Geophysical Research Abstracts
Vol. 13, EGU2011-4736, 2011
EGU General Assembly 2011

Theory and numerical models of compaction banding

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The onset and evolution of tabular compaction bands is studied based on the discontinuous bifurcation analysis and finite-difference simulations. In numerical models, the bands are initiated as constitutive instabilities resulting from the deformation bifurcation. Band spacing, length and aspect strongly depend on the constitutive parameters and particularly on the hardening modulus h, both spacing and length rapidly increasing with h. Compaction banding is only possible when h lies within certain limits h_{min} and h_{max} defined by other parameters. If $h > h_{max}$, the deformation localisation is either impossible at all or occurs in the form of shear banding, depending on the parameters. The transition from shear to compaction banding is gradual and corresponds to the formation of crooked or zigzag bands similar to those obtained in the experimental rock tests and also observed in the field. These bands are very dense and have small wavelength when h approaches h_{min}. On the other hand, when h approaches h_{max}, the forming compaction bands are linear and long. After the initiation of these bands (from deformation bifurcation) some of them are dying, while others continue a post-bifurcation evolution accumulating the inelastic deformation/damage and compressive stress at their tips. The stress concentration/increase, however, does not exceed 0.1% of the background value. Starting from some stage, the bands begin to propagate similarly to cracks. The propagation then slows down simultaneously with the beginning of bands' thickening that occurs due to the incorporation of not yet compacted material at the band flanks. The response of the already compacted "core" part of the band becomes mostly elastic. Then the propagation practically stops and the bands undergo only the heterogeneous thickening, maximal in the middle of the band and reducing toward its tips. This scenario obtained directly in the numerical models (without any specific hypotheses about the propagation mechanism) appears more complicated than what can be expected from the LEFM anti-crack model. The band propagation distance is proportional to the initial (resulted from the bifurcation) band length that in turn is proportional to the hardening modulus and theoretically can reach infinity. These bands are thicker in the central band segment and are progressively thinning toward the ends, while the thickness of dense zigzag bands is rather uniform. The microphysics of the observed difference between the bands of various types is discussed and related to the evolution (continuous versus discontinuous) of the hardening modulus with inelastic deformation.