

Homework Assignment (Due April 3).

1) Conventional triaxial tests ($\sigma_1, \sigma_2=\sigma_3$) were conducted on cylindrical specimens of Indiana limestone. The test results are reported in the following table.

σ_1 (psi)	$\sigma_2=\sigma_3$ (psi)
7000	250
7500	400
8500	500
9700	1000
10300	1000
11600	2000
13400	2000
13700	2000
15000	3000
15000	3000

Direct tension tests gave a tensile strength $T_o=500$ psi. Discuss the applicability of the following criteria to model the rock strength:

- (a) Two-parameter Mohr-Coulomb criterion;
- (b) Three-parameter Mohr-Coulomb criterion;
- (c) Hoek and Brown criterion.

2) Consider an opening of radius R_1 subjected to a hydrostatic stress $p_o = \gamma z$ acting at infinity. The internal pressure in the tunnel is p_i . The rock is assumed to be isotropic and has a linearly elastic -perfectly plastic behavior. Failure of the rock is assumed to be described by a Mohr Coulomb criterion

$$\sigma_1 = C_o + q \sigma_3 \quad (1)$$

with $q = \tan^2(\pi/4 + \phi/2)$ and $C_o = 2S_o \tan(\pi/4 + \phi/2)$. In equation (1), ϕ and S_o are the friction angle and internal shear strength (cohesion) of the rock, respectively.

For certain values of the applied stresses and the rock strength properties, failure of the rock may occur in a region $R_1 < r < R$ in which equation (1) is satisfied. Outside this region ($r > R$), the rock behaves elastically.

Consider the following equation of equilibrium

$$\frac{d\sigma_r}{dr} + \frac{\sigma_r - \sigma_\theta}{r} = 0 \quad (2)$$

Also, assume that $\sigma_\theta > \sigma_r$.

(a) Determine the expressions for the stresses in the plastic and elastic zones. Determine the expression of R/R_1 in terms of p_o/p_i and C_o/p_i .

(b) Assume $p_i = 5$ psi, $R_1 = 20$ ft, $\gamma = 160$ pcf, $\phi = 40^\circ$ and $S_o = 1,000$ psi. Show the variation of R/R_1 with depth z . Select a depth z for which R/R_1 is much larger than unity. For that depth show the stress distribution around the opening. How do those stresses differ from those obtained assuming elastic response only ?

