

Evolution of Shear bands in Saturated Sand Tested using Triaxial Compression

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1. Introduction

The failure of sheared granular materials is manifested in zones of intensive shearing known as shear bands. The onset and evolution of shear bands are influenced by many factors including specimen density, particle morphology, gradation, boundary conditions, and loading conditions. This paper investigated how particle morphology and drainage condition (drained versus undrained) affect the evolution of shear bands for saturated sand.

2. Materials and Methods

A special triaxial apparatus was used to conduct in situ drained and undrained axisymmetric triaxial compression (ATC) on uniform natural silica sands (F35 and GS40 to represent rounded and angular particles, respectively) with grain size between U.S. sieves #40 (0.429 mm) and #50 (0.297 mm). The ATC experiments were conducted at 30 kPa and 300 kPa initial back pressures (BPs) and an effective confining pressure of 50 kPa. Synchrotron micro-computed tomography (SMT) scans were collected at GSECARS bending magnet beamline 13D (13 BM-D) at the Advanced Photon Source (APS), Argonne National Laboratory (ANL), Illinois, USA.

3. Results and Discussion

The acquired SMT scans were processed for dark field correction, flat field correction, zinger removal, and image reconstruction. Sand particles were indexed and separated to calculate the relative particle translation (RPT) gradient by averaging the particle translation relative to other particles in contact [1]. RPT at low axial strains ($\varepsilon_1 < 1.5\%$) showed no clear evidence of the onset of shear bands with relative particle movement happening almost over the entire height of specimens except for particles in zones near the endplates. At ε_1 before the peak effective principal stress ratio (EPSR), the RPT gradient exposed a clear shear band formation with shear bands fully developed at the peak EPSR. All GS40 specimens exhibited multi-shear band failure (bulging failure) while all F35 sand specimens developed a single shear band except for the drained experiment at BP = 300 kPa. Undrained experiments exhibited a thicker shear band when compared to drained experiments due to the drop in porewater pressure which caused higher effective stresses within the specimens which resulted in higher effective

stresses. After the peak state, specimens showed a stress softening behavior accompanied by the development of a well-defined shear band until reaching the critical state.

4. Conclusions

The effects of particle morphology and drainage conditions on the evolution of shear bands were studied using ATC testing of uniform sand. Angular sand specimens exhibited the formation of multi-shear bands with a larger zone of intense shearing due to a higher interlocking between particles when compared to rounded sand specimens. Undrained experiments showed thicker shear bands in comparison to drained experiments.

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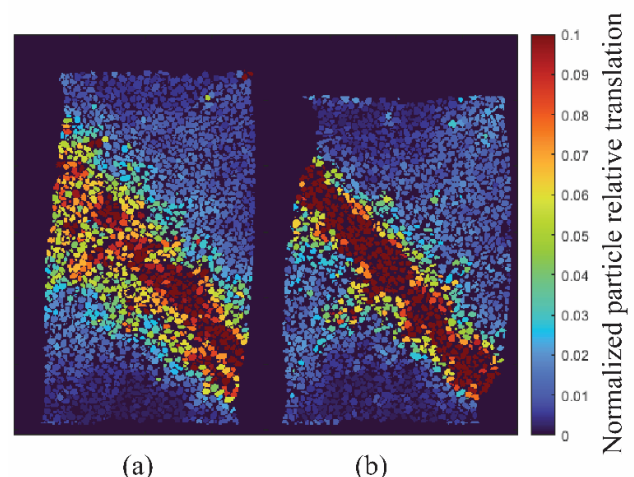


Figure 1. Relative particle translation gradient normalized relative to end platen displacement for F35 sand at: (a) peak state; (b) critical state.

6. References

- [1] A. M. Druckrey, K. A. Alshibli, and R. I. Al-Raoush, "Discrete particle translation gradient concept to expose strain localisation in sheared granular materials using 3D experimental kinematic measurements," *Géotechnique*, vol. 68, no. 2, pp. 162-170, 2018, doi: 10.1680/jgeot.16.P.148.

