FINITE ELEMENT APPROXIMATION OF PLASTIC HINGES IN BEAMS AND PLATES

by

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A recent analysis [1] shows the inconsistencies of plastic beam models with strain softening, despite the presence of a characteristic length in the constitutive model (namely the thickness of a Timoshenko beam). The closed-form solutions of wave propagation in a plastic Timoshenko beam with strain softening included in this reference reveal the need of incorporating a localized dissipative mechanism. This can be efficiently accomplished through the consideration of a strong discontinuity of the generalized displacements. In the context of the structural theories of interest here, these include transversal and longitudinal displacement fields and the rotation field. The classical notion of a plastic hinge is then recovered.

The main goal of this contribution is the development of finite element methods that incorporate objectively the discontinuous solutions associated to plastic hinges. We consider both the aforementioned case of a Timoshenko beam and the extension of these ideas to plastic/damage models of plates. The plastic hinges are modeled as strong discontinuities of the deflection and rotation fields. A cohesive law between the stress resultants and the discontinuity jumps is introduced, thus modeling objectively the localized failure of these structural members. As noted above, the emphasis in this contribution will be on the formulation of enhanced strain finite elements incorporating these discontinuities and their cohesive laws at the element level. The linked role played by the deflection and the rotation in the definition of the structural strain measures requires a careful analysis of the contributions of the discontinuities in order to avoid undesired effects. More precisely, we need to avoid the locking of the finite element formulation in the thin-beam and thin-plate limits, respectively, and the stress locking observed in some of the finite element treatment of cohesive law models. In the case of stress locking, the assumed finite element kinematics do not allow a complete release of the stress around the cohesive law. We present in particular some new finite elements that avoid these difficulties, thus leading to an improved approximation of the plastic hinges and the modeling of the overall failure of beams and plates. Several numerical examples will be presented illustrating the applications of these results.

References

1. Armero, F. and Ehrlich, D. [2002] An analysis of strain localization and wave propagation in plastic models of beams at failure, submitted to *Computer Methods in Applied Mechanics and Engineering.*