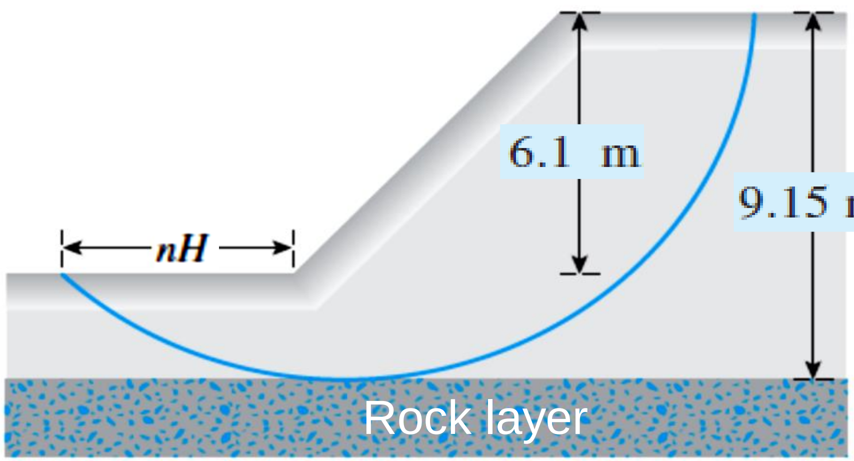
EXAMPLE

A cut slope was excavated in a saturated clay. The slope made an angle of 40° with the horizontal. Slope failure occurred when the cut reached a depth of 6.1 m. Previous soil explorations showed that a rock layer was located at a depth of 9.15 m below the ground surface. Assuming an undrained condition and $\gamma_{sat} = 17.29 \text{ kN/m}^3$, find the following.

a. Determine the undrained cohesion of the clay (Figure 15.13).
b. What was the nature of the critical circle?
c. With reference to the toe of the slope, at what distance did the surface of sliding intersect the bottom of the excavation?



SOLUTION

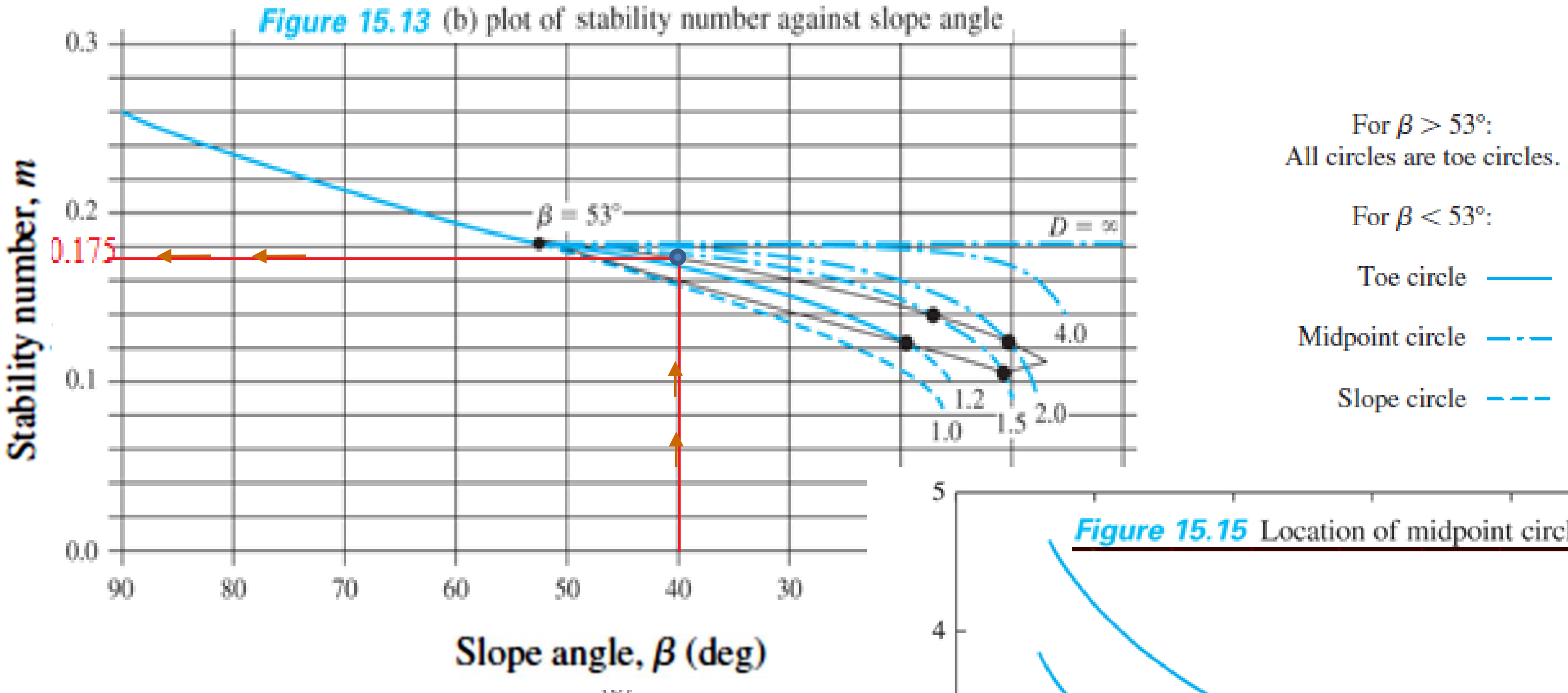


Figure 15.13 (b) plot of stability number against slope angle
Stability number, m
0.3
0.2
0.175
0.1
0.0
β = 53°
D = ∞
4.0
1.2
1.0
1.5
2.0
90
80
70
60
50
40
30
Slope angle, β (deg)
For β > 53°:
All circles are toe circles.
For β < 53°:
Toe circle
Midpoint circle
Slope circle

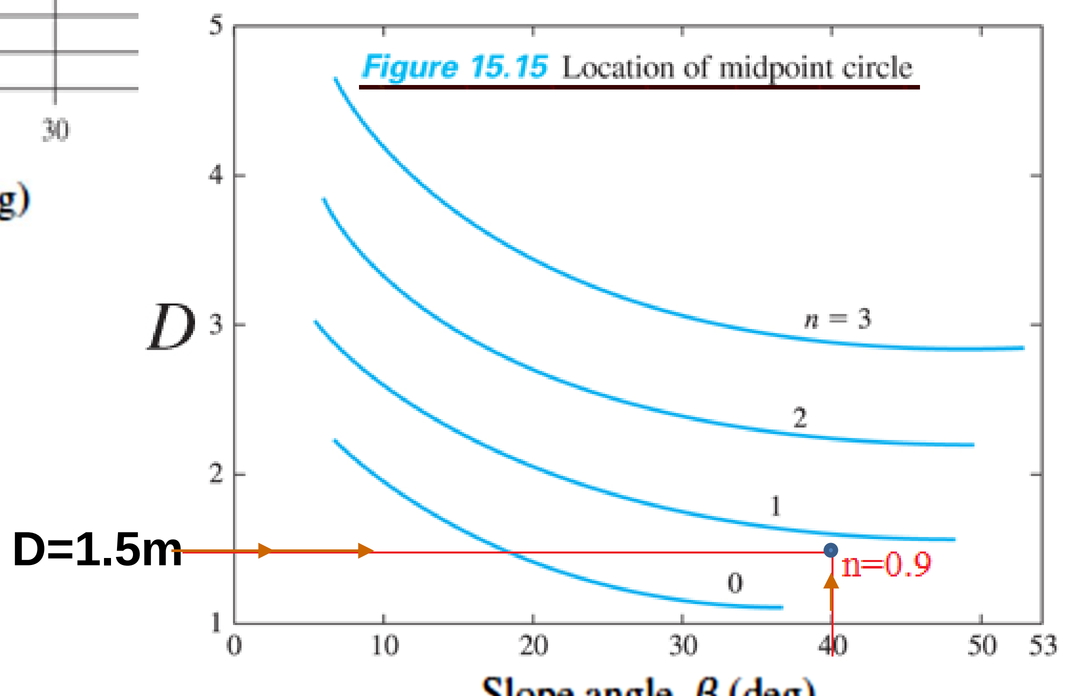


Figure 15.15 Location of midpoint circle
D
D=1.5m
n = 3
2
1
0
n=0.9
5
4
3
2
1
0
10
20
30
40
50
53

SOLUTION

$$F_s = \frac{C_u}{\gamma H m}$$

Solution

Part a

Referring to Figure 15.13,

$$D = \frac{9.15}{6.1} = 1.5$$

$$\gamma_{sat} = 17.29 \text{ kN/m}^3$$

$$H_{cr} = \frac{c_u}{\gamma m}$$

From Figure 15.13, for $\beta = 40°$ and $D = 1.5$, $m = 0.175$. So,

$$c_u = (H_{cr})(\gamma)(m) = (6.1)(17.29)(0.175) = \mathbf{18.46\ kN/m^2}$$

Part b

Midpoint circle.

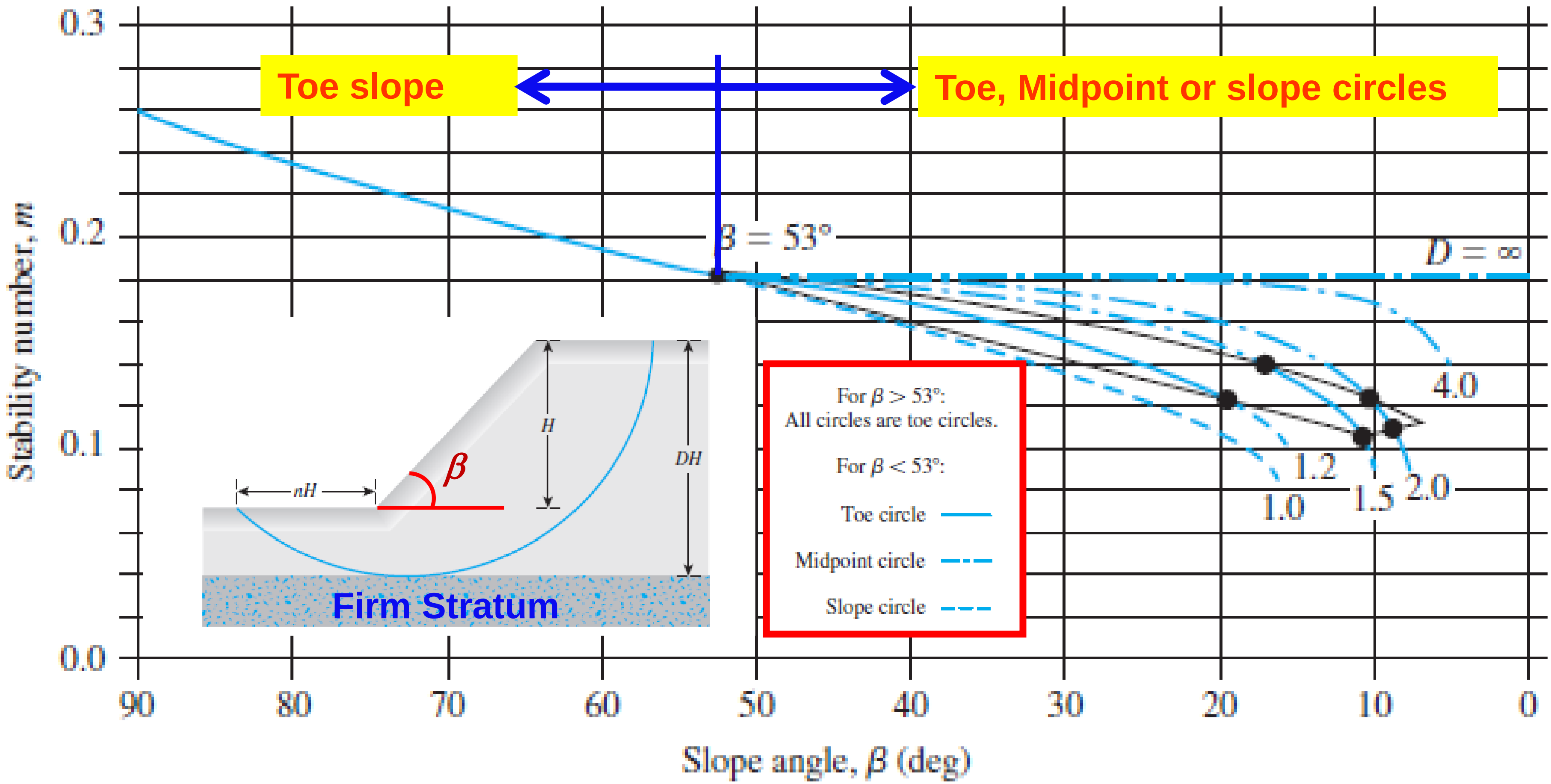
Part c

Again, from Figure 15.15, for $D = 1.5$, $\beta = 40°$; $n = 0.9$. So,

$$\text{Distance} = (n)(H_{cr}) = (0.9)(6.1) = \mathbf{5.49\ m}$$

Slopes in Homogeneous clay Soil with $c \neq 0$, $\phi = 0$

- The results of analytical solution to obtain critical circles was represented graphically as the variation of stability number, m , with slope angle β.



m is obtained from this chart depending on angle β

REMARKS

- Since we know the magnitude and direction of W and the direction of C_d and F we can draw the force polygon to get the magnitude of C_d.
- We can then calculate c'_d from $c'_d = \frac{C_d}{AC}$
- Determination of the magnitude of c'_d described previously is based on a trial surface of sliding.
- Several trails must be made to obtain the most critical sliding surface, minimum factor of safety or along which the developed cohesion is a maximum
- The maximum cohesion developed along the critical surface as

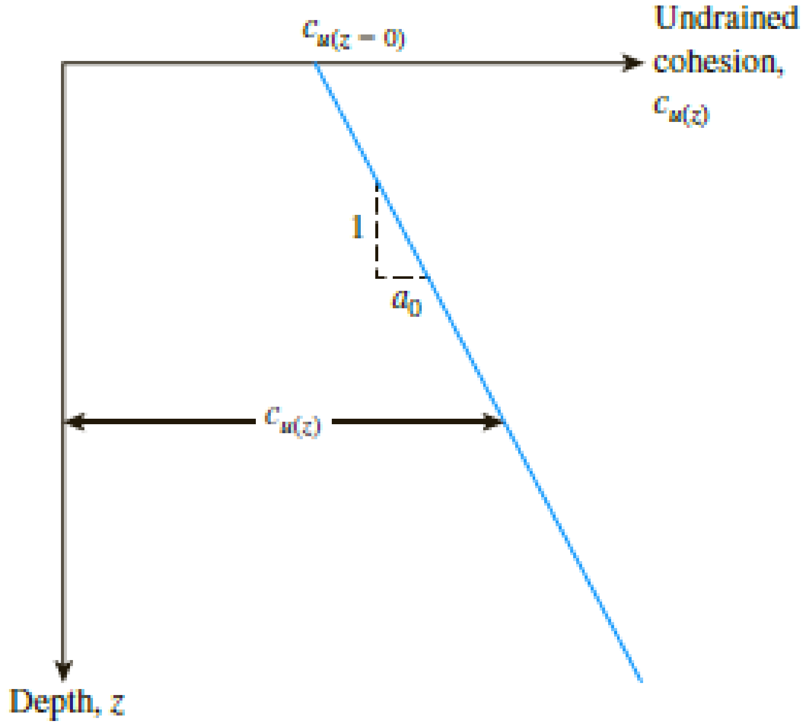
$$c'_d = \gamma \mathrm{H}\left[f\left(\alpha, \beta, \theta, \phi'\right)\right] \Rightarrow \frac{c'_d}{\gamma\,\mathbf{H}} = f\left(\alpha, \beta, \theta, \phi'\right) = m = stability\,number$$

- The results of analytical solution to obtain minimum F_s was represented graphically as the variation of stability number, m, with slope angle β for various values of ϕ' (Fig. 15.21).
- Solution to obtain the minimum F_s using this graph is performed by trial-and-error until $F_s = F_{c'} = F_{\phi'}$

Slopes in clay Soil with $\phi = 0$; C_u Increasing with Depth

$$c_{u(z)} = c_{u(z=0)} + a_0 z$$

where $c_{u(z)}$ = undrained shear strength at depth z
$c_{u(z=0)}$ = undrained shear strength at depth $z = 0$
a_0 = slope of the line of the plot of $c_{u(z)}$ vs. z



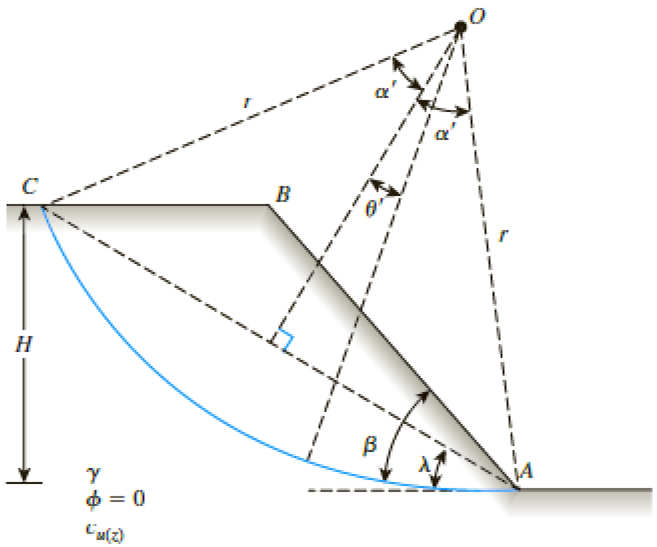
Slopes in Clay Soil with $\phi = 0$; and c_u Increasing with Depth

Slopes in clay Soil with $\phi = 0$; C_u Increasing with Depth

$$m = \left[\frac{c_{u(z=0)}}{\gamma H}\right]\frac{1}{F_s}$$

where m = stability number, which is also a function of

$$c_R = \frac{a_0 H}{c_{u(z=0)}}$$



Analysis of slope in clay soil ($\phi = 0$ concept) with increasing undrained shear strength

Slopes in clay Soil with $\phi = 0$; C_u Increasing with Depth

$$m = \left[\frac{c_{u(z=0)}}{\gamma H}\right]\frac{1}{F_s}$$

$$c_R = \frac{a_0 H}{c_{u(z=0)}}$$

Table 15.2 Variation of m, c_R, and β

	m					
c_R	1H:1V $\beta = 45°$	1.5H:1V $\beta = 33.69°$	2H:1V $\beta = 26.57°$	3H:1V $\beta = 18.43°$	4H:1V $\beta = 14.04°$	5H:1V $\beta = 11.31°$
0.1	0.158	0.146	0.139	0.130	0.125	0.121
0.2	0.148	0.135	0.127	0.117	0.111	0.105
0.3	0.139	0.126	0.118	0.107	0.0995	0.0937
0.4	0. 131	0.118	0.110	0.0983	0.0907	0.0848
0.5	0.124	0.111	0.103	0.0912	0.0834	0.0775
1.0	0.0984	0.086	0.0778	0.0672	0.0600	0.0546
2.0	0.0697	0.0596	0.0529	0.0443	0.0388	0.0347
3.0	0.0541	0.0457	0.0402	0.0331	0.0288	0.0255
4.0	0.0442	0.0371	0.0325	0.0266	0.0229	0.0202
5.0	0.0374	0.0312	0.0272	0.0222	0.0190	0.0167
10.0	0.0211	0.0 175	0.0151	0.0121	0.0103	0.0090

Based on the analysis of Koppula (1984)

EXAMPLE 15.7

Example 15.7

A cut slope was excavated in saturated clay. The slope was made at an angle of 45° with the horizontal. Given:

- $c_{u(z)} = c_{u(z=0)} + a_o z = 9.58 \text{ kN/m}^2 + (8.65 \text{ kN/m}^3)z$
- $\gamma_{sat} = 19.18 \text{ kN/m}^3$
- Depth of cut $= H = 3.05$ m

Determine the factor of safety, F_s.

Solution

From Eq. (15.56)

$$c_R = \frac{a_0 H}{c_{u(z=0)}} = \frac{(8.65)(3.05)}{9.58} = 2.75$$

From Eq. (15.55)

$$m = \left[\frac{c_{u(z=0)}}{\gamma H}\right]\frac{1}{F_s}$$

Referring to Table 15.2, for $c_R = 2.75$ and $\beta = 45°$, we obtain $m = 0.058$. So,

$$0.058 = \left[\frac{9.58}{(19.18)(3.05)}\right]\frac{1}{F_s}$$

$$F_s = \mathbf{2.82}$$