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POROMECHANICS SOLUTIONS IN SINGLE AND DUAL POROSITY ANISOTROPIC MEDIA FOR LABORATORY TESTING

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ABSTRACT

Poromechanics Solutions

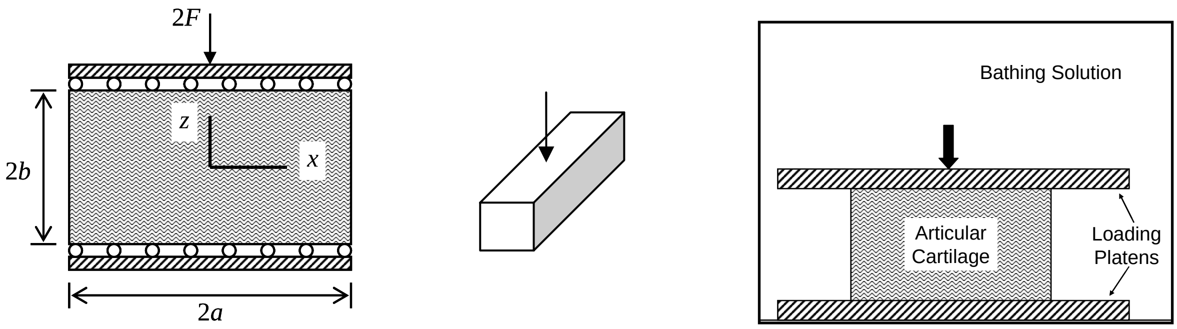
The isotropic and anisotropic poromechanics solutions for laboratory setups with initial and boundary conditions on prepared bio-geo samples easily traverse the boundaries of Biomechanics and Geomechanics. The two-dimensional Mandel-type problem geometry is very well known to the geomechanics community, yet almost unheard of for biomechanics experimentalists. However, this problem geometry is equivalent to the popular unconfined compression test in biomechanics community, in particular for cartilages and bones, with two-dimensional solutions in Cartesian for rectangular specimens (Fig. 1) or polar coordinates (Fig. 2) for cylindrical or disk samples.

This work will extend the Mandel-type problems, from single to dual-porosity poromechanics including viscoelastic effect and coupled with electro-chemical gradients. As such, the corresponding poromechanical analytical solutions presented herein are general and find their applications spanning both geomechanics and biomechanics fields. In the petroleum industry, the Mandel's problem and solutions are now used by many reservoir geomechanics modelers as a benchmark for their numerical algorithms and validation of the associate numerical schemes. In addition, its geometry also matches one of the testing configurations of rock or stiff clay samples. The dual-porosity poromechanics solution incorporating electro-chemical gradient allows geomechanicians the ability to study the effect of fractures and electro-kinetics on the overall responses of fractured rock formations. In biomechanics, the same solutions can be applied to the popular unconfined compression testing of biomaterials. In particular, the porosviscoelastic solution is applied to simulate creep/relaxation of articular cartilages. The dual-porosity model is also applicable to study the response of bones weakened through osteoporosis. On the other hand, the electrokinetic effects are of significant importance in the study of living tissues.

New Laboratory Testing Device and Technique in Geomechanics and Biomechanics

The Inclined Direct Shear Testing Device, IDSTD^{TM}, was developed by the authors to address the problem of long characteristic diffusion times as well as the limited availability of standard-size samples in geomechanics. This device allows mechanical strength characterization of bio- or geo-materials under variable confining pressure, with tested material exposed to different fluids at any desired exposure time, while dynamic elastic moduli can be simultaneously monitored as functions of applied stress state and fluid chemical composition. Figure 3 shows how IDSTD^{TM} method can be applied for mechanical characterization in both geomechanics

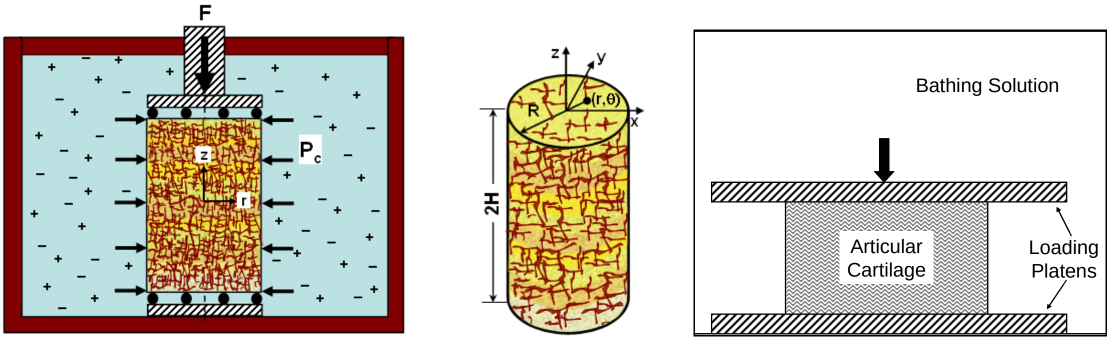
and biomechanics.



Mandel problem (Mandel 1953)
Anisotropic Mandel problem (Abousleiman et al. 1996)
Anisotropic poroviscoelastic Mandel problem (Hoang & Abousleiman 2007)

Unconfined compression test
(Soltz et al. 1999, Wang et al. 2003)
No published analytical solutions

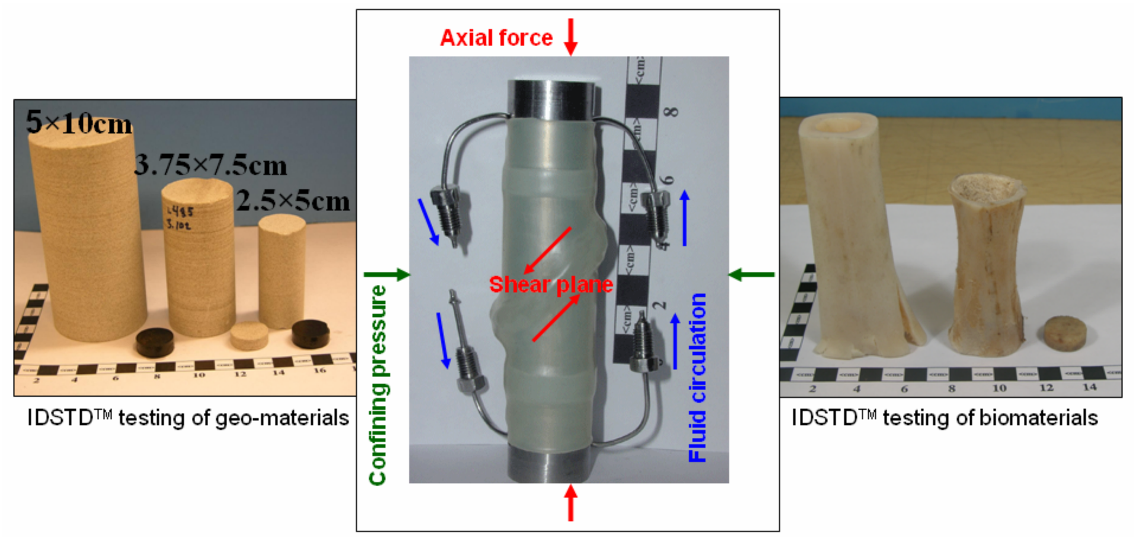
Fig. 1. Two-dimensional Mandel-type problems in geo- and bio-mechanics



Anisotropic poroelastic axisymmetric Mandel-type problem (Abousleiman & Cui 1998).
Dual-anisotropic porochemoelectro axisymmetric Mandel –type problem (Nguyen & Abousleiman 2008).

No existing publications

Fig. 2. Axisymmetric Mandel-type problem in geo- and bio-mechanics with dual-porosity/dual-permeability and electro-chemical gradients



The Inclined Direct Shear Testing Device IDSTD™ (Abousleiman et al..2008)

Fig. 3. IDSTD™ testing in geo- and bio-mechanics