Continuum mathematical modeling of slip weakening in geological systems

Ronaldo I. Borja*,[a], Craig D. Foster, and David D. Pollard
Stanford University, Stanford, CA 94305, USA

Abstract

We describe a framework for mathematical modeling of slip weakening in an initially intact rock mass due to shear strain localization along any arbitrary slip plane. The modeling technique considered is based on continuum mechanics and may be cast directly into a standard nonlinear finite element algorithm for the analysis of pre- and post-failure responses of geological systems in a boundary-value problem. The pre-failure behavior is represented by a continuum constitutive model; the post-failure behavior is characterized by frictional yielding on a slip surface with state- and velocity-dependent coefficient of friction. In the context of finite element analysis, slip planes are represented by an embedded strong discontinuity introduced into an initially intact finite element to signal the beginning of post-failure behavior. This paper focuses on the narrow time interval of slip weakening, from the moment the strong discontinuity has been embedded into a finite element until the relative slip has grown to a large enough value for the coefficient of friction to reach steady-state. To this end, we formulate a linear slip weakening constitutive law in which the weakening component decays to zero at the same time that the frictional component increases to its value at residual state.

* Corresponding author. E-mail: borja@stanford.edu (R.I. Borja).
[a] Supported by U.S. Department of Energy, Grant No. DE-FG02-03ER15454, and U.S. National Science Foundation, Grant No. CMG-0417521.