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Shear banding in a micromechanics-based brittle damage model

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The Earth's brittle upper crust is commonly modeled as a non-associated Mohr-Coulomb (MC) elasto-plastic continuum. This framework enables the localization of shear strain through a process referred to as structural softening: dilatancy related to the build-up of plastic strain inside a shear band can elastically unload the surrounding material as principal stresses rotate inside the band. The strains required to weaken the material and corresponding stress drops are compatible with experimental observations, and provide useful theoretical insights into strain softening parameterizations used in numerical geodynamics. This model however does not account for time-dependent behavior documented in rock deformation experiments, such as the loading rate dependence of the peak strength, and sample failure under a fixed applied stress in brittle creep tests. It also relies on macroscopic properties (e.g., dilatancy angle) which are not straightforwardly related to micro-mechanical and micro-structural rock properties. The MC model thus inherently carries an empirical parameterization which can be an obstacle to a deeper understanding of brittle inelastic deformation.

On the other hand, models that account for time-dependent brittle behavior typically invoke the development of tensile microcracks around shear defects, and derive macroscopic constitutive laws from the micro-mechanics of fracture growth and interaction through a damage state variable. To investigate whether this class of models can account for the time-dependence of strain localization, we perform post-bifurcation analysis on the damage rheology constructed by *Ashby & Sammis (1990)*, coupled with a stress corrosion law for crack growth kinetics. We calculate the co-evolution of stress and 2-D plane strain at a point located within an incipient damage shear band, and at a nearby point in the surrounding rock where damage cannot accumulate. We prescribe a constant shear strain rate within the band, enforce strain compatibility and stress continuity across the shear band boundary, and integrate the incremental constitutive relationships through time.

Dilatancy related to tensile crack growth in the band enables elastic unloading of the surrounding medium. In our simulations, this manifests as a sudden drop in shear stress coincident with a sharp increase in band damage. We characterize the localization phenomenon through the magnitude of both this stress drop and damage increase, and assess their sensitivity to macroscopic parameters such as shear strain rate, shear band orientation, confining pressure, as well as micro-mechanical parameters such as the orientation of shear defects, the stress exponent of the crack growth law, and the initial damage. This type of work may pave the way toward

micromechanics-based parameterizations of brittle deformation in long-term tectonic models.