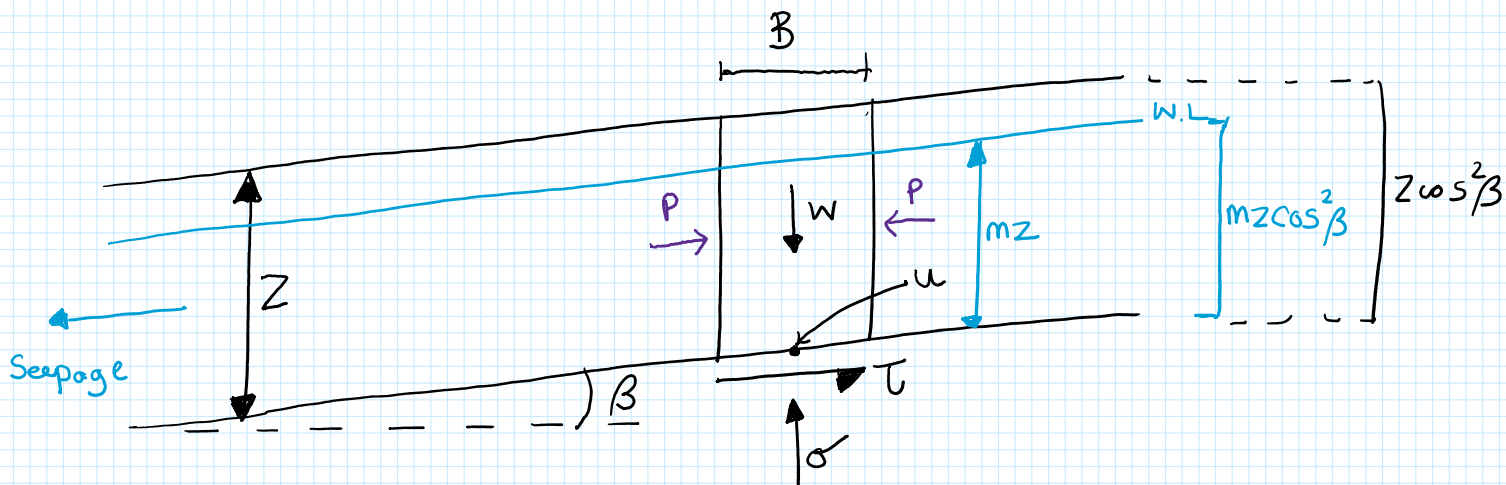




W = Weight

σ = Total Normal Stress

τ = Shear Stress

u = Pore Water Pressure

$$\text{Factor of Safety (FoS)} = \frac{\text{Resisting Forces}}{\text{Driving Forces}}$$

The main resisting force is the shear strength of the soil
Mohr - Coulomb Failure Criterion

$$\tau_f = c' + (\sigma - u) \tan \phi'$$

c' = Drained Shear Strength Parameter

σ = Total Normal Stress

u = Pore Water Pressure

ϕ = Shear Strength Parameter (Angle of Internal Friction)

$$\sigma = ((1-m)\gamma + m\gamma_{sat}) Z \cos^2 \beta$$

γ = Unit Weight

γ_{sat} = Saturated Unit Weight

$$u = m Z \gamma_w \cos^2 \beta$$

γ_w = Unit Weight Water

The driving force is the shear stress

$$T = ((1-m)\gamma + m\gamma_{sat}) Z \sin \beta \cos \beta$$

$$T = ((1-m)\gamma + m\gamma_{sat}) Z \sin\beta \cos\beta$$

$$\text{So } F_o S = \frac{T_f}{T}$$

Question 1.

$$\beta = 15^\circ$$

Determine $F_o S$

$$Z = 6 \text{ m}$$

$$\gamma_{sat} = 19 \text{ kN/m}^3$$

$$c' = 12 \text{ kN/m}^2$$

$$\phi' = 28^\circ$$

If W.L. is at the surface $m=1$

Resisting Force.

$$T_f = c' + (\sigma - u) \tan \phi$$

We need σ

$$\sigma = ((1-m)\gamma + m\gamma_{sat}) Z \cos^2 \beta$$

$$1-m \Rightarrow 1-1=0$$

$$\sigma = m\gamma_{sat} Z \cos^2 \beta = 19 \times 6 \times \cos^2 15 = \underline{\underline{106.36 \text{ kN/m}^2}}$$

We need u

$$u = \gamma_w Z \cos^2 \beta = 9.81 \times 6 \times \cos^2 15 = \underline{\underline{54.92 \text{ kN/m}^2}}$$

$$T_f = 12 + (106.36 - 54.92) \times \tan 28$$

$$= 12 + (51.44) \times \tan 28$$

$$= 12 + 51.44 \times 0.53$$

$$= 12 + 27.35$$

$$= \underline{\underline{39.35 \text{ kN/m}^2}}$$

Driving Force

Driving Force

$$\tau = ((1-m)\gamma + m\gamma_{sat})Z \sin\beta \cos\beta$$

$$m=1$$

$$\tau = \gamma_{sat} Z \sin\beta \cos\beta = 19 \times 6 \times \sin 15 \times \cos 15 = \underline{28.50 \text{ kN/m}^2}$$

$$F_o S = \frac{\tau_f}{\tau} = \frac{39.35}{28.50} = \underline{1.38}$$

STABLE
but close to
failure

Question 2

$$\beta = 10^\circ$$

Determine $F_o S$

$$Z = 4.5 \text{ m}$$

$$\gamma_{sat} = 18.5 \text{ kN/m}^3$$

$$c' = 14 \text{ kN/m}^2$$

$$\phi' = 30^\circ$$

$$m = 1$$

$$\tau_f = c' + (\sigma - u) \tan \phi'$$

$$\sigma = \gamma_{sat} Z \cos^2 \beta = 18.5 \times 4.5 \times \cos^2 10 = \underline{80.74 \text{ kN/m}^2}$$

$$u = \gamma_w Z \cos^2 \beta = 9.81 \times 4.5 \times \cos^2 10 = \underline{42.81 \text{ kN/m}^2}$$

$$\tau_f = 14 + (80.74 - 42.81) \times \tan 30$$

$$= 14 + (37.93) \times \tan 30$$

$$= 14 + 37.93 \times 0.58$$

$$= 14 + 21.90$$

$$= \underline{35.90 \text{ kN/m}^2}$$

$$\tau = \gamma_{sat} Z \sin\beta \cos\beta = 18.5 \times 4.5 \times \sin 10 \times \cos 10 = \underline{14.24 \text{ kN/m}^2}$$

$$F_o S = \frac{\tau_f}{\tau} = \frac{35 \cdot 90}{14 \cdot 24} = \underline{2.52} \quad \text{STABLE}$$

Question 3

$$\beta = 20^\circ$$

Determine $F_o S$

$$z = 7\text{m}$$

$$\gamma_{\text{sat}} = 21 \text{ kN/m}^3$$

$$c' = 8 \text{ kN/m}^2$$

$$\phi' = 25^\circ$$

$$m = 1$$

$$\tau_f = c' + (\sigma - u) \tan \phi'$$

$$\sigma = \gamma_{\text{sat}} z \cos^2 \beta = 21 \times 7 \times \cos^2 20 = \underline{129.80 \text{ kN/m}^2}$$

$$u = \gamma_w z \cos^2 \beta = 9.81 \times 7 \times \cos^2 20 = \underline{60.64 \text{ kN/m}^2}$$

$$\tau_f = 8 + (129.80 - 60.64) \tan 25$$

$$= 8 + (69.16) \times \tan 25$$

$$= 8 + 69.16 \times 0.47$$

$$= 8 + 32.25$$

$$= \underline{40.25 \text{ kN/m}^2}$$

$$\tau = \gamma_{\text{sat}} z \sin \beta \cos \beta = 21 \times 7 \times \sin 20 \times \cos 20 = \underline{47.24 \text{ kN/m}^2}$$

$$F_o S = \frac{\tau_f}{\tau} = \frac{40.25}{47.24} = \underline{0.85} \quad \text{FAILURE}$$

Question 4

$$\beta = 14^\circ$$

$$z = 6\text{m}$$

$$\beta = 14$$

$$Z = 6\text{m}$$

$$\gamma_{\text{sat}} = 19 \text{ kN/m}^3$$

$$\gamma = 17 \text{ kN/m}^3$$

$$c' = 13 \text{ kN/m}^2$$

$$\phi' = 29^\circ$$

$$m = 5/6$$

$$\tau_f = c' + (\sigma - u) \tan \phi'$$

$$\sigma = ((1-m)\gamma + m\gamma_{\text{sat}})Z \cos^2 \beta$$

$$= ((1 - 5/6) \times 17 + 5/6 \times 19) \times 6 \times \cos^2 14^\circ$$

$$= (1/6 \times 17 + 5/6 \times 19) \times 6 \times \cos^2 14^\circ$$

$$= (2.83 + 15.83) \times 6 \times \cos^2 14^\circ$$

$$= 18.67 \times 6 \times \cos^2 14$$

$$= \underline{\underline{105.46 \text{ kN/m}^3}}$$

$$u = mZ\gamma_w \cos^2 \beta = 5/6 \times 6 \times 9.81 \times \cos^2 14 = \underline{\underline{46.18 \text{ kN/m}}}$$

$$\tau_f = 13 + (105.46 - 46.18) \tan 29$$

$$= 13 + (59.28) \times \tan 29$$

$$= 13 + 59.28 \times 0.55$$

$$= 13 + 32.86$$

$$= \underline{\underline{45.86 \text{ kN/m}^2}}$$

$$\tau = ((1-m)\gamma + m\gamma_{\text{sat}})Z \sin \beta \cos \beta$$

$$= ((1 - 5/6) \times 17 + 5/6 \times 19) \times 6 \times \sin 14 \cos 14$$

$$= (0.17 \times 17 + 0.83 \times 19) \times 6 \times \sin 14 \cos 14$$

$$\begin{aligned}
 &= (0.17 \times 17 + 0.83 \times 19) \times 6 \times \sin 14 \cos 14 \\
 &= (2.89 + 15.77) \times 6 \times \sin 14 \cos 14 \\
 &= 18.66 \times 6 \times \sin 14 \cos 14 \\
 &= \underline{26.28 \text{ kN/m}^2}
 \end{aligned}$$

$$F_o S = \frac{\tau_f}{\tau} = \frac{45.86}{26.28} = \underline{1.74} \quad \text{STABLE}$$

Question 5

$$\beta = 12^\circ$$

$$z = 5.5 \text{ m}$$

$$\gamma_{\text{sat}} = 18.8 \text{ kN/m}^3$$

$$\gamma = 16.5 \text{ kN/m}^3$$

$$c' = 15 \text{ kN/m}^2$$

$$\phi' = 31^\circ$$

$$m = \frac{4}{5.5}$$

$$\tau_f = c' + (\sigma - u) \tan \phi'$$

$$\sigma = ((1-m)\gamma + m\gamma_{\text{sat}})z \cos^2 \beta$$

$$= \left(\left(1 - \frac{4}{5.5}\right) \times 16.5 + \frac{4}{5.5} \times 18.8 \right) \times 5.5 \times \cos^2 12$$

$$= (0.27 \times 16.5 + 0.73 \times 18.8) \times 5.5 \times \cos^2 12$$

$$= (4.46 + 13.72) \times 5.5 \times \cos^2 12$$

$$= 18.18 \times 5.5 \times \cos^2 12$$

$$= \underline{95.67 \text{ kN/m}^3}$$

$$u = m z \gamma_w \cos^2 \beta = \frac{4}{5.5} \times 5.5 \times 9.81 \times \cos^2 12 = \underline{37.54 \text{ kN/m}}$$

$$\tau_f = 15 + (95.67 - 37.54) \times \tan 31$$

$$\begin{aligned}
 T_f &= 15 + (95.67 - 37.54) \times \tan 31 \\
 &= 15 + (58.13) \times \tan 31 \\
 &= 15 + 58.13 \times 0.60 \\
 &= 15 + 34.88 \\
 &= \underline{\underline{49.88 \text{ kN/m}^2}}
 \end{aligned}$$

$$\begin{aligned}
 T &= ((1-m)\gamma + m\gamma_{\text{sat}})z \sin\beta \cos\beta \\
 &= \left(\left(1 - \frac{4}{5.5}\right) \times 16.5 + \frac{4}{5.5} \times 18.8 \right) \times 5.5 \times \sin 12 \times \cos 12 \\
 &= (0.27 \times 16.5 + 0.73 \times 18.8) \times 5.5 \times \sin 12 \times \cos 12 \\
 &= (4.46 + 13.72) \times 5.5 \times \sin 12 \cos 12 \\
 &= 18.18 \times 5.5 \times \sin 12 \cos 12 \\
 &= \underline{\underline{20.34 \text{ kN/m}^2}}
 \end{aligned}$$

$$FOS = \frac{T_f}{T} = \frac{49.88}{20.34} = \underline{\underline{2.45}} \quad \text{STABLE}$$

Question 6

$$\beta = 18^\circ$$

$$Z = 6 \text{ m}$$

$$\gamma_{\text{sat}} = 19.5 \text{ kN/m}^3$$

$$\gamma = 17 \text{ kN/m}^3$$

$$c' = 8 \text{ kN/m}^2$$

$$\phi' = 24^\circ$$

$$m = \frac{4.8}{6}$$

$$\tau_f = c' + (\sigma - u) \tan \phi$$

$$\sigma = ((1-m)\gamma + m\gamma_{sat})z \cos^2 \beta$$

$$= ((1 - \frac{4.8}{6}) \times 17 + \frac{4.8}{6} \times 19.5) \times 6 \times \cos^2 18$$

$$= (0.2 \times 17 + 0.8 \times 19.5) \times 6 \times \cos^2 18$$

$$= (3.40 + 15.60) \times 6 \times \cos^2 18$$

$$= 19 \times 6 \times \cos^2 18$$

$$= \underline{\underline{103.11 \text{ kN/m}^3}}$$

$$u = m z \gamma_w \cos^2 \beta = \frac{4.8}{6} \times 6 \times 9.81 \times \cos^2 18 = \underline{\underline{42.59 \text{ kN/m}}}$$

$$\tau_f = 8 + (103.11 - 42.59) \times \tan 24$$

$$= 8 + 60.52 \times \tan 24$$

$$= 8 + 60.52 \times 0.45$$

$$= 8 + 27.23$$

$$= \underline{\underline{35.23 \text{ kN/m}^2}}$$

$$\tau = ((1-m)\gamma + m\gamma_{sat})z \sin \beta \cos \beta$$

$$= ((1 - \frac{4.8}{6}) \times 17 + \frac{4.8}{6} \times 19.5) \times 6 \times \sin 18 \cos 18$$

$$= (0.2 \times 17 + 0.8 \times 19.5) \times 6 \times \sin 18 \times \cos 18$$

$$= (3.4 + 15.6) \times 6 \times \sin 18 \times \cos 18$$

$$= 19 \times 6 \times \sin 18 \times \cos 18$$

$$= \underline{\underline{33.50 \text{ kN/m}^2}}$$

$$F_o S = \frac{\tau_f}{\tau} = \frac{35.23}{33.50} = 1.05 \quad \text{CLOSE TO FAILURE}$$