Anisotropic poroelasticity of rocks and its effective stress dependency

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Abstract:

Deformation of rock changes the pore fluid pressure conditions. Pore fluid pressure fluctuations associated with earthquakes, tides, and atmospheric loading are examples of such changes. The theory of poroelasticity is frequently used to interpret deformation-related pore pressure fluctuations and it has been generally very successful. Researchers usually assume that the rocks and rock-masses are isotropic for data interpretation and analysis mainly because of its simplicity. However, recent laboratory experiments (Tokunaga et al., 1998; Hart and Wang, 1999; Lockner and Stanchits, 2002) strongly suggest that the rocks are anisotropic and their anisotropy depends on the "effective stress". Some field measurements also suggest the anisotropic behavior of the rock masses (Gwyther et al., 1996).

In this presentation, the constitutive relationships of linear isotropic and anisotropic poroelastic material are compared, and the major difference of material behaviors is discussed. The significant point by introducing anisotropy is that pore pressure can be generated by incremental shear as well as normal stresses, and vice versa.

Then, the results of experimental measurements of anisotropic poroelastic properties of Berea sandstone are presented, and its effective stress dependency is discussed. Here, it is found that the anisotropy decreases as the effective stress increases, and the sample behaves isotropically at the higher effective stress. Considering that the important geological/geophysical processes are related to effective stress conditions and that the rock materials tend to be weak as effective stress decreases, it might be necessary to introduce anisotropic poroelastic theory to better understand the deformation-pore pressure coupling problems.