Department of Civil Engineering
Katihar Engineering College, Katihar

Subject : Soil & Rock Mechanics
Topic : Stability of Slopes
Lecture : 05
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P-1. An embankment is inclined at an angle of 35° and its height is 15 m. The angle of shearing resistance is 15° & cohesion is 200 kN/m². The unit wt of soil is 18 kN/m³. If Taylor's stability no is 0.06. Find the FOS w.r.t cohesion.

Soln.

$\beta = 35^\circ$, $H = 15$ m

$\phi = 15^\circ$, $C = 200$ kN/m²

$\gamma = 18$ kN/m³, $S_n = 0.06$

$$(FOS)_C = \frac{C}{C_m}$$

We know that

Taylor stability No$(S_n) = \frac{C}{F_c \cdot \gamma \cdot H}$

$= \frac{C_m}{\gamma \cdot H}$

$$0.06 = \frac{C_m}{18 \times 15}$$

$$C_m = 0.06 \times 18 \times 15$$

$$= 16.2 \text{ kN/m}^3$$

Factor of safety w.r.t Cohesion $(F_c) = \frac{C}{C_m}$

$$= \frac{200}{16.2}$$

$$= 12.3$$

P.2 A slope is to be constructed at an inclination of 30° with the horizontal. Determine the safe height of the slope at factor of safety of 1.5. The soil has the following properties $\phi = 22.5°$, $\gamma = 19 \frac{kN}{m^3}$, $C = 15 kN/m^2$,

Soln. $\beta = 30°$ $F_{OS} = 1.5$ $C = 15 kN/m^2$

$\phi = 22.5°$, $\gamma = 19 kN/m^3$

The mobilised friction angle (ϕ_m)

$$\phi_m = \frac{\phi}{F_{OS}} = \frac{22.5}{1.5} = 15°$$

For $\beta = 30°$, $\phi_m = 15°$, $S_n = 0.046$.

$$S_n = \frac{C}{F_c \gamma H}$$

$$H = \frac{C}{S_n \cdot F_c \cdot \gamma} = \frac{15}{0.046 \times 1.5 \times 19} = 11.5m$$

P-3. A new canal is excavated to a depth of 5 m below ground level, through a soil having the following properties: $C = 14\ kN/m^2$, $\phi = 15°$, $e = 0.8$ & $G_s = 2.70$. The slope of banks is 1 in 1. Calculate the FOS w.r.t cohesion when the canal runs full. If it is suddenly & completely emptied, what will be the FOS.

Soln

Given Data

$H = 5m$, $C = 14\ kN/m^2$, $\phi = 15°$

$e = 0.8$, $G_s = 2.7$,

$\beta = \tan^{-1}\left(\frac{1}{1}\right) = 45°$

$F_c = ?$

$$\gamma_{sat} = \left(\frac{G+e}{1+e}\right)\gamma_w = \left(\frac{2.7+0.8}{1+0.8}\right) \times 9.81$$

$$= 19.08\ kN/m^3$$

$$\gamma_{sub} = \gamma_{sat} - \gamma_w = 19.08 - 9.81$$

$$= 9.27\ kN/m^3$$

(1) Submerged case or canal runs full.

For $\beta = 45°$, $\phi = 15°$, $S_n = 0.083$

$$S_n = \frac{C}{F_c \cdot \gamma \cdot H} = \frac{C}{F_c\, \gamma_{sub} \cdot H}$$

$$FOS = \frac{14}{9.27 \times 5 \times 0.083}$$

$$\boxed{FOS = 3.64}$$

(11) Drawdown Case.

$$\phi_w = \frac{\gamma_{sub}}{\gamma_{sat}} \cdot \phi_m$$

$$\phi_m = \tan^{-1}\left(\frac{\tan\phi}{FOS}\right)$$

or $$\phi_m = \frac{\phi}{FOS}$$

Let FOS w.r.t ϕ is F_ϕ

Assume $F_\phi = 1$

$$\phi_m = \frac{\phi}{1} = \phi$$

For $\beta = 45^\circ$, $\phi_w = ?$

$$\phi_w = \frac{9.27}{19.08} \times 15 \simeq 7.3^\circ$$

For $\beta = 45^\circ$, $\phi_w = 7.3^\circ$, $S_n = 0.122$

$$S_n = \frac{C}{F_c \cdot \gamma H}$$

$$F_c = \frac{C}{S_n \cdot \gamma_{sat} \times H} = \frac{14}{19.08 \times 5 \times 0.122}$$

$$\boxed{F_c = 1.2}$$

P-4 A temporary cutting 8m deep is to be made in a clay having a unit weight of 18 kN/m³ and an average cohesion of 20 kN/m². A hard stratum of rock exists at a depth of 12m below the ground surface. Use Taylor's stability curves to estimate if a 30° slope is safe. If a FOS of 1.25 is considered necessary. Find the safe slope Angle.

Soln. $H = 8\,m$, $\gamma = 18\,kN/m^3$, $C = 20\,kN/m^2$

$(H+D) = 12\,m$, $\beta = 30°$

$$\text{Depth factor} = \frac{H+D}{H} = \frac{12}{8} = 1.5$$

$D_f > 1$ (Base failure)

From Taylor's stability curve

For $D_f = 1.5$, $\beta = 30°$, $S_n = 0.163$

$$S_n = \frac{C}{F_c \cdot \gamma H}$$

$$F_c = \frac{20}{0.163 \times 18 \times 8} = 0.85 < 1$$

The proposed slope is therefore unsafe

For $F_c = 1.25$

$$S_n = \frac{c}{F_c \cdot \gamma \cdot H}$$

$$= \frac{20}{1.25 \times 18 \times 8} = 0.11$$

From Taylor Curve

For $S_n = 0.11$, and $D_f = 1.5$

Slope angle (β) = 12°

↳ Safe slope angle

P-5. A slope is 12 m high and has an inclination of 30°. If the soil of the slope has $c = 25\ kN/m^2$, $\phi = 12°$, $\gamma = 18.6\ kN/m^3$. Determine the FOS w.r.t shear strength.

Soln. $H = 12m$, $\beta = 30°$, $c = 25\ kN/m^2$, $\phi = 12°$, $\gamma = 18.6\ kN/m^3$

The factor of safety F ($= F_c = F_\phi$) is found by trial

First Trial let $F_\phi = 1.2$

$$\tan\phi_m = \frac{\tan\phi}{FOS_\phi} = \frac{\tan(12°)}{1.2}$$

$$\phi_m = 10.04°$$

From Table (β, ϕ, S_n)

For $\beta = 30^\circ$, and $\phi = \phi_m = 10.04$

$S_n = 0.0745$

$$FOS = \frac{c}{S_n \gamma H} = \frac{25}{0.0745 \times 14.6 \times 12}$$

$F_c = 1.503$

Second Trial Let $F_\phi = 1.4$

$$\phi_m = \tan^{-1}\left(\frac{\tan\phi}{F_\phi}\right)$$

$$= \tan^{-1}\left(\frac{\tan 12}{1.4}\right)$$

$\phi_m =$ ⁄

For $\beta = 30^\circ$, $\phi_m =$ ⁄

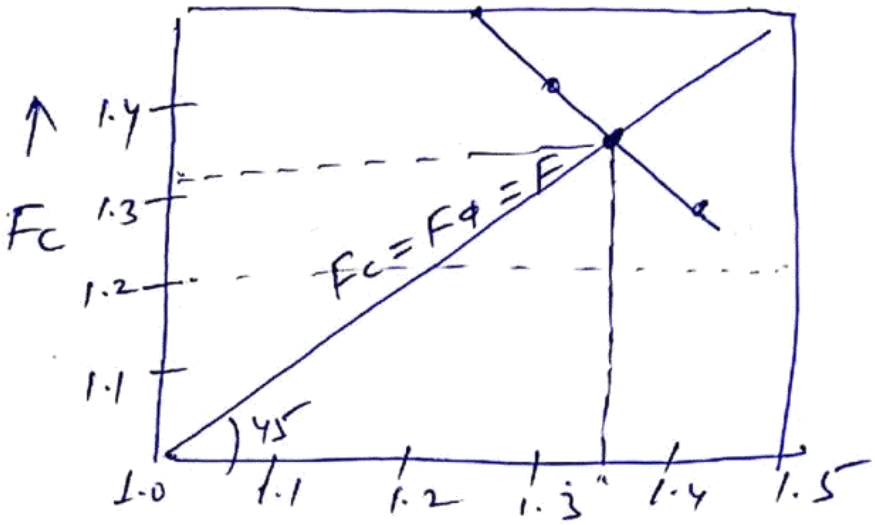
$S_n =$ ⁄

$F_c = 1.32$

Third Trial For $F_\phi = 1.3$, we get

$F_c = 1.4$

4th Trial For $F_\phi = 1.35$, $F_c = 1.358$



From the Curve

$$F_c = F_\phi = 1.36$$

$$F = F_c = F_\phi = 1.36$$ Ans

P-6 A slope is to be constructed in a soil for which $c' = 0$, $\phi' = 36°$. It is to be assumed that the water table may occasionally reach the surface of slope with seepage taking place parallel to the slope. Determine the maximum slope angle for a factor of safety 1.5. Assuming a potential failure surface parallel to the slope. What would be the FOS of the slope, constructed at this angle, if the water table should be well below the surface. $\gamma_{sat} = 17$ kN/m³

(a) When Seepage parallel to slope

$$FOS = \frac{\gamma_{sub}}{\gamma_{sat}} \cdot \frac{\tan\phi}{\tan\beta}$$

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

$\gamma_{sub} = 19 - 9.81 = 9.19\ kN/m^3$

$FOS = 1.5$

$$1.5 = \frac{9.19}{19} \times \frac{\tan 36^\circ}{\tan\beta}$$

$$\tan\beta = 0.2343$$

$$\boxed{\beta = 13.19^\circ}$$

(b) When No seepage : water table is well below the surface

$u = 0$

$$FOS = \frac{\tan\phi}{\tan\beta}$$

$$FOS = \frac{\tan 36^\circ}{\tan(13.19^\circ)} = 3.10$$

$$\boxed{FOS = 3.10}$$