5.5 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:

1) Consider a slope shown in Figure 5.14

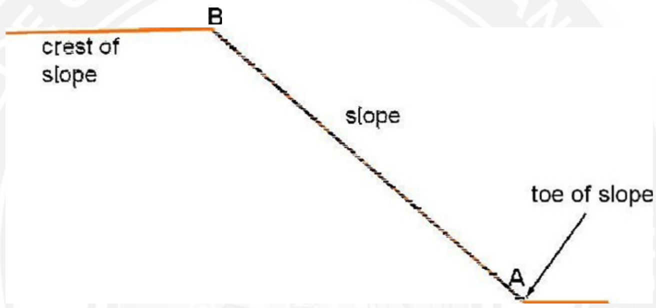

Fig 5.14 slope diagram

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

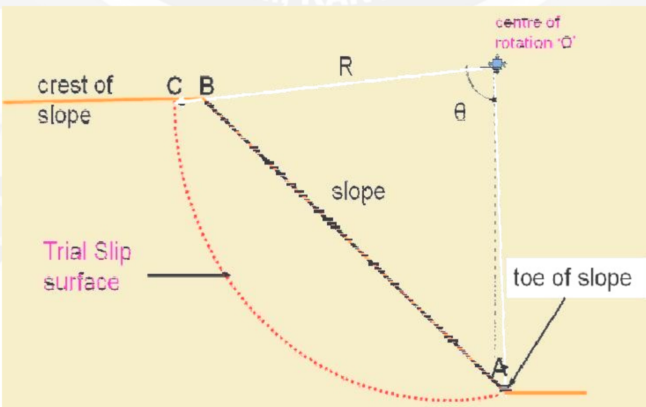

Fig 5.15 Trial circular slip surface (Arc AC)

3)Find the centroid of the sliding mass ABCA and calculate it's weight `W'

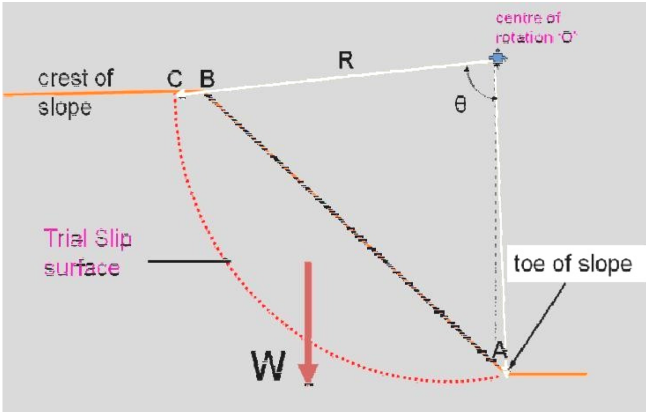

Fig 5.16 centroid of the sliding

4)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

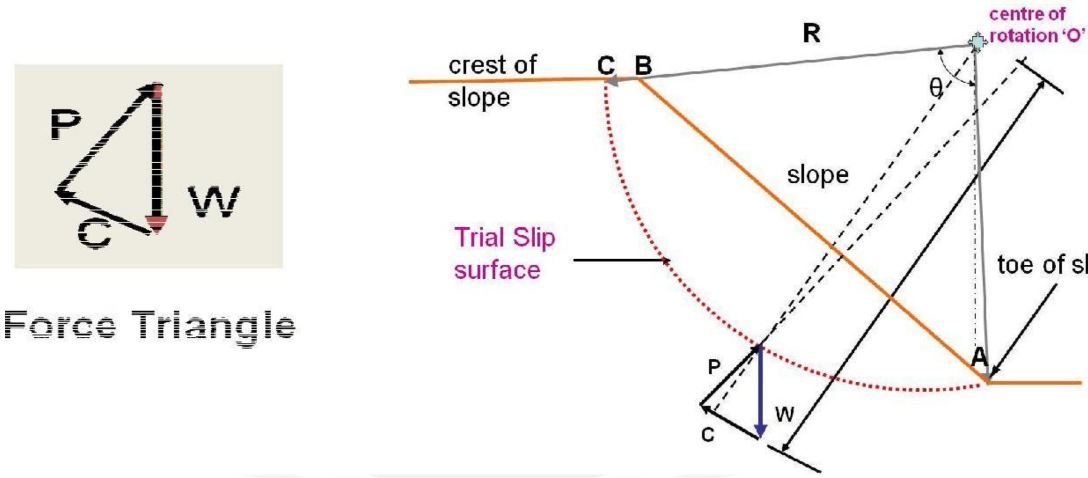

Fig 5.17 analysis of 3 forces

Resultant cohesive force C and its point of application

5)Let the slip circle be considered to be made up of a number of elementary arcs each of length L

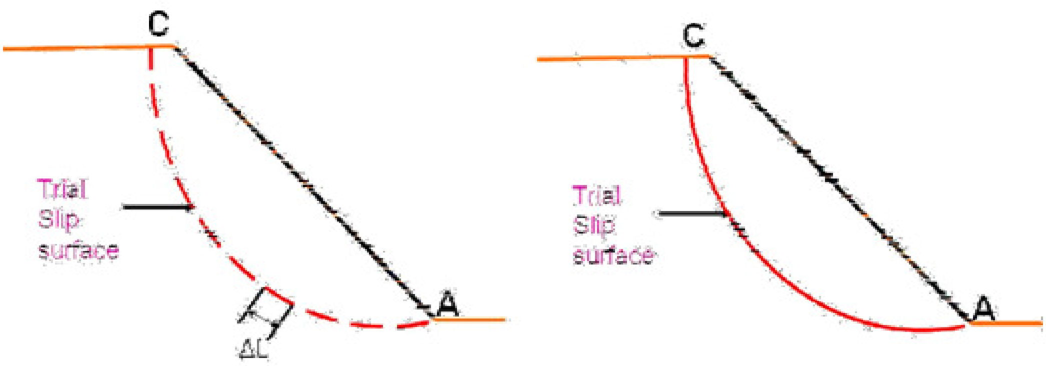

Fig 5.18 Trial slip circle

6)Let the cohesive force acting along this element opposing the sliding of soil be CmL .Where Cm is the mobilized cohesion.

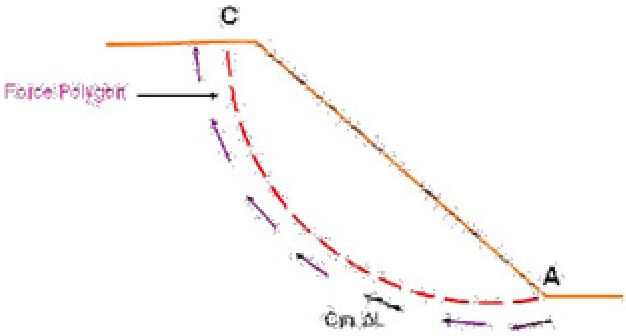

Fig 5.19 mobilized cohesion

The total cohesive force along the arc AC forms a force polygon

7)The closing side (AC) of the polygon represents the magnitude and direction of resultant cohesive force.

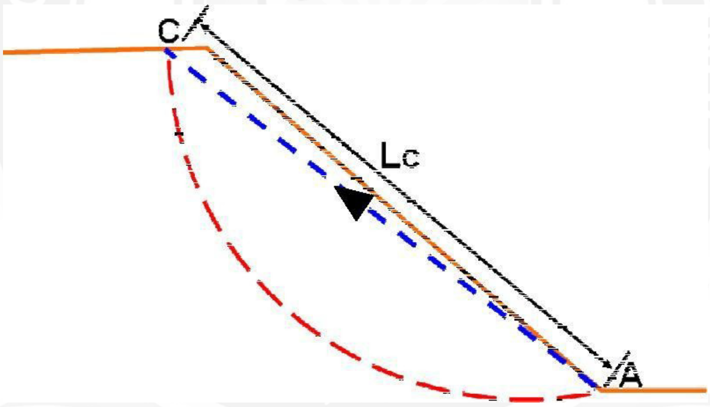

Fig 5.20 length of chord

The length of the chord AC be Lc and the length of arc AC be L. The magnitude of resultant force C = Cm X Lc

8)The position of resultant can be obtained by Varignon's theorem

$$C_a = C_m \Delta L R C_m$$

$$L_c a = C_m L R$$

$$La = RL_c$$

$$L > L_c \quad ; \quad a > R$$

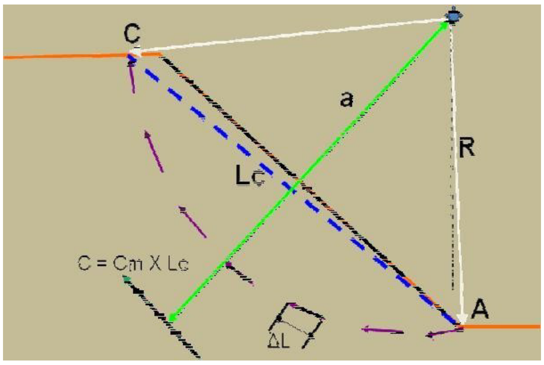

Fig 5.21 position of resultant in slip circle

9)The cohesive forces Cm.L along the slip circle can be replaced by their resultant C = Cm X Lc acting parallel to chord AC at a distance a>R from the centre of rotation as shown in fig 5.22

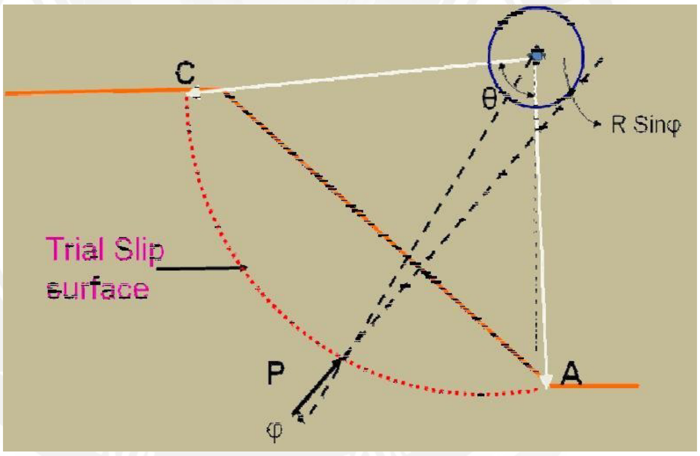

Fig 5.22 cohesive forces along the slip circle

Reaction 'P' due to frictional resistance on mobilization of frictional resistance.

Let P be the soil reaction opposing the sliding of soil mass as shown. P is inclined at an angle to the normal at the point of action as shown

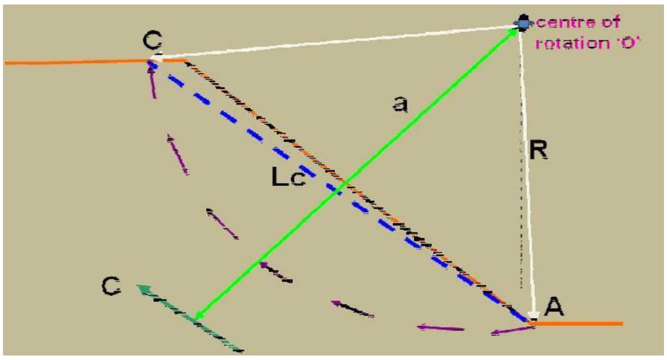

Fig 5.23 Mobilization of frictional resistance

The line of action of P will pass as tangent to a circle of radius R Sinφ drawn with `O' as centre called "Friction Circle" or - Circle

The three forces considered for analysis are:

The weight `W' drawn as vertical passing through the centroid of sliding mass (ABCA)

The resultant cohesive force `C' drawn parallel to the chord AC at a distance `a' from the centre `O'

The resultant reaction `P' passing through the point of intersection of `W' and `C' and tangential to friction circle

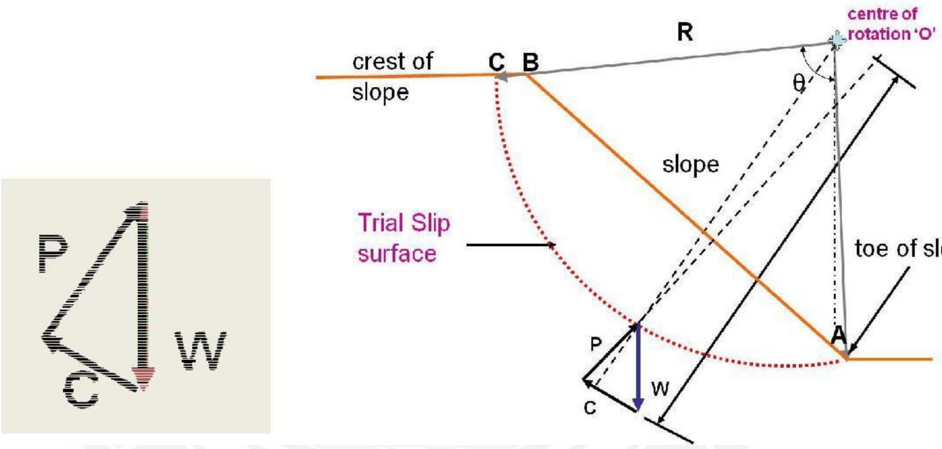

Fig 5.24 Force triangle

By knowing the magnitude and direction of `W' and the direction and line of action of other forces the force triangle can be completed. Measuring the magnitude of C the F.S. is computed as shown below

$$\text{The mobilized cohesion } C_m = \frac{C}{L_c}$$

F.S w.r.t cohesion is given by

$$F.S = \frac{C_u}{C_m}$$

The minimum F.S is obtained by locating the critical slip circle

Computation of F.S with respect to Strength

1)Assume a trial F.S with respect to friction as F

2)Draw a friction circle with a reduced radius R Sin φ

$$tan\varphi_m = \frac{tan\varphi_u}{F\varphi}$$

3)Carry out the friction circle analysis and find the FS with respect to cohesion

$$F_c = \frac{C_u}{C_m}$$

If Fc = F…..it represents F.S with respect to strength

Otherwise choose different F and repeat the procedure till Fc = F

FELLENIOUS METHOD FOR LOCATING CENTRE OF CRITICAL SLIP CIRCLE:

- In order to reduce the number of trials to locate the centre of critical slip circle, Fellenious has given this method illustrated in fig. in which the centre of critical slip circle is shown to lie on the line QP.
- The point Q is located at a distance of H below the toe and 4.5H away from it.
- The other point P is located with the help of directional angles α and β obtained from accompanying table.
- Trial centres are chosen on line QP and Factor of Safety corresponding to each centre is computed and plotted normal to line QP as shown in fig.
- A smooth curve is then drawn and the point corresponding to minimum ordinate represents the centre of Critical slip circle.
- The method is proposed for a homogeneous c-φ Soil.

For a purely cohesive soil (φ = 0), the point P itself represents the centre of Critical Slip Circle.

Table5.1 slope angle

Slope	Slope angle (i) (degree)	Directional angles (degree)	
		α	β
0.58 : 11 : 1	60	29	40
1.5 : 1 2 : 1	40	28	37
3 : 1	33.8	26	35
5 : 1	26.6	25	35
	18.4	25	35
	11.3	25	35

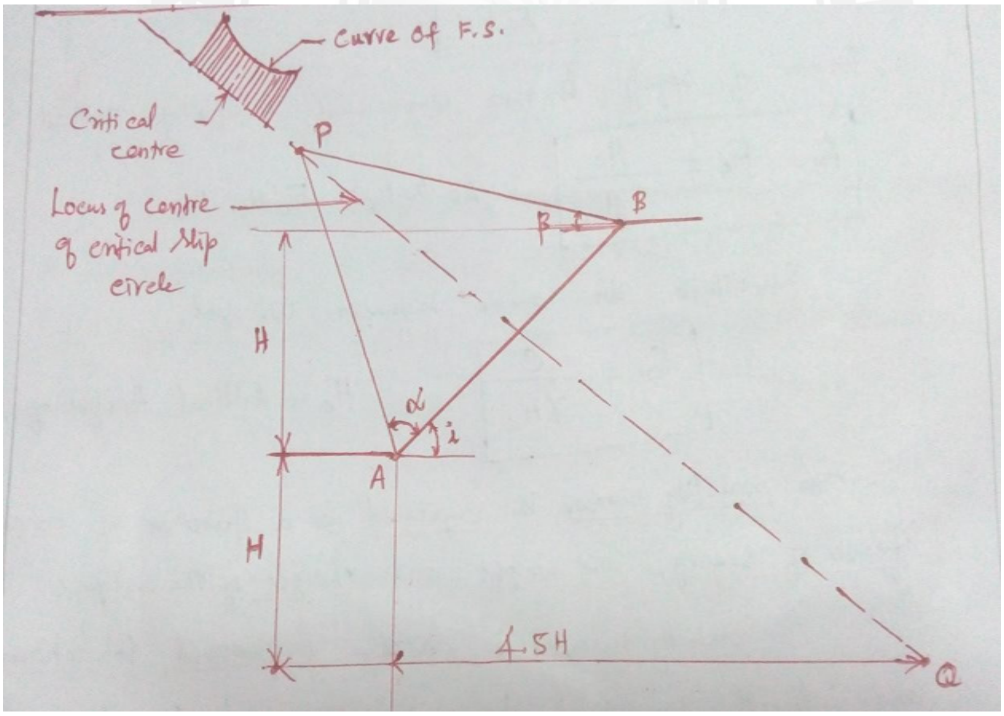

Fig 5.24 CRITICAL SLIP CIRCLE