Strength Factor

Mohr-Coulomb Failure Criterion

(compression positive)

c = cohesion

ϕ = friction angle

$$I_1 = \sigma_{xx} + \sigma_{yy} + \sigma_{zz}$$

$$J_2 = \frac{1}{6}\left[(\sigma_{xx} - \sigma_{yy})^2 + (\sigma_{yy} - \sigma_{zz})^2 + (\sigma_{zz} - \sigma_{xx})^2\right] + \tau_{xy}^2 + \tau_{yz}^2 + \tau_{zx}^2$$

$$J_3 = \left(\sigma_{xx} - \frac{I_1}{3}\right)\left(\sigma_{yy} - \frac{I_1}{3}\right)\left(\sigma_{zz} - \frac{I_1}{3}\right) + 2\tau_{xy}\tau_{yz}\tau_{zx} - \left(\sigma_{xx} - \frac{I_1}{3}\right)\tau_{yz}^2 - \left(\sigma_{yy} - \frac{I_1}{3}\right)\tau_{zx}^2 - \left(\sigma_{zz} - \frac{I_1}{3}\right)\tau_{xy}^2$$

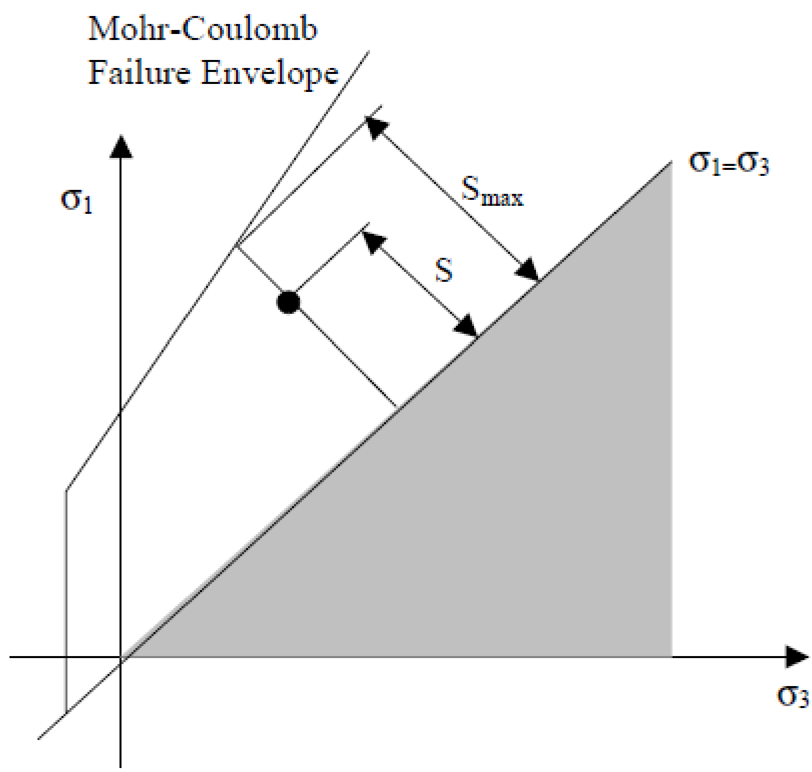
$$\Theta = \frac{1}{3}\arcsin\left[-\frac{3\sqrt{3}J_3}{2J_2^{3/2}}\right] \quad , \quad -\frac{\pi}{6} < \Theta < \frac{\pi}{6}$$

$$S = \sqrt{J_2}$$

$$S_{\max} = \frac{\frac{I_1}{3}\sin\phi + c\cos\phi}{\cos\Theta + \frac{\sin\Theta\sin\phi}{\sqrt{3}}}$$

$$\text{strength factor} = \frac{S_{\max}}{S}$$

2-D Graphical Representation



Hoek-Brown Failure Criterion

(compression positive)

m, s = Hoek-Brown parameters

σ_c = unconfined compressive strength of the intact rock

$$I_1 = \sigma_{xx} + \sigma_{yy} + \sigma_{zz}$$

$$J_2 = \frac{1}{6}\left[(\sigma_{xx} - \sigma_{yy})^2 + (\sigma_{yy} - \sigma_{zz})^2 + (\sigma_{zz} - \sigma_{xx})^2\right] + \tau_{xy}^2 + \tau_{yz}^2 + \tau_{zx}^2$$

$$J_3 = \left(\sigma_{xx} - \frac{I_1}{3}\right)\left(\sigma_{yy} - \frac{I_1}{3}\right)\left(\sigma_{zz} - \frac{I_1}{3}\right) + 2\tau_{xy}\tau_{yz}\tau_{zx} - \left(\sigma_{xx} - \frac{I_1}{3}\right)\tau_{yz}^2 - \left(\sigma_{yy} - \frac{I_1}{3}\right)\tau_{zx}^2 - \left(\sigma_{zz} - \frac{I_1}{3}\right)\tau_{xy}^2$$

$$\Theta = \frac{1}{3}\arcsin\left[-\frac{3\sqrt{3}J_3}{2J_2^{3/2}}\right] \quad , \quad -\frac{\pi}{6} < \Theta < \frac{\pi}{6}$$

$$S = \sqrt{J_2}$$

$$S_{\max} = \frac{\sqrt{\left(1 + \frac{\tan\Theta}{\sqrt{3}}\right)^2 \left(\frac{m\sigma_c}{8}\right)^2 + \left(\frac{m\sigma_c I_1}{12} + \frac{s\sigma_c^2}{4}\right)} - \frac{m\sigma_c}{8}\left(1 + \frac{\tan\Theta}{\sqrt{3}}\right)}{\cos\Theta}$$

$$\text{strength factor} = \frac{S_{\max}}{S}$$

Drucker-Prager Failure Criterion

(compression positive)

k, q = Drucker-Prager parameters

$$I_1 = \sigma_{xx} + \sigma_{yy} + \sigma_{zz}$$

$$J_2 = \frac{1}{6}\left[(\sigma_{xx} - \sigma_{yy})^2 + (\sigma_{yy} - \sigma_{zz})^2 + (\sigma_{zz} - \sigma_{xx})^2\right] + \tau_{xy}^2 + \tau_{yz}^2 + \tau_{zx}^2$$

$$S = \sqrt{J_2}$$

$$S_{\max} = k + q\frac{I_1}{3}$$

$$\text{strength factor} = \frac{S_{\max}}{S}$$

Calculation of the # of load steps in Phase²

$$N = \frac{100}{15}\left(\frac{1}{SF} - 1\right) = \frac{100}{15}\left(\frac{S}{S_{\max}} - 1\right)$$

1. Determine N for all elements using an elastic analysis
2. The number of load steps is the maximum value of N