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COMPUTATIONAL APPROACH FOR COMPACTION BANDS IN POROUS SANDSTONES

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ABSTRACT

This work adopts a computational approach for capturing the mechanism of compaction band formation in porous sandstones by applying the bifurcation theory at the macroscopic level and grain-scale fracture mechanisms within the deformation bands.

Pervasive localized failure during compaction has been documented in both geological and laboratory studies in porous sandstones [1, 2]. This "strain localization" can significantly influence the stress field, the strain partitioning and the fluid transport in many tectonic settings. It is therefore of fundamental importance to have a physical and computational understanding of the compaction localization phenomena and their relation to the constitutive behavior.

Wong et al. [3] investigated the transition from brittle dilatant failure to more ductile (cataclastic) compressive (or compactive) response for six sandstones that encompass a range of different porosities and grain sizes. They also compiled additional data from other publications to populate a table relating the pre-consolidation (grain crushing) pressure to the porosity and grain size. Attempts have also been made to analysis the mechanics of compaction localization using bifurcation theory. Critical conditions for the inception of localization and orientations of compactive shear and compaction bands have be derived as functions of the constitutive parameters. The simplest approach characterizes the yield envelope and inelastic volumetric change by the pressure-sensitivity parameter and dilatancy factor respectively [4-6]. Wong et al. [7] however observes that the mechanical data for sandstone samples that failed by compaction localization disagree with this theoretical prediction. They attribute the discrepancy to the inadequacy of the constitutive model and suggest that a more elaborated model is necessary to capture the multiple deformation mechanisms that may be occurring in the transitional regime; e.g. axial microcracks that grow and coalesce to form a shear fault, pores that collapse while grains are crushed, etc.

As a computational approach we investigate the prediction of compaction bands using macroscopic constitutive models and also grain-scale simulations using a finite/discrete

element approach with grain fracture. These numerical predictions are compared to experiments on several sandstones that have been shown experimentally to exhibit compaction bands in triaxial tests at higher confining pressures. The macroscopic constitutive model utilises a three-invariant primary yield function and plastic potential that combines the advantageous features of the superior sand model [8] and the sub-loading surface formulation [9]. The localization condition is identified by invoking either *weak* (jump in strain field) or *strong* (jump in displacement field) discontinuity assumptions. The constitutive model is first calibrated to reproduce the experimentally observed response in triaxial tests throughout the complete range of confining pressures and then the experiments where compaction bands are observed are studied in detail. The microscopic fracture mechanism within compaction bands is also investigated, using the combined finite/discrete element approach, to investigate the impact of grain-scale structure on the tendency for compaction band formation.

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