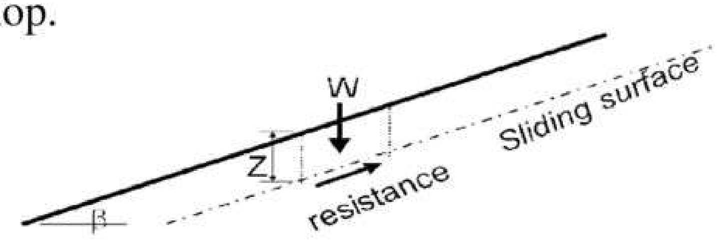
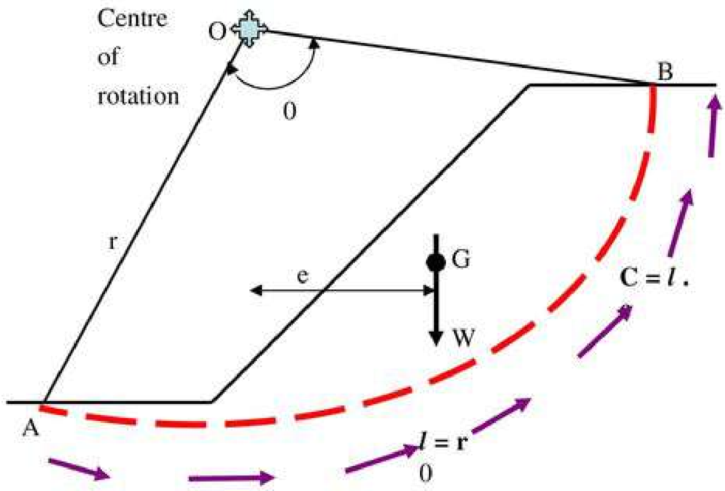
INTRODUCTION

- Slop : A surface of which one end or side is at a higher level than anothera rising or falling surface.
- There was two type of slop
  - Infinite slopes : If a slop represent the boundary surface of a semi-infinite soil mass inclined to the horizontal and the soil properites for all identical depths below the surface are constant, it is called an infinite slop.



  - Finite slop : If the slope is of limited extent, it is called a finite slope.

Total stress analysis for pure cohesive soil



The analysis is based on total stresses, it is also called □ = 0 analysis. It gives the stability of an embankment immediately after construction. It is assumed that the soil has no time to drain and the shear strength parameters used are obtained from undrained conditions with respect to total stresses. These may be obtained from either unconfined compression test or an undrained triaxial test without pore pressure measurements.

Let AB be a trial slip surface in the form of a circular arc of radius ‘r’ with respect to center of rotation ‘O’ as shown in

Let ‘W’ be the weight of the soil within the slip surface

Let ‘G’ be the position of its centre of gravity.

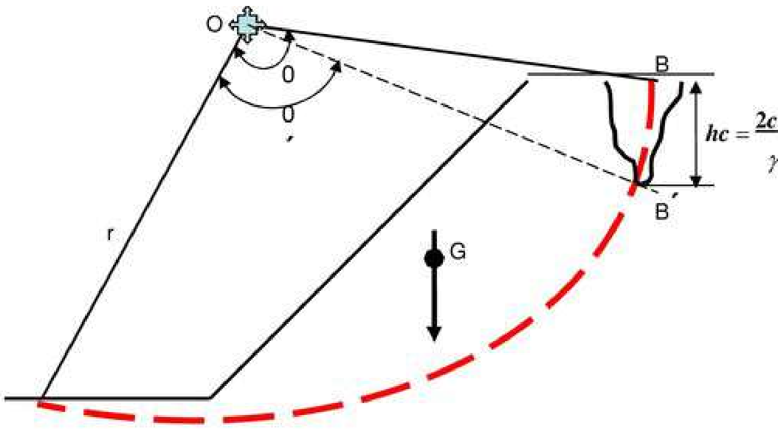
The exact position of G is not required and it is only necessary to ascertain the position of the line of action of W, this may be obtained by dividing the failure plane into a set of vertical slices and taking moments of area of these slices about any convenient vertical axis.

The shearing strength of the soil is c, since □ = 0°. The restoring moment (along the slip surface) =

= cr □ r □ cr ^{2} □

The driving moment =W.e

Effect of Tension cracks on Stability



in case of cohesive soil when the slope is on the verge slippage there develops a tension crack at the top of the slope as shown in Fig 11. the depth of tension crack is

$$hc = {}^{2c}\gamma$$

Where, c = cohesion

γ = unit weight

There is no shear resistance along the crack. The failure arc reduces from Arc AB to Arc AB' and the angle 0 reduces to 0´.

For computation of FS we have to

1.Use 0´ instead of 0 in the restoring moment component.
2.Consider the full weight 'W' of the soil within the sliding surface AB to compensate for filling of water in the crack in the driving moment component

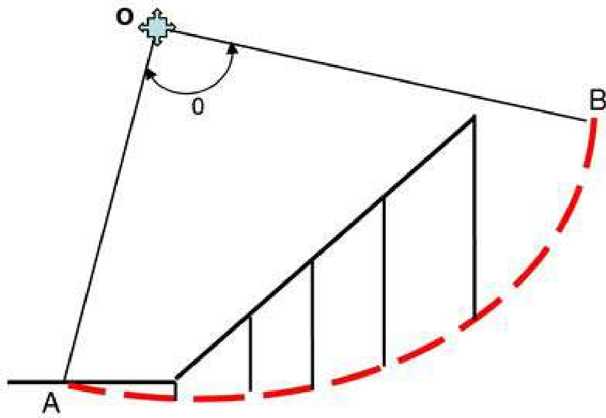
$$FS = \frac{c.r.\theta'}{W.e}$$

"Tension crack reduces F.S due to decrease in restoring moment"

The effect of tension cracks are

1.It modifies the slip surface and reduces the length of the slip surface.
2.It is usually filled with water and produces hydrostatic pressure along the depth.
3.It acts as channel for water to flow into underlying soil layers, inducing seepage forces.
4.It reduces the factor of safety.

The Swedish method of slices for a cohesive –frictional (c-ϕ) soil



For a c-ϕ soils the undrained strength envelope shows both c and ϕ values. The total stress analysis can be adopted.

The procedure is follows

1.Draw the slope to scale
2.A trail slip circle such as AB with radius ‘r’ is drawn from the center of rotation O.
3.Divide the soil mass above the slip surface into convenient number of slices (more than 5 is preferred)

4.Determine the area of each slice A1, A2, -------, An
A = width of the slice X mid height

= b X Z

5.Determine the total weight W including external load if any as
$W = \gamma\, b\, Z = \gamma\, A$

Where, γ = unit weight b = width of slice

Z = height of slice.

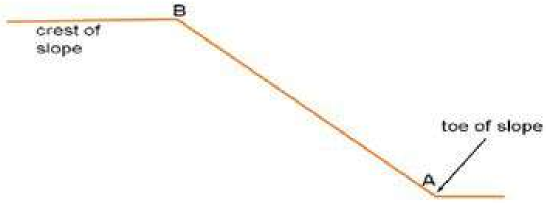
The forces on a typical slice are given in fig.

17. Friction Circle Method

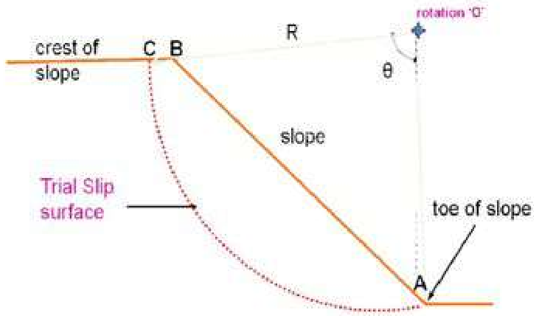
This method uses total stress based limit equilibrium approach. In this method the equilibrium of the resultant weight ‘w’, the reaction ‘p’ due to frictional resistance and the cohesive force ‘c’ are considered. The magnitude direction and line of action of ‘w’, the line of action of the reaction force ‘p’ and the cohesive force ‘c’ being known the magnitude of p and c are determined by considering the triangle of forces. The F.S. w. r. t. cohesion and friction is evaluated.

The procedure is as follows:

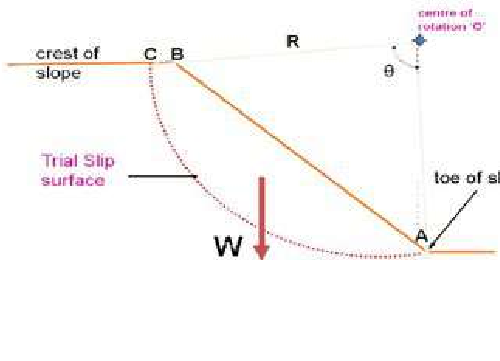
Consider a slope shown in Figure



Draw a trial circular slip surface (Arc AC) from the toe as shown with ‘O’ as centre and ‘R’ as radius

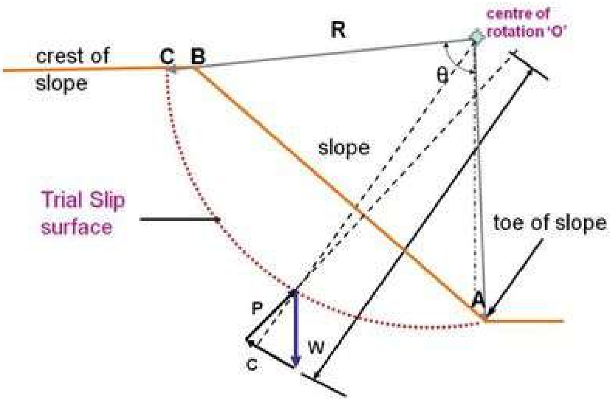


Find the centroid of the sliding mass ABCA and calculate it’s weight ‘W’



For analysis the following 3 forces are considered

- ❖The weight W of the sliding soil mass
- ❖The total reaction P due to frictional resistance
- ❖The total cohesive force C mobilized along the slip surface



•Stability of slopes of earth dam

•The stability of slopes of earth dam is tested under the following condition:

- •Stability of downstream slope during stedy seepage.
- •Stability of upstream slope during sudden daewdown.
- •Stability of upstream and downstream slopes during and immediately after construction.

When seepage occurs at a steady rate through an earth dam or embankment it represents critical condition for the stability of slope.

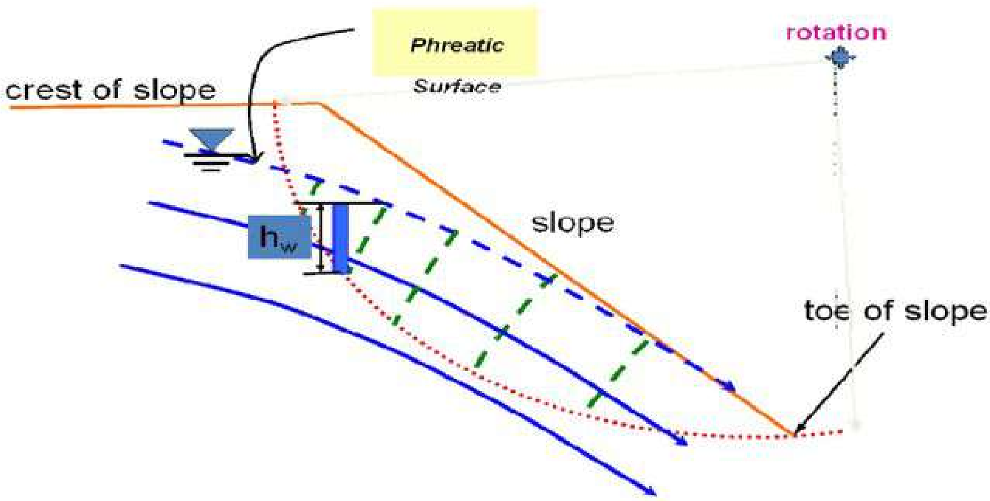
When seepage occurs pore water pressure (u) develops and this will reduce the effective stress which in turn decreases the shear strength along the failure surface.

The following procedure is adopted to obtain stability

1. Draw the C/S of the slope
2. Draw the potential failure surface
3. Divide the soil mass into slices
4. Calculate the weight W and the corresponding normal and tangential components for all the slices in the usual way

In addition

For the given slope construct flow net (network of equipotential and flow lines) as shown



Flow net in a finite slope under steady seepage

The average pore water pressure (u) at the bottom of the slice is given by the piezometric head (h_w) as

h_w = piezometric head above the base of the slice

The total force due to pore water pressure at the bottom of the slice

$$U = u\ \gamma_w$$

The F.S is computed as

$$Factor\ of\ Safety, FS = \frac{(c'\ r\ \theta + \tan\phi')(N - U))}{)\ T}$$

c´ and ϕ´ - Shear parameters based on effective stress analysis obtained from drained shear tests.

If the flownet is not constructed then F.S may be computed as

$$Factor\ of\ Safety, FS = \frac{(c'\ r\ \theta + \tan\phi')\ (N'))}{)\ T}$$

$$N' = W'\ Cos\ \delta = bZ\ \gamma'\ Cos\ \delta$$

N´= Weight of slice computed from effective unit weight

T = W Sinδ = b Z γ_{sat} Sinδ - Weight of slice computed from saturated unit weight.

Taylor's stability number

- In a slope the component of the self weight (γ) causes instability and the cohesion contributes to stability. The maximum height (H_c) of a slope is directly proportional to unit cohesion (C_u) and inversely proportional to unit weight (γ). In addition, H_c is also related to friction angle (ϕ_u) and slope angle β.

This can be expressed as $H_c = \frac{C_u}{\gamma} f(\phi_u, \beta)$

When the term $f(\phi_u, \beta)$ is dimensionless then equation above is dimensionally balanced

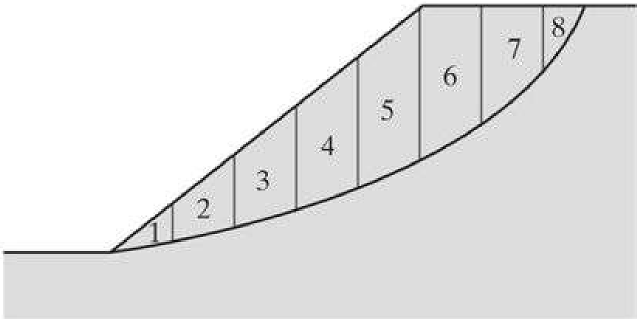
Taylor (1937) expressed $f(\phi_u, \beta)$ as a reciprocal of a dimensionless number called "Stability Number" (Sn) popularly called as Taylor's stability Number.

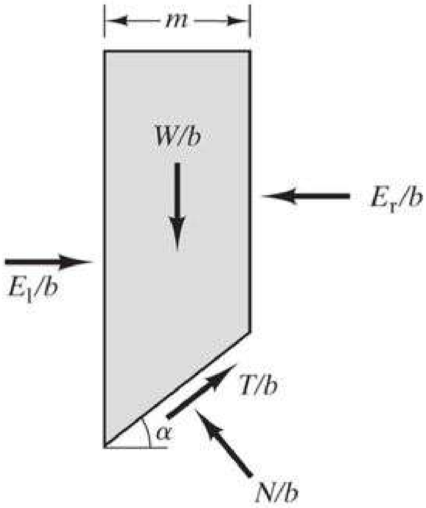
$$f(\phi_u, \beta) = \frac{1}{S_n}$$

$$\therefore H_c = \frac{C_u}{\gamma S_n}$$

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

Modified Bishop's Method





- Neglecting side forces (OMS) produces FS too low (conservative)
- Assume side shear forces are zero but account for side normal forces

Effective Stress Analysis (ESA)

$$FS = \frac{\sum \left\{ \frac{mc' + [(W/b) - um] \tan \phi'}{\psi} \right\}}{\sum [(W/b) \sin \alpha]} \qquad \psi = \cos \alpha + \frac{\sin \alpha \tan \phi'}{FS}$$

Total Stress Analysis (TSA)

$$FS = \frac{\sum \left(\frac{m s_u}{\cos \alpha} \right)}{\sum [(W/b) \sin \alpha]}$$

Method of improving stability of slopes

- flatting the slope in reduces the tendency of soil mass to side.
- Proper drainage helps in reducing the seepage forces and hence increasing the stability.
- Densification by use of explosive,vibroflotation etc.hepls in increasing the shear strength of cohesion less soils and thus increasing the stability.
- providing a berm below the toe of the slope increase the resistance to sliding of the soil. it is specially useful when there is a possibility of a base failure.
- Grouting and injection of cement or other compounds into specific zones help in increasing the stability of slopes.
- Soil stabilistion helps in increasing the stability of slopes.
- Fixing geogrids and geomembers on the slopes.
- Providing lateral support by installing sheet piles and retaining walls.
- Consolidation by surcharging,electro-osmosis helps in increasing the stability of slopes of cohesive soils.