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FEM Modeling of Spherical Indentation in a Poro-elasto-plastic Medium

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Poroelastic spherical indentation via step displacement loading has been applied in the literature as an experimental technique to characterize poroelasticity. In theory, for a fully saturated porous medium with incompressible constituents, if the indenter is subjected to step displacement loading, elastic constants can be determined from the early and late time responses according to the Hertzian contact solution, while hydraulic diffusivity or the coefficient of consolidation can be obtained from the transient response by matching the measured indentation force as a function of time against a master curve.

Our previous theoretical works have shown that for porous media with compressible constituents, such poroelastic master curves can be constructed for three distinct types of surface drainage conditions, namely, case I - a fully permeable surface, case II - a fully impermeable surface and case III - a mixed drainage condition where the surface is impermeable in the contact region, but permeable everywhere else. These master curves have only weak dependence on material properties through a single derived parameter. However, for geomaterials such as soils and rocks, yielding and tensile fracturing may occur if the indentation depth exceeds a threshold. Understanding how plastic deformation and tensile failure affect the spherical indentation process is therefore crucial to establishing spherical indentation as an experimental technique for poroelasticity characterization of geomaterials.

In this work, a fully coupled finite element analysis is conducted to investigate the poro-elasto-plastic spherical indentation process. We show that hydromechanical coupling gives rise to four distinct types of poro-elasto-plastic responses. Even though plasticity occurs immediately at the undrained limit, if cohesion is within a certain threshold, there is no plastic strain accumulation during the transient phase. The normalized force relaxation behavior could still be approximated as poroelastic. Insights gained from this numerical analysis therefore could be valuable in supporting the use of spherical indentation for poroelasticity characterization for geomaterials.

Time Block Preference

Time Block C (18:00-21:00 CET)

References

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Primary author: Prof. HUANG, Haiying (Georgia Institute of Technology)

Co-author: Mr LIU, Ming (Georgia Institute of Technology)

Presenter: Prof. HUANG, Haiying (Georgia Institute of Technology)

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