Anisotropic viscodamage-viscoplastic consistency model with a parabolic cap for rocks

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ABSTRACT

This work presents a novel constitutive model for rocks with either brittle or ductile behavior. The model, being an enhanced version of the original model developed in [1], is based upon a judicious combination of the viscoplastic consistency model in compression and an anisotropic viscodamage consistency model in tension. The main novelty of the model is in the damage part that accounts for rate-dependency in the same manner as the viscoplastic consistency model by Wang et al. [2] - hence, the name viscodamage consistency model. The proposed model not only takes into account a very strong strain-rate sensitivity of rocks by suitable choice of viscosity parameter, but also the damage induced anisotropy by the corresponding evolution of damage compliance tensor, see e.g. [3].

Moreover, microcrack unilateral effects are represented for by the projector operator approach. The Drucker-Prager yield function and the Modified Rankine criterion as a tension cut-off and a parabolic cap surface as a compression cut-off are used to indicate the stress states transition to strain softening/hardening and damage. A confining pressure dependent parabolic hardening-linear softening law in compression is calibrated with respect to the degradation index. Thereby, the model is able to capture the brittle-to-ductile transition exhibited by many rocks (e.g. marble, sandstone) under highly confinement pressure. The hardening behaviour of rock under hydrostatic and extremely high confined stress states is described by the cap, which employs the viscoplastic consistency approach as well.

The consistent viscoplasticity formulation of the model enables an employment of the standard stress integration methods of computational rate-independent plasticity. This results in a robust and simple update scheme for the stress, the damage tensor and the internal variables.

The model performance is illustrated at the material point level with various uniaxial and triaxial tests. For example, the triaxial compression test on Carrara marble is very accurately predicted at various confinement levels. In addition, a very good agreement was found between the model prediction and the experimental curve of the hydrostatic compression test on Salem limestone.

REFERENCES

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