Particle Dissolution: Effects on k_o

J. Carlos Santamarina and Hosung Shin

Dept. of Civil and Environmental Engineering, Georgia Institute of Technology
790 Atlantic Drive Atlanta, GA 30332 U.S.A
E-Mail: carlos@ce.gatech.edu

Introduction

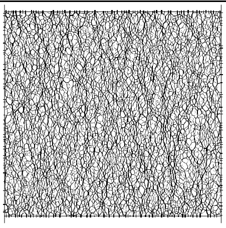
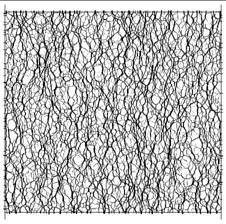
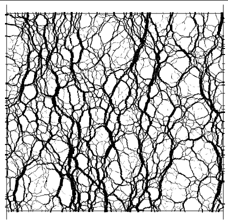
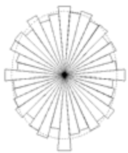
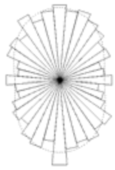
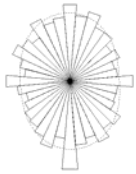
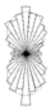
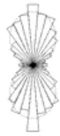
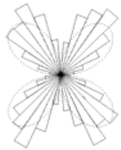
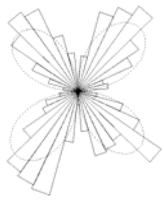
The current stress level in the ground has important effects on the deformation and strength characteristics of soils and on the performance of the engineered geosystems. The value of $k_o=\sigma'_h/\sigma'_v$ reflects soil type and formation history. In particular, post-depositional physical and chemical alterations not only affect the mechanical and chemical properties of soils [1], but may alter the values of k_o as well. The purpose of this study is to explore the evolution of k_o during mineral dissolution using a combination of experimental, analytical and numerical methods.

A soft oedometer cell is used to measure k_o [2]. Changes in k_o during dissolution are investigated using mixtures of glass beads and 10% NaCl grains, mixed under a salt-saturated brine to prevent dissolution. After vertical stress application, diarized water is allowed from the bottom of the specimen to gradually dissolve the salt in the specimen. Results show a pronounced decrease in the value of k_o, which reaches the k_a failure condition, followed by stress recovery.

The volumetric strain required to evolve from k_o to k_a is analytically shown to depend on the friction angle and the burial depth. Volumetric strains as low as $\varepsilon_v \approx 5\times10^{-4}$ can bring a soil with φ=30° to the k_a shear failure condition at 5m depth.

Discrete element simulation provide particle level insight into the consequences of mineral dissolution: anisotropy in coordination reaches a maximum as k approaches k_a (see Figure). Furthermore, there is a profound difference in internal fabric between the initial and post-dissolution conditions. The evolution in internal parameters can be used to estimate the mobilized friction angle [3], which reaches the maximum value near k minimum; this confirms that internal shear failure condition may be reached during dissolution.

In summary, experimental, analytical and numerical results show that mineral dissolution produces a pronounced horizontal stress drop under zero lateral strain boundary conditions and the state of stress may reach the k_a shear failure condition. While horizontal stress recovery often follows upon further dissolution, marked differences in soil fabric are observed between the pre and post-dissolution fabrics. This complex stress history may lead to internal shear planes in diagenetically modified sediments.

	Before dissolution	At k minimum	After dissolution
Contact force chains			
No. of contacts			
Average normal contact forces			
Average tangential contact forces			
Mobilized friction angle, $\sin(\varphi_{mob})$	0.41	0.58	0.45

References

[1] Herrera, M.C., Lizcano, A., and Santamarina, J.C., 2007, Colombian Volcanic Ash Soils, in Tan, T.S., Phoon, K.K., Hight, D.W., and Leroueil, S., eds., Characterization and Engineering Properties of Natural Soils, p. 2385-2409.

[2] Kolymbas, D. & Bauer, E., 1993, Soft oedometer. A new testing device and its application for the calibration of hypoplastic constitutive laws. Geotechnical Testing Journal 16, 263-270

[3] Rothenburg, L., and Bathurst, R.J., 1989, Analytical study of induced anisotropy in idealized granular materials: Geotechnique, v. 39, p. 601-614.