**

Numerical formulations to model failure in quasi-brittle materials often consist in either representing cracks as localized damage zones or as strong discontinuities. The main aim of this contribution is to develop a numerical framework capable of describing the formation of non-orthogonal cracks (due to complex stress-strain states) including a transition step from anisotropic damage, modeled using "microplane" model [1], to multiple strong discontinuities formulated within the context of the Embedded Finite Element Method (EFEM) [2]. According to the microplane theory, a constraint between the strain vector on the microplanes and the strain tensor at a given material point is assumed. The virtual work principle is then invoked to compute the stress tensor from an integration over a sphere/circle of quantities defined at the microplanes. Strong discontinuities are subsequently embedded into finite elements as cohesive cracks after certain transition criteria are reached. Cohesive laws parameters (fracture energy, traction level at the transition point) are calibrated from the equivalence between the energy dissipation of the fracture process described by a microplane model and that of the cohesive crack law. The equilibrium across the cracked finite element is then ensured using traction/continuity conditions (one per crack). This is necessary to solve the additional degrees of freedom and to perform the static condensation technique at the finite element level. Within this numerical framework, the multiple cracks case can be addressed straightforwardly. Indeed, the main advantage of using microplane model is that transition criteria based on the variables on the microplanes can be formulated which is promising for capturing directional phenomena like multi-cracking, which is not a priori straightforward to describe using EFEM. Different transition criteria are studied and introducing the developed algorithms in the existing finite element codes [3] needs little effort. Both the theoretical formulation and representative numerical examples are presented to demonstrate the relevancy of the proposed numerical setting.

## REFERENCES

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