Importance of the intermediate principal stress on failure and localization behavior in high porosity rocks

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ABSTRACT

The localization criterion developed by Rudnicki and Rice (1975), whereas intended for low porosity rocks has been found to be applicable to many other types of materials, including high porosity rocks such as sandstone. The localization criterion shows that regardless of the constitutive model, intermediate principal stress dependence arises as a result of the localization framework. This means, that to investigate localization, under anything but the simplest conditions, true triaxial tests are required.

A series of true triaxial tests was performed to investigate the localization criterion and the effect of the intermediate principal stress. Tests were run at Sandia National Laboratories using the smaller of their true triaxial systems. Tests were run at five mean stresses (30–150 MPa) and five different Lode angles ranging from Axisymmetric compression to axisymmetric extension. It was found that the intermediate principal stress did have a significant effect on failure and band angle orientation at low mean stresses. It was found that as the stress state moves from compression to extension band angles increase (with respect to the maximum principal stress direction) and that localization can occur at higher mean stresses under extensile stress states that under compressive stress states.

In order to compare the experimental results to theoretical predictions, values for the inelastic parameters must be determined from the experimental data. This required separation of elastic and plastic strains, which due to the goal of the work, was performed in a much more rigorous strain separation process than has been undertaken earlier. Strains were separated into four components, elastic constant modulus, elastic stress dependent, elastic plastic strain dependent, and plastic. This allowed for much more detailed information to be developed about the local slope of the yield surface and the dilation coefficient. These parameters were used to develop predictions for the band angle using the Rudnicki and Rice framework that were then compared to the band angles measured through an acoustic emission plane fit algorithm and what was expressed on the jacket of the specimen after testing. Reasonable agreement was found at low mean stresses; however, on the cap of the yield surface the predictions were not as good. This is likely due to difficulties in fitting the yield surface on the cap, and the fact that the bifurcation condition breaks down at high mean stresses (specimens undergo cataclastic compaction).

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