The benefit of smoothing the unloading-reloading response and rough crack-contact relationships in a finite element concrete model.

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ABSTRACT

Convergence problems are frequently encountered in nonlinear finite element solutions when using material models that include strain softening behaviour. When this strain-softening relates to directional cracking, as in the case of concrete structures, the problems can be compounded when crack closing behaviour is also simulated. The principal sources of these difficulties are the existence of non-unique equilibrium paths, when non-positive definite tangent matrices are used in solutions, and alternating crack opening-closing behaviour in adjacent elements or regions.

Solutions to these problems are possible by using secant, or approximate, positive definite stiffness matrices [1] but these methods can be very slow to converge and sometimes do not reach a converged solution. As a response to these difficulties, some researchers have developed approaches that do not require equilibrium iterations [2],[3]. These methods are robust but do not always produce smooth solutions and require extension to be compatible with other nonlinear material models.

As an alternative to the above, the authors have developed a new approach that uses a nonlinear smooth unloading-reloading function as the basis for an approximate stiffness in an incremental-iterative solution scheme [4]. This function has a very small gradient at its intersection with the damage evolution function. A study by the authors showed that this method achieved efficient reliable solutions for a range of cracking problems in far fewer iterations than solutions obtained with a secant stiffness approach. The approach also includes a predictive step in which a damage variable is extrapolated in a semi-log space.

This contribution will describe how the above approach has been linked to a new smoothed rough crack contact model [5], in which a contact function with signed-distance properties has been employed. A set of examples are used to illustrate the robustness and accuracy of the combined model.

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