The evolution of shear bands under rapid drawdown conditions in variably permeable porous soils

Rapid drawdown (RDD) is a specific slope stability problem in geo-mechanics that can be approached both deterministically and probabilistically and simulated numerically with the Finite Element Method (FEM) or Random Finite Element Method (RFEM) on Multi-scale levels. The field (large-scale) boundary problem is simulated herein with a coupled- (water flow- solid skeleton) deformation formulation, assuming an elastic medium using the Random Finite Elements Method (RFEM). This renders an assessment of the probability of a slope sliding from gravitational-, seepage- and water-boundary forces corresponding to RDD. On the pore-scale, the effect of non-homogeneity in the degree of saturation is closely studied using the RFEM on an element level. The element (small-scale) analysis however implemented an elastic-plastic constitutive relationship. The heterogeneity that results from random permeability fields are found to strongly influence the location and magnitude of hydraulic gradients and shear stresses in both the large- and element-scale representation of an idealized partial immersed levee under RDD. Presence of such random field enhances shear bands development at local (elements) scale that might trigger levee's (mass) collapse during or after RDD.

Close-ups are shown for the evolution of shear bands of soil elements under compression and subsequent decompression conditions that are found prevalent during RDD. When considering plasticity, the decrease in effective pre-consolidation pressure through the increased saturation drives the onset of shear bands. This is enhanced by the random permeability field and results in heterogeneity in the degrees of saturation of the soil. Elastic material descriptions do not lead to such levels of heterogeneity since (effective) pre-consolidation pressure is not considered. During the subsequent decompression reaction almost instant softening and bifurcation was discovered due to reversal of strain from compression to extension in regions where prior intense shearing was present. This result is consistent with observations that material variability drives the onset and evolution of shear bands in many actual geotechnical situations.

Despite promising results numerical difficulties where encountered when the momentum- and mass equations where solved on the element level. These difficulties are discussed in and some suggestions are made to improve the performance of the algorithm which is used to solve the coupled elastic-plastic constitutive equations that constitute the model.

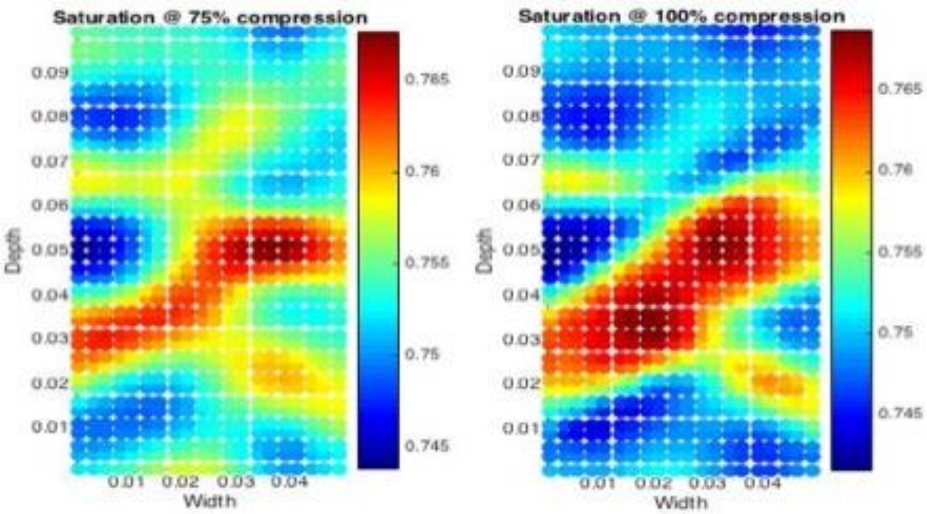

Figure 1: increase of the degree of saturation with the development of a shear band

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