Inelastic analysis of frames using thin beam-column elements with multiple embedded plastic hinges

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The development of a variational formulation of the mechanical behavior of thin beam-columns with multiple embedded plastic hinges is developed. The boundary value problem, which is valid throughout the domain of the structural member, is obtained from the proposed formulation that provides the necessary tools to deal mathematically with the singularities. The plastic hinges are modelled as strong embedded discontinuities, which are adapted to represent the strain localization. These embedded discontinuities represent the material failure process as hinges for beams and cracking or crushing for bars, in which a displacement jump, and the stain concentration are lumped into a zero-thickness localization zone. The non-linear behavior of the materials is described by a multilinear plasticity model.

Closed form solutions for bars [1] and thin beams [2] with strong embedded discontinuities are obtained by solving the proposed formulation. From these solutions, bar and beam finite elements with embedded discontinuities are developed, which model the occurrence of damage in frame elements. Based on conventional procedures of structural analysis and the developed closed form solutions, a symmetric stiffness matrix of a thin beam-column element with multiple strong embedded discontinuities with arbitrary locations is developed. This matrix is naturally condensed, its coefficients are not in terms of integrals and any type of loads can be modelled, which reduce the computational cost and avoid possible numerical instabilities [3].

Representative examples of beams and frames validate the capability of the formulated thin beam-column element for modelling damage. In these examples, the load-displacement curves agreed with those reported in the literature. The induced work on a structure is adequately release as energy in the development of hinges in the thin beam-column element. The computed solutions with the developed element are mesh independent because the same results were computed with different meshes. This developed element adequately models the snap-back behavior in frames. Finally, it is important to mention that this element is able to model multiple hinges per element; therefore, only one finite element is required per structural member.

References

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