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## Granular micromechanics model for cementitious materials

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### ABSTRACT

Granular micromechanics is a strong tool for modeling the behavior of different types of materials wherein the global (i.e., macroscopic) response of the material is assumed to be derivable as a summation of the local (i.e., microscopic) responses between grains that compose the material point. Cementitious materials are clear examples of micromechanically complicated materials in which microscopic response significantly influences the global behavior. Modeling of these materials using traditional tensorial constitutive equations leads to the neglect of several microscopic features. Because in granular micromechanics, interactions between all particles are taken into account separately, the method naturally provides a robust tool for implementing different micromechanical features in the material structure. By introducing potential and dissipation functions at the local scale, a Clausius–Duhem type inequality in the microscopic scale is obtained and an expression of macroscopic Cauchy stress in terms of interparticle kinematics and forces is developed. Subsequently, we introduce a set of interparticle interaction functions to establish thermodynamically consistent intergranular constitutive relations particularly applicable to cementitious materials. As a result we obtain force laws which ensure asymmetric behavior in tension and compression. Updated loading–unloading–reloading criteria are implemented in the model with the capability of modeling damage and plasticity. Damage parameter in tangential direction is defined as a function of not only the tangential displacement component, but also the normal component of displacement as well as the average stress. Normal compressive force law parameters are also obtained as functions of the average stress which enables the model to capture the effects of confining stress. Tensile and compressive triaxial tests with different confining stresses have been simulated indicating “brittle” to “ductile” transition of the material behavior by increasing the confining stress. Biaxial failure surface is computed and the effect of change in the direction of loading and the resulting induced anisotropy on the failure stress state is captured. Moreover, volume control tests with different ratios of normal versus lateral strain increments and with different initial hydrostatic confining pressures have been modeled providing failure envelopes in the  $q$ – $p$  (deviatoric stress–mean stress) plane.