Types of Slope Failures

- Falls
- Topless
- Slides
- Spreads
- Flows

Falls
- Slope failures consisting of soil or rock fragments that droprapidly down a slope
- Most often occur in steep rock slopes
- Usually triggered by water pressure or seismic activity

Topless
- Similar to a fall, except that it begins with a mass of rock of stiff clay rotating away from a vertical joint
Slides
- Slope failures that involve one or more blocks of earth that move downslope by shearing along well defined surfaces or thin shear zones

Spreads
- Similar to translational slides except that the block separate and move apart as they also move outward
- Can be very destructive

Flows
- Downslope movement of earth where earth resembles a viscous fluid
- Mudflow can start with a snow avalanche, or be in conjunction with flooding

Types of Slides
- Rotational slides
  - Most often occur in homogeneous materials such as fills or soft clays
- Translational slides
  - Move along planar shear surfaces
- Compound slides
- Complex and composite slides
The driving force (gravity) **overcomes** the resistance derived from the **shear strength** of the soil along the rupture surface.

**Slope stability analysis**

- Calculation to check the safety of natural slopes, slopes of excavations and of compacted embankments.

- The check involves determining and comparing the **shear stress** developed along the most likely rupture surface to the **shear strength** of soil.
**Factor of Safety**

\[ F_s = \frac{\tau_f}{\tau_d} \]

- \( F_s \) = factor of safety with respect to strength
- \( \tau_f \) = average shear strength of the soil
- \( \tau_d \) = average shear stress developed along the potential failure surface

\[ \tau_f = c + \sigma \tan \phi \]
- \( c \) = cohesion
- \( \phi \) = angle of friction
- \( \sigma \) = average normal stress on the potential failure surface

\[ \tau_d = c_d + \sigma \tan \phi_d \]

subscript ‘d’ refer to potential failure surface

\[ F_s = \frac{c + \sigma \tan \phi}{c_d + \sigma \tan \phi_d} \]

when \( F_s = 1 \), the slope is in a state of impending of failure.

In general \( F_s > 1.5 \) is acceptable

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**Stability of Slope**

- Infinite slope without seepage
- Infinite slope with seepage
- Finite slope with Plane Failure Surface (Cullman's Method)
- Finite slope with Circular Failure Surface (Method of Slices)
Infinite slope

\[ Fs = \frac{c}{\gamma H \cos^2 \beta \tan \beta} + \frac{\tan \phi}{\tan \beta} \]

- For granular soils, \( c = 0 \), \( Fs \) is independent of height \( H \), and the slope is stable as long as \( \beta < \phi \)

Finite slope with Plane Failure Surface

\[ \theta_{cr} = \frac{\beta + \phi_d}{2} \]

\[ H_{cr} = \frac{4c}{\gamma} \left[ \frac{\sin \beta \cos \phi}{1 - \cos(\beta - \phi)} \right] \]
Finite slope with Circular Failure Surface

### Slope Failure

- **Toe Circle**
- **Firm Base**

### Shallow Slope Failure

### Base Failure

- **Midpoint circle**
- **Firm Base**

### Slopes in Homogeneous Clay ($\phi=0$)

For equilibrium, resisting and driving moment about O:

\[
M_R = M_d
\]

\[
c_d r^2 \theta = W l_1 - W_2 l_2
\]

\[
c_d = \frac{W l_1 - W_2 l_2}{r^2 \theta}
\]

\[
F_S = \frac{\tau_f}{c_d} = \frac{c_u}{c_d}
\]

Critical when $F_S$ is minimum, → trials to find critical plane solved analytically by Fellenius (1927) and Taylor (1937)

\[
H = \frac{c_u}{\gamma m}
\]

Presented graphically by Terzaghi & Peck, 1967 in Fig 11.9 Braja

$m$ is stability number
Slopes in Homogeneous Clay ($\phi > 0$)

$$\tau_f = c + \sigma \tan \phi$$

$$c_d = \gamma H \left[ f (\alpha, \beta, \theta, \phi) \right]$$

$$\frac{c}{\gamma H_{cr}} = f (\alpha, \beta, \theta, \phi) = m$$

where $m$ is stability number
Method of Slices

For equilibrium
\[ N_r = W_n \cos \alpha_n \]

\[
Fs = \sum_{n=1}^{n=p} \left( c \Delta L_n + W_n \cos \alpha_n \tan \phi \right) \frac{1}{\sum_{n=1}^{n=p} W_n \sin \alpha_n}
\]

\[ \Delta L_n \approx \frac{b_n}{\cos \alpha_n} \] where \( b \) is the width of the \( n^{th} \) slice

Bishop Method

Bishop (1955) refine solution to the previous method of slices.

In his method, the effect of forces on the sides of each slice are accounted for some degree.

\[
Fs = \left( \sum_{n=1}^{n=p} \left( c b_n + W_n \tan \phi \right) \right) \frac{1}{m_{\alpha(n)}} \frac{1}{\sum_{n=1}^{n=p} W_n \sin \alpha_n}
\]

where
\[ m_{\alpha(n)} = \cos \alpha_n + \frac{\tan \phi \sin \alpha_n}{Fs} \]

The ordinary method of slices is presented as learning tools. It is rarely used because it is too conservative.
Computer Programs

- STABL
- GEO-SLOPE
- etc

Bibliography

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