5.4 Finite Slopes

A finite slope is one with a base and top surface, the height being limited. The inclined faces of earth dams, embankments, excavation and the like are all finiteslopes.

Investigation of the stability of finite slopes involves the following steps

a) assuming a possible slip surface,

b) studying the equilibrium of the forces acting on this surface, and

c) Repeating the process until the worst slip surface, that is, the one with minimum margin of safety is found.

Methods:-

I. (Swedish methodof slices or Method of slices)

II. Friction circle method

III. Cullman's method.

IV. Bishop's method

1)Swedish circle method:

The method, developed by Swedish engineers assumes that the surface-of sliding is an arc of a circle.

We shall consider two cases:

(i) analysis of purely cohesive soil (C=0analysis) and

(ii) analysis of a soil possessing both cohesion and friction($c-\varphi$ analysis).

(i)$\varphi_u = 0$ analysis : Figure 5.11 shows a slope AB, the stability of which is to be determined. The method consists in assuming a number of trial slip circles, and finding the factor of safety of each. The circle corresponding to the minimum factor of safety is the trial slip circle.

Let AD be a trial slip circle, with r as the radius and O as the centre of rotation Let W be the weight of the soil of the wedge ABDA of unit thickness, acting through its centroid.

The driving moment M_D be equal to $w\bar{x}$.

Where x is the distance of line of action of W from the vertical line passing through the centre of rotation, If C_u is the unit cohesion and

L= length of the slip arc AD $= \frac{2\pi r\delta}{360°}$

The shear resistance developed along the Slip surface will be equal to $C_u\hat{L}$ which acts at a radial distance r from the centre of rotation O.

Hence.the resisting moment M_R be equal to $rC_u\hat{L}$

The factor of safety is given by

$$F = \frac{M_R}{M_D} = \frac{C_u\hat{L}r}{w\bar{x}} - - - - - - (1)$$

Let C_m =mobilized shear resistance of soil(φ=0)

$$w\bar{x} = C_m\hat{L}r$$

$$C_m = \frac{\hat{L}r}{w\bar{x}}$$

$$F = \frac{C_u}{C_m} = \frac{C_u\hat{L}r}{w\bar{x}} - - - - (2)$$

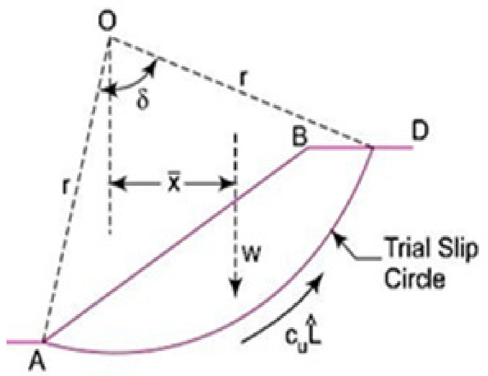


Fig 5.11 slip circle

The distance $\bar{x}$ of the centroid of the wedge from the centre of rotation O,can be determined by dividing the wedge into a number of vertical slice and dividing the algebraic sum of moment of weight of each slice by the weight of the wedge.

Effect of tension crack: The tension crack at a depth

$$h_c = \frac{2C}{\gamma}$$

The hydrostatic pressure at a depth $\frac{Z_0}{3}$.

(ii)c-φ analysis: In order to test the stability of the slope of a c-φ soil, trial slip circle is drawn, and the material above the assumed slip surface is divided into a convenient number of vertical strips or slices.

The forces between the slices are neglected, and each slice is assumed to act independently as a column of soil of unit thickness and of width b. The weigh W of each slice is assumed to act it centre.

If this weight of each slice is resolved into normal (N) and tangential (T) components, the normal components will pass through the centre of rotation (0) and hence do not cause any driving moment on the slice.

However, the tangential component T causes a driving moment

$$MD=T \times r.$$

Where r is the radius of the slip circle. The tangential components of the few slices at the base may cause resisting moment; in that case T is considered negative.

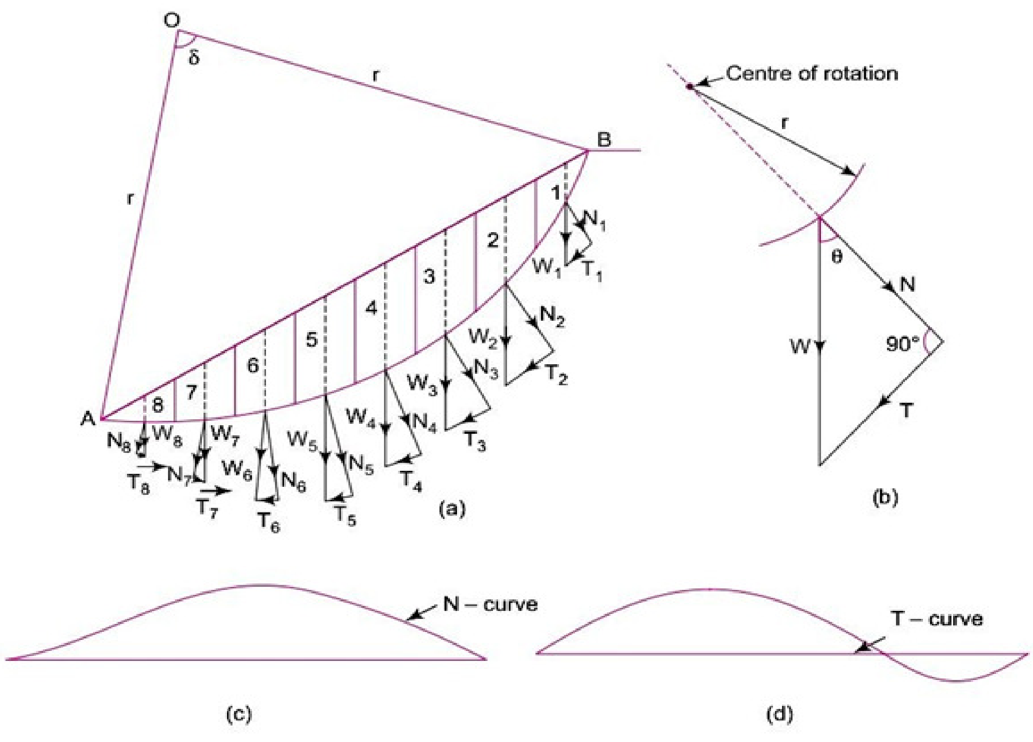


Fig 5.12 trial slip circle for c-φ

If c is the unit cohesion and ΔL is the curved length of each slice then the resisting force, from coulombs equation is equal to $(c.\Delta L+N\tan\varphi)$

For the entire slip surface AB

Driving moment $M_D = r\sum T$,

Resisting moment $M_R=r[c.\Delta L+\Sigma N\tan\varphi]$

$$\sum \text{T} = \text{algebraic sum of all tangential components}$$

$$\sum \text{N} = \text{algebraic sum of all normal components}$$

$$\sum \Delta L = \hat{L} = \frac{2\pi r\delta}{360^\circ} = length\ AB\ of\ slip\ circle$$

Hence, factor of safety against sliding is $F = \frac{M_R}{M_D} = \frac{C\hat{L}+tan\varphi\sum N}{\sum T} - - - - - - (3)$

A number of trial slip circles are chosen and factor of safety of each is computed. The circle giving the minimum factor of safety is the critical slip circle.

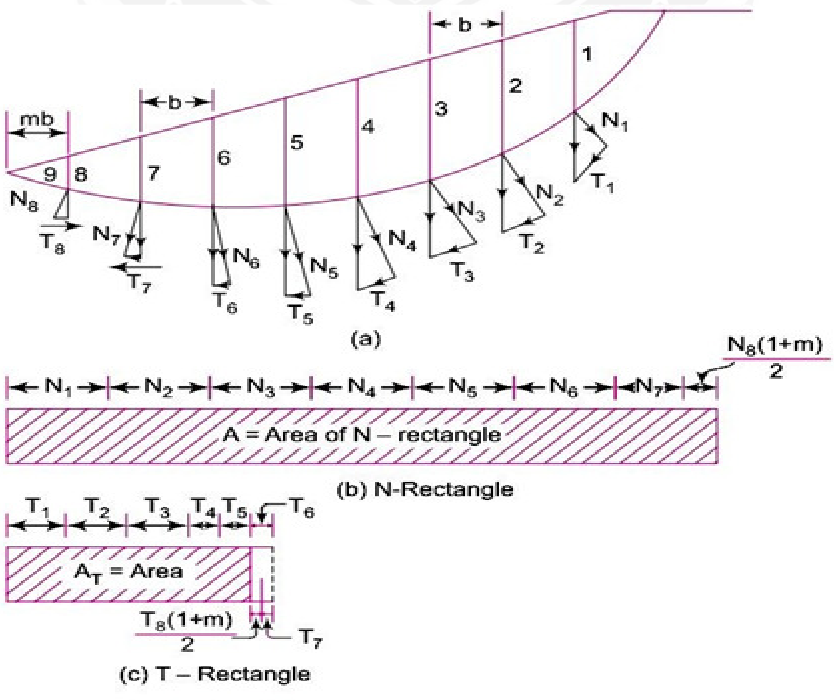


Fig 5.13 trial slip circle for c-φ in T and N

In rectangular plot method:

$$\sum N = A_N.x^2\gamma\ KN$$

$$\sum T = A_T.x^2\gamma\ KN$$

This method of slices is a general method which is equally applicable to homogenous soils, stratified soils,fully or partially submerged soils,non uniform slopes and to cases when seepage and pore pressure exists within thesoil

Problems:

1).In order tofind thefactor of safety of d/s slope of an earth dam. During steady seepage the section of the dam was drawn to a scale of 1cm=4cm and the following result obtained on a critical slip circle:

Area of N-rectangle=14.4.sq.cm.

Area of T-rectangle=6.4sq.cm.

Area of U-rectangle =6.9.sq.cm

Length of arc=12.6cm.

Laboratory tests have furnished will less of 26° for effective angle of shear resistance and 19.5kN/m^2 for cohesion. Determine the factor of safety of the slope. Unit wt of soil 19kN/m^3.

Solution:

Scale 1cm=4cm ;x=4

Consider 1cm length of the dam

$$\sum N = A_N.x^2\gamma = 14.4(4^2)x19 = 4378KN$$

$$\sum T = A_T.x^2\gamma = 6.4(4^2)x19 = 1946\ KN$$

$$\sum U = A_U.x^2\gamma = 6.9(4^2)x19 = 1083\ KN$$

$$\hat{L} = 12.4x4 = 50.4\ m, c' = 19.5KN/m^2$$

$$F = \frac{C'\hat{L} + tan\varphi \sum(N-U)}{\sum T}$$

$$= \frac{(19.5x50.4) + tan26°(4378 - 1083)}{1946}$$

$$= 1.33$$

2)Fig shows an earth slope of clayed soil having c=55KN/m^2 and φ=0.Corresponding to a trial slip circle AB, we have the following data.

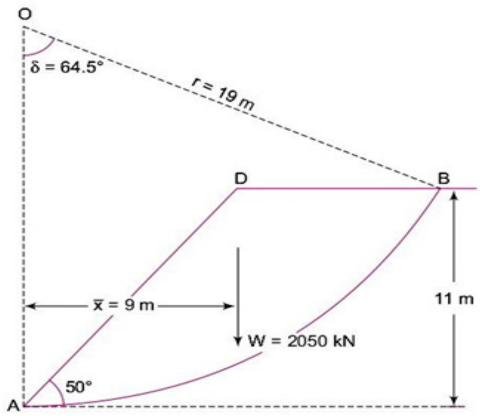
i)Radius of slip circle=19m

ii)weight of wedge ABD=2050 KN

iii)Distance of W from AO=9m

iv)Angle δ subtended by the arc AB at the centre=64.5^0

Determine the factor of safety against sliding along the slip surface.



Solution:

Length of arcAB,

$$\hat{L} = \frac{2\pi r\delta}{360°}$$

$$= \frac{2\pi(19)5^\circ}{360^\circ}$$

$$= 21.39\,m$$

Driving moment $M_D = w\bar{x}.$ =2050x9=18450KNm

Resisting moment $M_R = rC_u\hat{L}$=19x55x21.39=22353KNm

$$F = \frac{M_R}{M_D}$$

$$= \frac{22353}{18450}$$

$$= 1.212$$

$$F = \frac{C_u}{C_m} = \frac{C_u\hat{L}r}{w\bar{x}}$$

$$C_m = \frac{w\bar{x}}{\hat{L}r} = \frac{2050x9}{21.39x19} = 45.4\ KN/m^2$$

$$F = \frac{C}{C_m} = \frac{55}{45.4} = 1.212$$