5.6 Definition of Key Terms

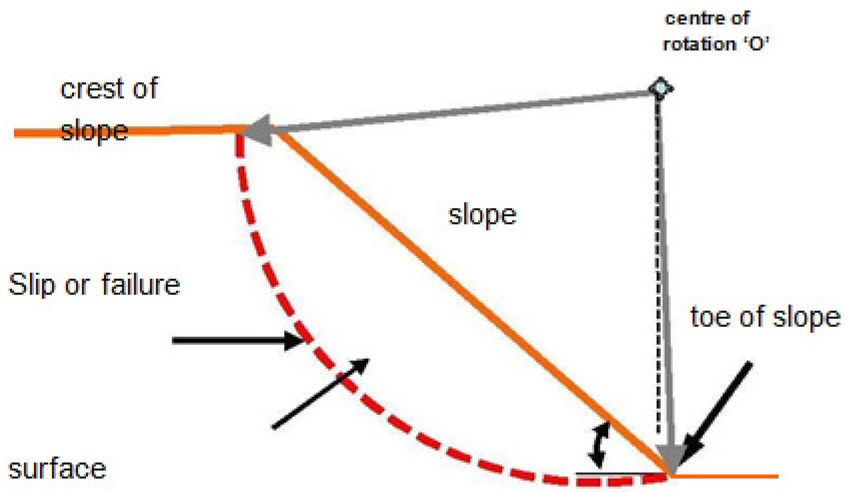

Fig 5.25 Slip circle

Slip or failure zone: It is a thin zone of soil that reaches the critical state or residual state and results in movement of the upper soil mass.

Slip plane or failure plane or slip surface or failure surface: It is the surface of sliding.

Sliding mass: It is the mass of soil within the slip plane and the ground surface.

Slope angle (i): It is the angle of inclination of a slope to the horizontal. The slope angle is sometimes referred to as a ratio, for example, 2:1 (horizontal: vertical).

5.6.1Factor of safety

Factor of safety of a slope is defined as the ratio of average shear strength (τ_f) of a soil to the average shear stress (τ_d) developed along the potential failure surface.

$$FS = \frac{\tau_f}{\tau}$$

FS = Factor of safety

τ_f = average shear strength of the soil

τ_d = average shear stress developed along the potential surface.

5.6.2Shear Strength:-

Shear strength of a soil is given by

$$\tau_f = c + \sigma \tan\varphi$$

Where, c = cohesion

φ= angle of internal friction

σ= Normal stress on the potential failure surface

Similarly, the mobilized shear strength is given by

$$\tau_d = c_d + \sigma \tan\varphi_d$$

Let C_d and φ are the cohesion and angle of internal friction that develop along the potential failure surface.

$$FS = \frac{\tau_f}{\tau}$$

$$FS = \frac{c + \sigma \tan\varphi}{c_d + \sigma \tan\varphi_d}$$

$$F_c = \frac{C}{C_d}$$

$$F = \frac{tan\varphi}{tan\varphi_d}$$

When Fc = F it gives Factor of safety w.r.t strength

C= tan φ

C_d = tan φ_d

Then Fs = Fc =F

When FS = 1, then the slope is said to be in a state of failure

5.6.3 USE OF STABILITY NUMBER [OR] TAYLOR'S STABILITY NUMBER [OR]STABILITY NUMBER [OR] STABILITY NUMBEDR

Taylor Stability number is a dimensionless quantity denoted by S_n ad defined as

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

Cm- Mobilized cohesion on slipγ- Unit weight of soil

H- Height of slope

$$Also, F_c = \frac{C}{C_m} \ so\ that\ , C_m = \frac{C}{F_c}$$

Substituting in above equation, we get,

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

Factor of safety is also expressed in terms of critical height

$$F_H = F_c = \frac{H_c}{H}$$

So that $F_c H = H_c$

Substitute in above equation we get,

$$S_n = \frac{C_m}{\gamma H_c}$$

H_c – critical height of slope

Table 5.1 Taylors stability number for cohesive soil

i ↓ \ φ →	0°	5°	10°	15°	20°	25°
90°	0.261	0.239	0.218	0.199	0.182	0.166
75°	0.219	0.195	0.173	0.152	0.134	0.117
60°	0.191	0.162	0.138	0.116	0.097	0.079
45°	(0.170)	0.136	0.108	0.083	0.062	0.044
30°	(0.156)	(0.110)	0.075	0.046	0.0625	0.009
15°	(0.145)	(0.068)	(0.023)	–	–	–

Table 5.2 values of S_n for slope in cohesive soils(φ=0)with depth factors

Slope angle	Stability number S_n				
	Depth factor D_f				
	1	1.5	2	3	∞
90	0.261				
75	0.219				
60	0.191				
53	0.181	0.181	0.181	0.181	0.181
45	0.164	0.174	0.177	0.180	0.181
30	0.133	0.164	0.172	0.178	0.181
22.5	0.113	0.153	0.166	0.175	0.181
15	0.083	0.128	0.150	0.167	0.181
7.5	0.054	0.080	0.107	0.140	0.181

The stability number is expressed as a function of cohesion, Factor of safety, Unitweight and Height of slope.

The stability number is directly proportional to cohesion and indirectly proportional tounit weight and the height of the slope. This is also called as Taylor's stability number (Sn)

The factor of safety with respect to cohesion is given by

$$Fc = {}^{C}/_{Cm}$$

Since Taylor stability number Sn is based on Factor of safety with respect to cohesion, Fc, the table and chart give 'Sn' only for the case where ϕ is assumed to be fully mobilized. But in cases where factor of safety is applicable to both cohesion and friction, wehave mobilized shearing resistance given by,

$$\varphi_m = \tan^{-1}\left(\frac{tan\varphi}{F}\right)$$

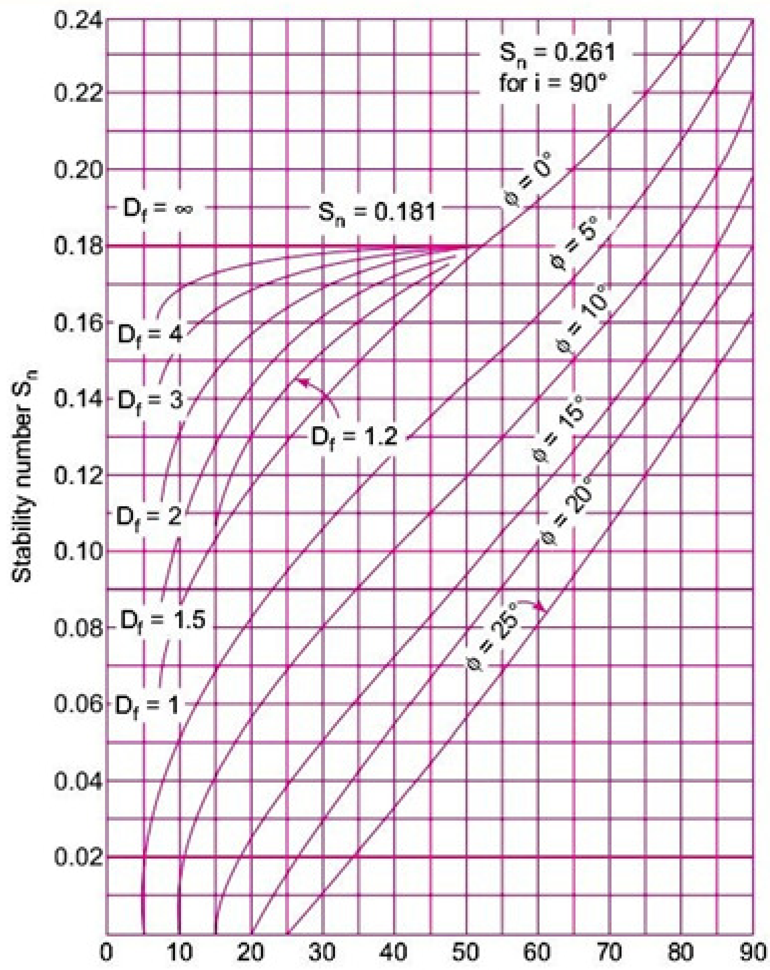

Fig5.26 chart of Taylors stability number

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

As an appropriation ϕ_m may be taken equal to φ_F

For cohesionless soil (C = ϕ) S_n is zero. It is not applicable.

$$F = \frac{tan\varphi}{tani}$$

For long term stability – C' and ϕ' to be used,

Fully submerged slope – γ' should be used for Sn

Saturated slope - γ_{sat} should be used for Sn

Purely friction soil – $S_n = 0$

Sudden draw down – ϕ' replaced by ϕ_w

$$\varphi_w = \frac{\gamma'}{\gamma_{sat}}\varphi$$

Problems:

1)A canal with a depth of 5m has banks with slope 1:1. The properties of soil are : C =20 KN/m^2 ; ϕ =15º ; e = 0.7; G=2.6

Calculate the factor of safety with respect to cohesion

- When canal runs full
- It is suddenly and completed emptied

Given: C = 20 KN/m^2

ϕ =15º

e = 0.7

G=2.6 ; H= 5m

Solution:

Case (1): When canal runs full, the side slopes are submerged (S=1)

$$\gamma_{sat} = \frac{(G + e\,S)\gamma_w}{1 + e}$$

$$= \frac{(2.6 + 0.7)9.81}{1 + 0.7}$$

$$= 19.04\ KN/m^2$$

γ' = γsat - γw =19.04 – 9.81 = 9.23 KN/m^2

From Taylors stability chart,

For i=45º and ϕ =15º, Sn = 0.083

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

$$F_c = \frac{20}{0.083x9.81x5} = 5.22$$

Case(ii) When canal is suddenly and completely emptied:

For sudden drawdown condition, S_n is to be obtained for slope angle i and weightedfrictional angle $\phi_{w.}$

$$\varphi_w = \frac{\gamma'}{\gamma_{sat}}\varphi$$

$$\varphi_w = \frac{9.23}{19.04}(15) = 7.3$$

From Taylors stability chart,

For i=45° ; ϕw = 7.3° ; Sn= 0.122

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

$$F_c = \frac{20}{0.122x9.81x5}$$

$$= 1.72$$

2) A temporary cutting 8m deep is to be made in a clay having a unit weight of 18KN/m^3 and an average cohesion of 20 KN/m^2 . A hard stratum of rock exists at adept of 12m below the ground surface. Use Taylor's stability curves to estimate if a 30^0slope is safe. If a factor of safety of 1.25 is considered necessary, find the safe slope angle.

Solution:

Depth factor$D_f = \frac{12}{8} = 1.5$

From taylor's stability curve D_f=1.5,i=30^0,S_n=0.163

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

$$= \frac{20}{0.163x18x18} = 0.85$$

For F_c=1.25 the stability number $S_{n,}$

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

$$= \frac{20}{1.25x18x18}$$

$$= 0.11$$

From Taylor's curve $S_n = 0.11$ and D_f=1.5

We get i=12^0

3) A new canal is excavated to a depth of 5m below ground level,troug a soil having the following characteristic,c=14KN/m^2 ,φ=15^0,e=0.8 and G=2.7. The slope of banks is 1 in1.Calculate the factor of safety wit respect to cohesion when tha canal runs full.If it is suddenly and completely emptied, what will will be the factor of safety?

Solution:

$$\gamma_{sat} = \frac{G+e}{1+e}\gamma_w$$

$$= \frac{2.7+0.8}{1+0.8}x9.81$$

=19.08 KN/m^3

$$\gamma' = 19.08 - 9.81 = 9.27\ KN/m^3$$

i=45^0 ;φ=15^0

i)submerged Case: For i=45^0 ;φ=15^0;S_n=0.083

$$F_c = \frac{C}{S_n \gamma' H} = \frac{14}{9.27x5x0.083} = 3.64$$

ii)Drawdown case: Taking F_φ=1 and φ_m=φ

$$\varphi_w = \frac{\gamma'}{\gamma_{sat}}\varphi$$

$$\varphi_w = \frac{9.27}{19.08}(15) = 7.3°$$

For $i=45^0$;$\varphi=7.3^0$;$S_n=0.122$

$$F_c = \frac{C}{S_n \gamma_{sat} H} = \frac{14}{0.122x19.08x5} = 1.2$$

4)Calculate the factor of safety with respect to cohesion of a clay slope laid at 1 in 2 to a height of 10m ,if the angle of internal friction $\varphi=10^0$;$c=25KN/m^2$ and $\gamma=19KN/m^3$.What will be the critical height of the slope in this soil?

Solution:

$i = \tan^{-1}\left(\frac{1}{2}\right) = 26.5°$ and $\varphi=10^0$ $C=25KN/m^2$ and $\varphi=10^0$,$S_n=0.064$

For $i=26.5^0$

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

$$F_c = \frac{C}{S_n \gamma H} = \frac{25}{0.064x19x10} = 2.06$$

The critical height H_c is given by

$$H_c = F.H = 2.06x10 = 20.6m$$

Alternatively,

$$H_c = \frac{c}{\gamma S_n} = \frac{25}{0.064x19} = 20.6m$$

5) A slope is to be constructed at an inclination of 30^0 with the horizontal . Determine the safe height of the slope at factornof safety of 1.5.The soil has the following properties $C=15N/m^2$,$\varphi=22.5^0$ and $\gamma=19KN/m^3$.

The mobilised frictional angle φ_m is given by

$$\varphi_m = \frac{\varphi}{F} = \frac{22.5}{1.5} = 15^\circ$$

For $i=30^0$ and $\varphi_m=15^0$, $S_n=0.046$

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

$$H = \frac{C}{F_c \gamma S_n} = \frac{15}{0.046x1.5x19} = 11.5m$$