11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 - 25, 2014, Barcelona, Spain

MULTISURFACE DAMAGE-PLASTICITY CONSTITUTIVE MODEL FOR CONCRETE

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Key Words: *Damage, Plasticity, Viscoplasticity, Constitutive relations, Stress-update algorithm.*

Strain softening of concrete is primary attributed to propagation and coalescence of micro-cracks resulting in decrease of stiffness of respective structural components. Proper modelling of degradation in the mechanical properties of concrete requires therefore approaches of damage mechanics. In this work we refer to the macroscale approach, which assumes a homogeneous material and relies on the domain of continuum damage mechanics. Coupling of the damage constitutive models with plasticity [1] is nowadays well established and realistically reproduces irreversible flow of concrete with degradation of its stiffness. The focus of this paper is twofold: to incorporate rate-dependent effects in constitutive modelling of concrete degradation and to provide a robust integration scheme for the constitutive relations.

In [2], degradation mechanisms associated with micro-cracking are reproduced by two damage variables, the one is driven by plastic yielding and reflects degradation at compression, whereas another reproduces damage accumulation induced by tensile stresses. Both damage contributions are assumed to be isotropic. The Drucker-Prager and Rankine criteria represent yielding and failure surfaces in the effective stress space.

In this paper, the damage-plasticity framework is extended to viscoplasticity in order to incorporate the rate-dependent effects. To this end, an additional Drucker-Prager yield surface is introduced, which bounds the elasticity domain and activates the rate-dependent yielding. This is the only contribution to yielding between the yield surfaces activating viscoplastic and plastic flow mechanism. The rate-independent flow mechanism becomes active once the yielding surface associated with plasticity is reached. Thus, the compressive damage variable of the extended model is now driven by rate-dependent and rate-independent flows.

Straightforward application of the conventional return-mapping technique to multi-surface problems may provide a non-physical solution with negative Lagrange multiplier(s) [3]. Commonly, an additional numerical procedure is required, which iteratively updates the active constraints. Each update is related to solving the respective constitutive equations resulting in further computational efforts. These may considerable increase for models with a high number of yield surfaces. We present therefore an alternative solution strategy which finds only the physically meaningful solution and avoids the update of active constraints reducing redundant computational costs.

Numerical examples demonstrate predictive ability of the constitutive model and computational efficiency of the presented solution scheme.

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