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A SMOOTHED DAMAGE-CONTACT FORMULATION WITH IMPROVED CONVERGENCE CHARACTERISTICS AND NUMERICAL ROBUSTNESS.

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Analysts who work with finite element models for concrete often experience convergence problems with nonlinear solution schemes, which can be both frustrating and expensive. These convergence difficulties are usually associated with the simulation of softening material behaviour but, in many situations, are exacerbated when crack closure behaviour is included.

The surfaces of macro-cracks in concrete are rough in nature and this means that cracks regain contact with combinations on shear and normal movements. When models that simulate this rough contact behaviour are incorporated into finite element constitutive models, the aforementioned convergence difficulties can become particularly severe. This is true of rough crack contact models applied to embedded element discontinuities, interface elements and embedded planes in smeared crack formulations.

The contribution addresses this issue and considers the conditions that give rise to the break-down of solution procedures when crack contacts occur. A new rough crack contact model is then described in which a smoothed contact transition zone is introduced into a damage-contact model. This employs a contact surface, defined in relative displacement space, and a function that provides a smooth transition between open and contact states. The incorporation of this damage-contact formulation into a 3D concrete constitutive model is then described.

The contribution also discusses the implementation of the model with an algorithm that uses a predicted damage evolution function. This aims to predict the final state of damage at the end of an increment (or load step) in which the nonlinear predictive function is only updated if the final stress-strain state violates the damage function by more than a selected tolerance. The challenges of developing the algorithm were to develop rules which provide good predictions for a range of stress-strain paths, and to find a predictive function that naturally allows little drift from a target damage evolution function.

A number of examples are provided to illustrate the characteristics of the overall model. These explore (i) the improvement in convergence properties brought about by including the transition functions into the contact model (ii) the improved accuracy, relative to experimental observations, of the smoothed contact formulation relative to a model which used an abrupt contact approach and (iii) the benefits and challenges of employing the predictive algorithm.