Theory of Poroelasticity

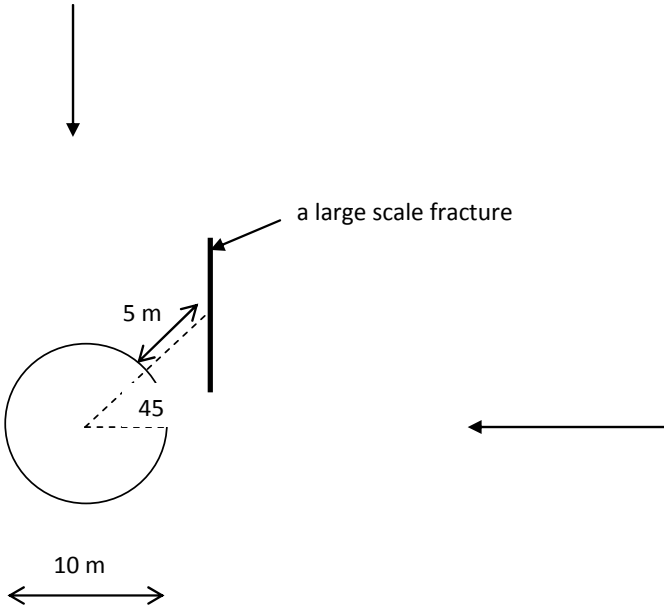
Semester 1, 2010

Final Exam (7 June) 16:00 - 18:00

Answer the questions in English.
Try to give a succinct explanation and try to give a physical meaning of equation, if applicable.
Make your own assumption, if necessary.

1. What is the physical meaning of the first stress invariant and the first strain invariant? (10)

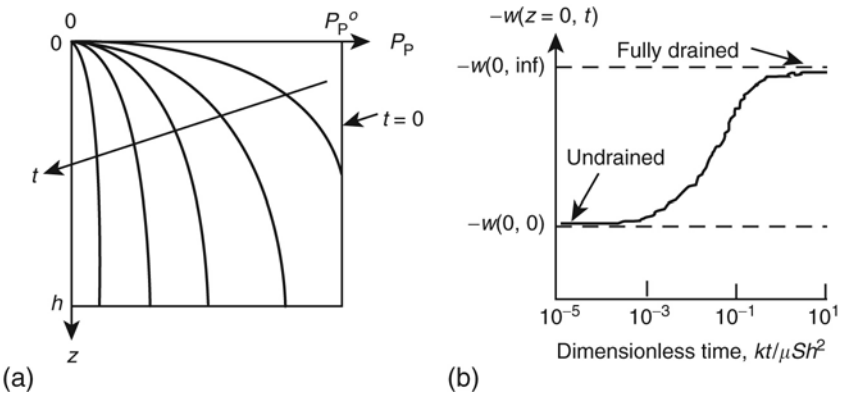
2. At a depth of 500 m (a typical depth of underground repository of nuclear waste), a 10-m diameter circular tunnel is driven in rock having a density of 2500 kg/m3 and uniaxial compressive and tensile strengths of 60.0 MPa and 3.0 MPa, respectively. Assuming that the vertical stress is calculated from the gravitational stress and pore pressure in the rock is hydrostatic, will the strength of the rock on the tunnel boundary be reached if
(a) k (the ratio of horizontal stress to vertical stress) = 2.0? Also indicate the location of failure if it is expected.
(b) investigate the possibility of shear slip of a fault shown below using the determined stress ratio. What is the minimum friction angle of the fault to be stable. Assume that the state of stress in the fracture is the same as the stress state at the center of the fault and stress is not disturbed by the existence of the fault. Use the Coulomb failure criteria ($\tau = \sigma \tan \phi$), which means that the shear strength of the fault is purely frictional.
Assume that Biot's coefficient, α, is one. (20)



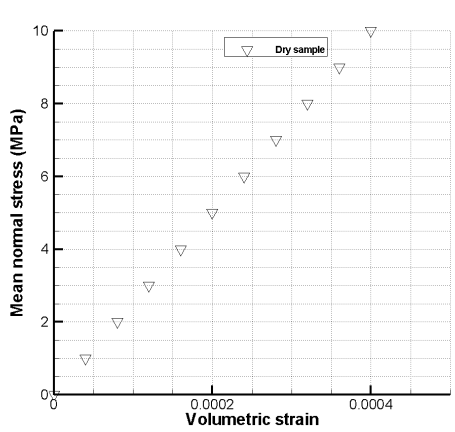
3. Discuss the displacement formulation and stress formulation for the problem of elasticity (10).

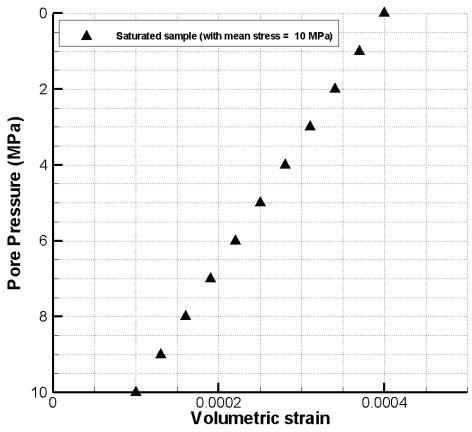
4. Without using any equation, explain the physical meaning of Biot's coefficient, α and Skempton's coefficient, B (10).

5. Explain the following two graph from Fig.7.7 of the textbook (10).



6. Following data are available from a laboratory test on a rock sample. The first test was conducted on a dry sample. The second test started when mean normal stress reached 10 MPa. In the second test, pore pressure was increased from zero to 10 MPa while maintaining the mean normal stress (confining stress) as 10 MPa. The Biot's coefficient α is calculated to be 0.75. Draw a expected response of saturated sample under the same mean stress of 10 MPa if the Biot coefficient were 0.9 (10).





7. Discuss the similarity and differences between poroelasticity and thermoelasticity (15).

8. A x-directional stress of 10 MPa and y-directional stress of 20 MPa are being applied on a rock sample in the size of 10 m × 10 m × 10 m with free surface in z-direction. One sides of x- and y-directions are fixed using roller boundary condition as shown in the figure. Calculate the stress and strain tensor when temperature was increased from 20°C to 80°C assuming that the temperature increase is occurring uniformly and initial strain tensor at temperature 20°C equal zero. (15)
The parameters for the rock, which was determined from the laboratory are as follows; Elastic modulus: 50 GPa, Poisson's ratio: 0.25, Linear expansion coefficient: $0.7x10^{-5}$ /°C, Heat conductivity: 2.7 W/m°C. (15)