INFLUENCE OF THIRD INVARIANT OF DEVIATORIC STRESS ON LOCALIZATION CONDITIONS FOR HIGH POROSITY SANDSTONE

Vennela Challa and Kathleen A. Issen

Mechanical and Aeronautical Engineering
Clarkson University
Potsdam, NY 13699, USA
vennelac@gmail.com

High porosity sandstones in field and laboratory settings are observed to fail by the formation of localized deformation bands. The important localized deformation structures, shear bands, compaction bands, and dilation bands, are characterized by the strain type within the band: shear strain and/or strain (compactant or dilatant) normal to the band. Compaction bands and dilation bands, which have been identified recently, are of specific interest since they significantly affect local porosity and permeability characteristics within fluid reservoirs, and could impact drilling, fluid storage and extraction applications. Using a bifurcation approach to localization [1], conditions governing localized deformation have typically been determined using constitutive models independent of the third invariant of deviatoric stress (J_3). However, recent experimental evidence indicates that the mechanical behavior of some high porosity sandstones is J_3 dependent. Therefore, J_3 dependent single and two yield surface constitutive models were developed in this work, and resulting localization conditions were determined.

Since laboratory experiments are often conducted under axisymmetric (AS) stress states (axisymmetric compression, ASC, or axisymmetric extension, ASE: the intermediate principal stress equals the minimum or maximum compressive stress, respectively), localization conditions have commonly been investigated for these AS stress states. However, stress states in the field are not limited to AS, therefore, this work investigates the influence of varying the stress state (by varying the value of the intermediate principal stress with respect to the minimum and maximum principal stress) on conditions governing compaction and dilation band formation. Analyses indicate that, under AS stress states, material behavior is independent of J_3, and band orientation predictions remain unchanged: compaction bands are favored under ASC, and dilation bands are favored under ASE. The influence of J_3 dependence on localization conditions was found to be significant for a stress state slightly perturbed from ASC; however, for a stress state slightly perturbed from ASE, J_3 dependence is less important. In general, for stress states perturbed from AS, conditions for shear band formation are more favorable than those for compaction or dilation band formation. If the material is strongly J_3 dependent, localization conditions are unlikely to be satisfied for commonly reported values of key material parameters, thus, band formation is inhibited and homogeneous deformation is predicted. These results provide one possible explanation as to why compaction bands and dilation bands are rarely reported in the field settings, compared to shear bands.

References

[1] J.W. Rudnicki and J.R. Rice, "Conditions for the localization of deformation in pressure-sensitive dilatant materials," *J. Mech. Phys. Solids*, **23**, 371-394, 1975.

Keywords: localization, stress state