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A comparative study on finite elements for capturing strong discontinuities: E-FEM vs X-FEM. (English) [Zbl 1144.74043](#)

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Summary: We present a comparative study on finite elements for capturing strong discontinuities by means of elemental (E-FEM) or nodal enrichments (X-FEM). Based on the same constitutive model (continuum damage) and linear elements (triangles and tetrahedra), optimized implementations of both types of enrichments in the same nonlinear code are tested for a representative set of 2D and 3D crack propagation examples. It is shown that both methods provide the same qualitative and quantitative results for enough refined meshes. For the performed tests, E-FEM exhibited, in general, a higher accuracy, mostly for coarse meshes, whereas, convergence rate with mesh refinement, which is super-linear, showed slightly higher for X-FEM. As for the computational costs for single crack modelling X-FEM showed, depending on the case, from 1.1 to about 2.5 times more expensive than E-FEM. For multiple cracks, the computational cost of E-FEM keeps constant, whereas the cost associated to X-FEM increases linearly with the number of modelled cracks.

MSC:

74S05 Finite element methods applied to problems in solid mechanics

74R10 Brittle fracture

Cited in **36** Documents

Keywords:

[mesh refinement](#); [single crack modelling](#)

Software:

[XFEM](#); [COMET](#)

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References:

- [1] Alfaiate, J., New developments in the study of strong embedded discontinuities infinite elements, *Adv. fract. damage mech.*, 251-252, 109-114, (2003)
- [2] Armero, F.; Garikipati, K., An analysis of strong discontinuities in multiplicative finite strain plasticity and their relation with the numerical simulation of strain localization in solids, *Int. J. solids struct.*, 33, 2863-2885, (1996) · [Zbl 0924.73084](#)
- [3] Bazant, Z.; Cedolin, L., *Fracture mechanics of reinforced concrete*, J. eng. mech. div. ASCE, 1287-1305, (1980)
- [4] Belytschko, T.; Chen, H.; Xu, J.X.; Zi, G., Dynamic crack propagation based on loss of hyperbolicity and a new discontinuous enrichment, *Int. J. numer. methods engrg.*, 58, 1873-1905, (2003) · [Zbl 1032.74662](#)
- [5] Belytschko, T.; Moes, N.; Usui, S.; Parimi, C., Arbitrary discontinuities in finite elements, *Int. J. numer. methods engrg.*, 50, 993-1013, (2001) · [Zbl 0981.74062](#)
- [6] C. Feist, G. Hofstetter, Computational aspects of concrete fracture simulations in the framework of the SDA. Presented at Fracture Mechanics of Concrete Structures FRAMCOS 2004, Vale, Co, USA, 2004.
- [7] Garikipati, K.; Hughes, T.J.R., A study of strain-localization in a multiple scale framework. the one dimensional problem, *Comput. methods appl. mech. engrg.*, 159, 193-222, (1998) · [Zbl 0961.74009](#)
- [8] Gasser, T.C.; Holzapfel, G.A., Geometrically non-linear and consistently linearized embedded strong discontinuity models for 3D problems with an application to the dissection analysis of soft biological tissues, *Comput. methods appl. mech. engrg.*, 192, 5059-5098, (2003) · [Zbl 1088.74541](#)
- [9] Gasser, T.C.; Holzapfel, G.A., Modeling 3D crack propagation in unreinforced concrete using PUFEM, *Comput. methods appl. mech. engrg.*, 194, 2859-2896, (2005) · [Zbl 1176.74180](#)
- [10] Jirasek, M., Comparative study on finite elements with embedded discontinuities, *Comput. methods appl. mech. engrg.*, 188, 307-330, (2000) · [Zbl 1166.74427](#)
- [11] A.S. Kobayashi, M.N. Hawkins, D.B. Barker, B.M. Liaw, Fracture process zone of concrete, in: S.S.P. (Ed.), *Application of Fracture Mechanics to Cementitious Composites*, Marinus Nuijhoff Publ., Dordrecht, 1985, pp. 25-50.
- [12] P. Laborde, J. Pommier, Y. Renard, M. Salaün, High order extended finite element method for cracked domains. Presented at Computational Plasticity VIII: Fundamentals and Applications, Barcelona, Spain, 2005. · [Zbl 1181.74136](#)
- [13] Larsson, R.; Runesson, K.; Ottosen, N.S., Discontinuous displacement approximation for capturing plastic localization, *Int.*

- J. numer. methods engrg., 36, 2087-2105, (1993) · [Zbl 0794.73074](#)
- [14] Liao, K.; Reifsnider, K.L., A tensile strength model for unidirectional fiber-reinforced brittle matrix composite, *Int. J. fract.*, 106, 95-115, (2000)
- [15] Cervera, M.; Agelet, C.; Chiumenti, M., COMET: A multipurpose finite element code for numerical analysis in solid mechanics, (2001), Technical University of Catalonia (UPC)
- [16] Mariani, S.; Perego, U., Extended finite element method for quasi-brittle fracture, *Int. J. numer. methods engrg.*, 58, 103-126, (2003) · [Zbl 1032.74673](#)
- [17] N. Moës, N. Sukumar, B. Moran, T. Belytschko, An extended finite element method (X-FEM) for two and three-dimensional crack modelling. Presented at ECCOMAS 2000, Barcelona, Spain, 2000.
- [18] Mosler, J.; Meschke, G., 3D modelling of strong discontinuities in elastoplastic solids: fixed and rotating localization formulations, *Int. J. numer. methods engrg.*, 57, 1553-1576, (2003) · [Zbl 1062.74623](#)
- [19] Mosler, J.; Meschke, G., Embedded crack vs. smeared crack models: a comparison of elementwise discontinuous crack path approaches with emphasis on mesh bias, *Comput. methods appl. mech. engrg.*, 193, 3351-3375, (2004) · [Zbl 1060.74606](#)
- [20] Oliver, J., Modelling strong discontinuities in solid mechanics via strain softening constitutive equations. 2. numerical simulation, *Int. J. numer. methods engrg.*, 39, 3601-3623, (1996) · [Zbl 0888.73018](#)
- [21] Oliver, J., On the discrete constitutive models induced by strong discontinuity kinematics and continuum constitutive equations, *Int. J. solids struct.*, 37, 7207-7229, (2000) · [Zbl 0994.74004](#)
- [22] Oliver, J.; Huespe, A.E., Continuum approach to material failure in strong discontinuity settings, *Comput. methods appl. mech. engrg.*, 193, 3195-3220, (2004) · [Zbl 1060.74507](#)
- [23] Oliver, J.; Huespe, A.E., Theoretical and computational issues in modelling material failure in strong discontinuity scenarios, *Comput. methods appl. mech. engrg.*, 193, 2987-3014, (2004) · [Zbl 1067.74505](#)
- [24] J. Oliver, A.E. Huespe, S. Blanco, D.L. Linero, Stability and robustness issues in numerical modeling of material failure in the strong discontinuity approach, *Comput. Methods Appl. Mech. Engrg.* accepted for publication. · [Zbl 1331.74168](#)
- [25] J. Oliver, A.E. Huespe, M.D.G. Pulido, S. Blanco, Recent advances in computational modelling of material failure. Presented at 4th European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2004), University of Jyväskylä, Jyväskylä, Finland, 2004.
- [26] J. Oliver, A.E. Huespe, M.D.G. Pulido, S. Blanco, D. Linero, New developments in computational material failure mechanics. Presented at Sixth World Congress on Computational Mechanics (WCCM VI), Beijing, PR China, 2004.
- [27] Oliver, J.; Huespe, A.E.; Pulido, M.D.G.; Chaves, E., From continuum mechanics to fracture mechanics: the strong discontinuity approach, *Engrg. fract. mech.*, 69, 113-136, (2002)
- [28] Oliver, J.; Huespe, A.E.; Samaniego, E., A study on finite elements for capturing strong discontinuities, *Int. J. numer. methods engrg.*, 56, 2135-2161, (2003) · [Zbl 1038.74645](#)
- [29] Borja, R.L.; Regueiro, R.A., A finite element model for strain localization analysis of strongly discontinuous fields based on standard Galerkin approximation, *Comput. methods appl. mech. engrg.*, 1529-1549, (2000) · [Zbl 1003.74074](#)
- [30] Rots, J.G., Computational modeling of concrete fractures, (1988), Delft University of Technology
- [31] Runesson, K.; Mroz, Z., A note on nonassociated plastic flow rules, *Int. J. plast.*, 5, 639-658, (1989) · [Zbl 0697.73025](#)
- [32] Simo, J.; Oliver, J.; Armero, F., An analysis of strong discontinuities induced by strain-softening in rate-independent inelastic solids, *Comput. mech.*, 12, 277-296, (1993) · [Zbl 0783.73024](#)
- [33] Simone, A., Partition of unity-based discontinuous elements for interface phenomena: computational issues, *Commun. numer. methods engrg.*, 20, 465-478, (2004) · [Zbl 1058.74082](#)
- [34] Spencer, B.W.; Shing, P.B., Rigid-plastic interface for an embedded crack, *Int. J. numer. methods engrg.*, 56, 2163-2182, (2003) · [Zbl 1038.74650](#)
- [35] Wells, G.N.; Sluys, L.J., A new method for modelling cohesive cracks using finite elements, *Int. J. numer. methods engrg.*, 50, 2667-2682, (2001) · [Zbl 1013.74074](#)
- [36] Willam, K.; Sobh, N., Bifurcation analysis of tangential material operators, (), C4/1-C4/13
- [37] Zi, G.; Belytschko, T., New crack-tip elements for XFEM and applications to cohesive cracks, *Int. J. numer. methods engrg.*, 57, 2221-2240, (2003) · [Zbl 1062.74633](#)

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