Fayoum University
Faculty of Engineering
Department of Civil Engineering

CE 402: Part D
Slope Stability Analysis
Lecture No. (18)

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Simplified Bishop Method

☐ Requires iteration
  - Assume initial F, then solve for F
  - When trial F and determined F are equal, it’s a solution

☐ Spreadsheet for simple slopes

☐ XSLOPE and GALENA otherwise
  - 1000 trial surfaces in 1 minute
Stability analysis of earth slope

<table>
<thead>
<tr>
<th>Layer</th>
<th>Cohesion</th>
<th>Phi</th>
<th>Gamma</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.0</td>
<td>40.0</td>
<td>18.0</td>
</tr>
<tr>
<td>2</td>
<td>0.0</td>
<td>35.0</td>
<td>19.2</td>
</tr>
<tr>
<td>3</td>
<td>20.0</td>
<td>0</td>
<td>19.0</td>
</tr>
<tr>
<td>4</td>
<td>40.0</td>
<td>0</td>
<td>19.6</td>
</tr>
</tbody>
</table>
Stability analysis of earth slope
Other Methods

- More exact solutions exist, but little improvement on accuracy

- Choosing the soil shear strength factors and soil layers are far more important
Numerical Approach to Slopes

Finite Element Analysis (FEA)

Finite Difference

Benefits:

- Progressive failure
  - shear strength *mobilization* not uniform along sliding surface

- Distortions as well as safe slope angle

But more effort
Tension Cracks

In cohesive soil, tension cracks are usually present at the crest. The depth of such cracks may be computed from the equation

The effective length of any trial arc of failure is the difference between the total length of arc minus the depth of crack
Tension Cracks

This same crack can fill up with water and so a hydrostatic force (acting horizontally) can be introduced which adds to the potential instability;

\[ P_W = \frac{\gamma_w z_c^2}{2} \]
Taylor’s Charts

- Simple slopes
- Homogeneous
- Dry slope or fully submerged slope

**WARNING:** slopes are rarely homogeneous
Taylor’s Charts – $F = F.S.$

Unit weight of soil = $\gamma$
Shear strength = $c_u$

$$N_s = \frac{c_u}{F} \left( \frac{1}{\gamma H} \right)$$
Example (1)

- **H** = 10 m, **D_H** = 13 m
- **Fs** = 1.25
- **γ** = 18 kN/m³, **c_u** = 30 kPa

\[ N_s = \frac{30}{1.25(18)10} = \frac{30}{225} = 0.133 \]

**D** = 13/10 = 1.3

**β** = 20°
An embankment is to be made from a soil having $c' = 420$ lb/ft$^2$, $0' = 18^\circ$ and $\gamma = 121$ lb/ft$^3$. The desired factor of safety with respect to cohesion as well as that with respect to friction is 1.5.

Determine

1. The safe height if the desired slope is 2 horizontal to 1 vertical.
2. The safe slope angle if the desired height is 50 ft.
Example (3)

- $\tan \phi = \tan 18^\circ = 0.325$
- $\tan \phi_m = (\tan \phi) / 1.50$
- $\phi_m = 12.23^\circ$
- For $\phi_m = 12.23^\circ$ and
- $\beta = 26.6^\circ$ (i.e., 2 horizontal and 1 vertical)
- the chart gives $N_s = 0.055$
- $c' = 420$

$$N_s = \frac{c}{F}\left(\frac{1}{\gamma H}\right) \quad H = 42 \text{ ft}$$
Example (3)

\[ N_s = \frac{c}{F} \left( \frac{1}{\gamma H} \right) = \frac{420}{1.50} \left( \frac{1}{121 \times 50} \right) = 0.046 \]

For \( \phi_m = 12.23^\circ \) and \( N_s = 0.055 \)

the chart gives:

\( \beta = 23.50^\circ \)
Summary: Key Points

a. Angle of repose for dry granular soils
b. Influence of seepage on granular soils
c. Slope stability for homogeneous slopes in saturated clay (NC)
   • simple analyses
   • Taylor’s charts
d. Frictional soils more difficult
   • Method of slices
e. Slope stability programs use limit equilibrium
f. Slope stability programs search for the failure surface with lowest FoS
   • circular or non-circular slips?

g. Bishop’s simplified method for circular slips
   • further refinement unwarranted?

h. Importance of shear strength parameters
   • drained and/or undrained?
   • peak, ultimate or critical state?