ADVENTURES BEYOND THE INDIVIDUAL DEFORMATION BAND

Richard A. Schultz
Geomechanics–Rock Fracture Group
Department of Geological Sciences and Engineering/172
University of Nevada, Reno, NV 89557-0138 USA
schultz@mines.unr.edu

Localized plastic yielding in porous granular rocks such as sandstone can produce either dilatant or compactional shear deformation bands, depending on the confining pressure and stress path [1, 2]. As these bands localize and grow, they form spatially distributed patterns such as backward-breaking echelon stepovers (recognized in mode-II view) [3, 4] and the related inosculating lenses (observed in mode-III view) [e.g., 1]. The clusters of deformation bands that grow into these patterns, now referred to as "damage zones" [5], serve as the locus for slip-surface nucleation due to frictional failure of the band-host rock interface [6], leading eventually to a through-going fault that slices through the damage zone.

The well-known sequence summarized here has useful consequences for mechanical modeling of bifurcation and strain localization in porous granular rocks, particularly as strains and sample size increase beyond those associated with single bands. These include:

1. Studies of initial yielding in porous rocks [e.g., 1] are intrinsically limited to localization and, perhaps, growth of individual bands. These studies probably relate most directly to the initial yield surface in Cam clay and similar models [e.g., 1].
2. The growth of damage zones consisting of mechanically interacting and linking bands can be understood by using volumetric and distortional strain energy density criteria [e.g., 3, 4]. These studies have, to date, been associated only phenomenologically with inward (for dilational shear bands) or outward (for compactional shear bands) migration of the yield surface, indicating the need for quantitative modeling of relationships between damage zones and yield caps.
3. Faulting, or failure, of the damage zone superimposes a focused strain-softening regime (shearing slip surfaces) onto the formerly distributed strain-hardening one, as suggested by two-yield surface models of strain localization [e.g., 7]. Because slip surfaces are now recognized to nucleate at the edges of a ~ 5 mm-thick zone of deformation bands [5] within the damage zone, rather than long individual bands, instability analyses such as [6] may perhaps need to be modified to account for the constitutive relations and stress state within a network of strain-hardened bands. Such an analysis may hold promise for relating fault nucleation and growth to activation of a shear yield (or failure) surface as the formerly active yield cap shuts down.

Understanding the mechanics of this sequence for both classes of bands is important to predicting the growth, physical properties, and hydrologic characteristics of damage zones and subsequent faults.

References

[1] R.I. Borja and A. Aydin, "Computational modeling of deformation bands in granular media. I. Geological and mathematical framework," *Comp. Methods Appl. Mech. Eng.* **193**, 2667–2698, 2004. [2] A. Aydin, R.I. Borja, and P. Eichhubl, "Geological and mathematical framework for failure modes in granular rock," *J. Struct. Geol.* in press, 2005. [3] R.A. Schultz and C.M. Balasko, "Growth of deformation bands into echelon and ladder geometries," *Geophys. Res. Lett.* **30**, 2033, 10.1029/2003GL018449, 2003. [4] C.H. Okubo and R.A. Schultz, "Evolution of damage zone geometry and intensity in porous sandstone: Insight from strain energy density," *J. Geol. Soc. London* **162**, 939–949, 2005. [5] Z.K. Shipton and P.A. Cowie, "A conceptual model for the origin of fault damage zone structures in high-porosity sandstone," *J. Struct. Geol.* **25**, 333–344, 2003. [6] A. Aydin and A. Johnson, "Analysis of faulting in porous sandstones," *J. Struct. Geol.* **5**, 19–31, 1983. [7] V. Challa and K.A. Issen, "Conditions for compaction band formation in porous rock using a two-yield surface model," *J. Eng. Mech.* **130**, 1089–1097, 2004.

Keywords: deformation bands, faults