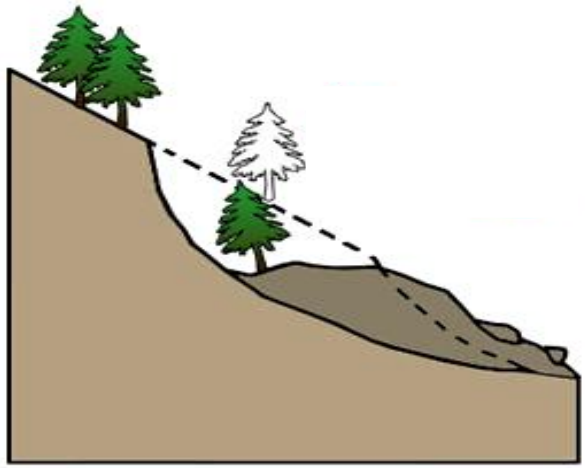
SLOPE STABILITY

Chapter 15

Omitted parts:

Sections 15.13, 15.14,15.15



TOPICS

- Introduction
- Types of slope movements
- Concepts of Slope Stability Analysis
- Factor of Safety
- Stability of Infinite Slopes
- Stability of Finite Slopes with Plane Failure Surface
  - Culmann's Method
- Stability of Finite Slopes with Circular Failure Surface
  - Mass Method
  - Method of Slices

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SLOPE STABILITY

What is a Slope?

An exposed ground surface that stands at an angle with the horizontal.

Why do we need slope stability?

In geotechnical engineering, the topic stability of slopes deals with:

1. **The engineering design of slopes of man-made slopes in advance**

   (a) Earth dams and embankments,
   (b) Excavated slopes,
   (c) Deep-seated failure of foundations and retaining walls.

2. **The study of the stability of existing or natural slopes of earthworks and natural slopes.**

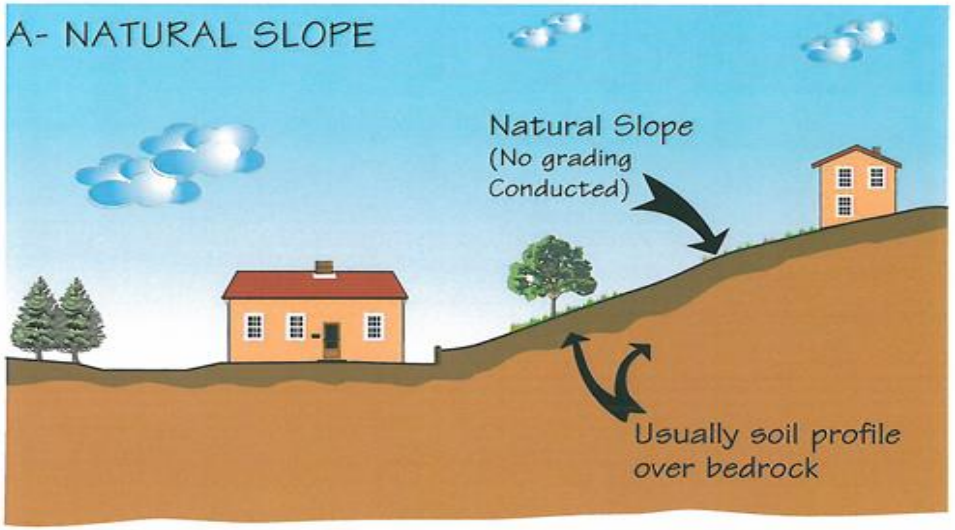
- **In any case the ground not being level results in gravity components of the weight tending to move the soil from the high point to a lower level. When the component of gravity is large enough, slope failure can occur, i.e. the soil mass slide downward.**
- **The stability of any soil slope depends on the shear strength of the soil typically expressed by friction angle (ϕ) and cohesion (c).**

TYPES OF SLOPE

Slopes can be categorized into two groups:

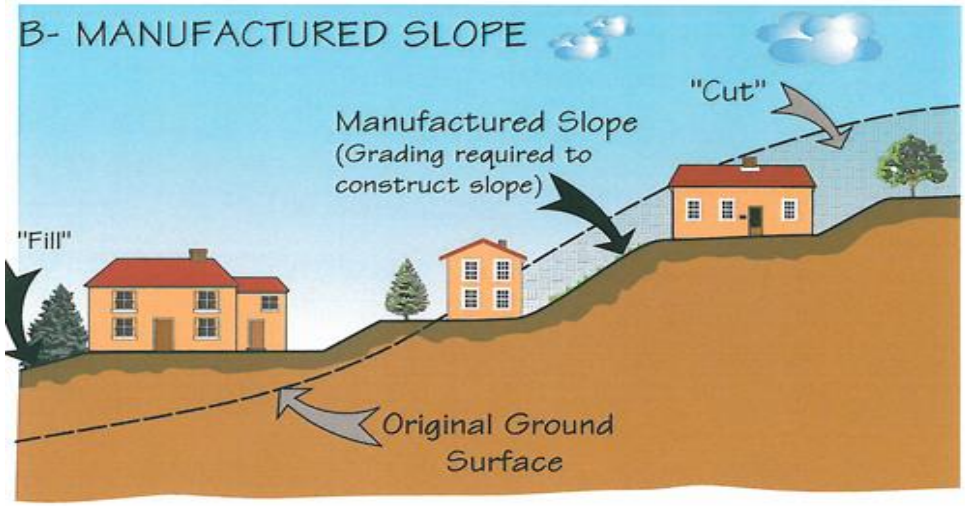
A. Natural slope

- Hill sides
- Mountains
- River banks



B. Man-made slope

- Fill (Embankment)
- Earth dams
- Canal banks
- Excavation sides
- Trenches
- Highway Embankments



Case histories of slope failure

Bolivia, 4 March 2003, 14 people killed, 400 houses buried

Case histories of slope failure

Brazil, January 2003, 8 people killed

Case histories of slope failure

Case histories of slope failure

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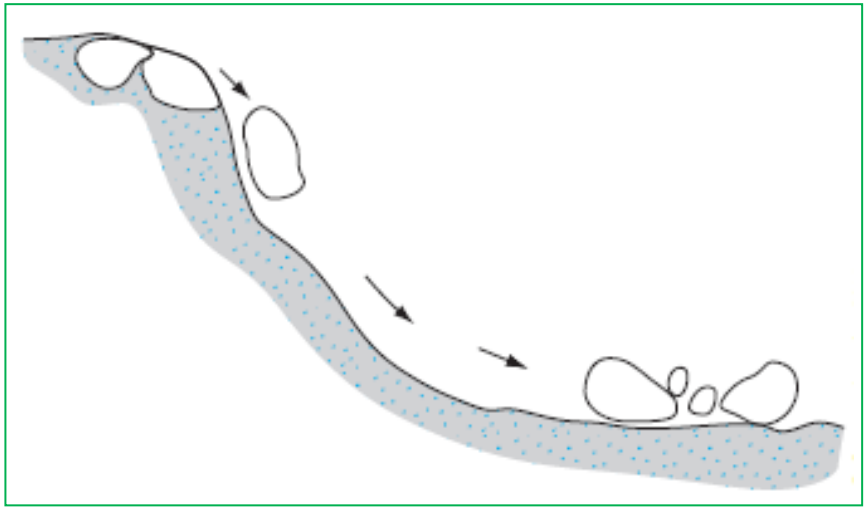
Types of Slope Movements

- Slope instability (movement) can be classified into six different types:
  - Falls
  - Topples
  - Slides
  - Flows
  - Creep
  - Lateral spreads
  - Complex

Falls

- Rapidly moving mass of material (rock or soil) that travels mostly through the air with little or no interaction between moving unit and another.
- As they fall, the mass will roll and bounce into the air with great force and thus shatter the material into smaller fragments.
- It typically occurs for rock faces and usually does not provide warning.
- Analysis of this type of failure is very complex and rarely done.



Falls

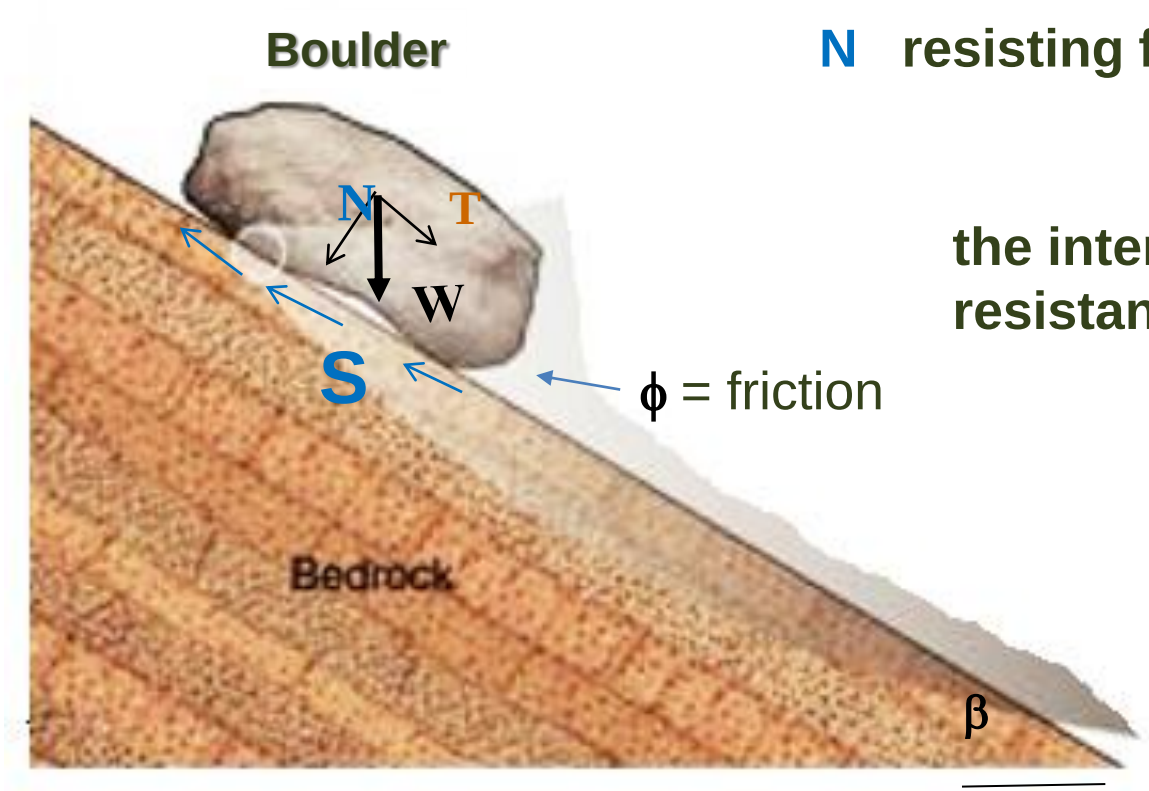
- **Gravitational effect and shear strength**

Gravity has two components of forces:

T driving forces: $T = W . \sin \beta$

N resisting forces (because of friction)

$N = W . \cos \beta$



the interface develop its resistance from friction (ϕ):

$S = N \tan \phi$

In terms of stresses:

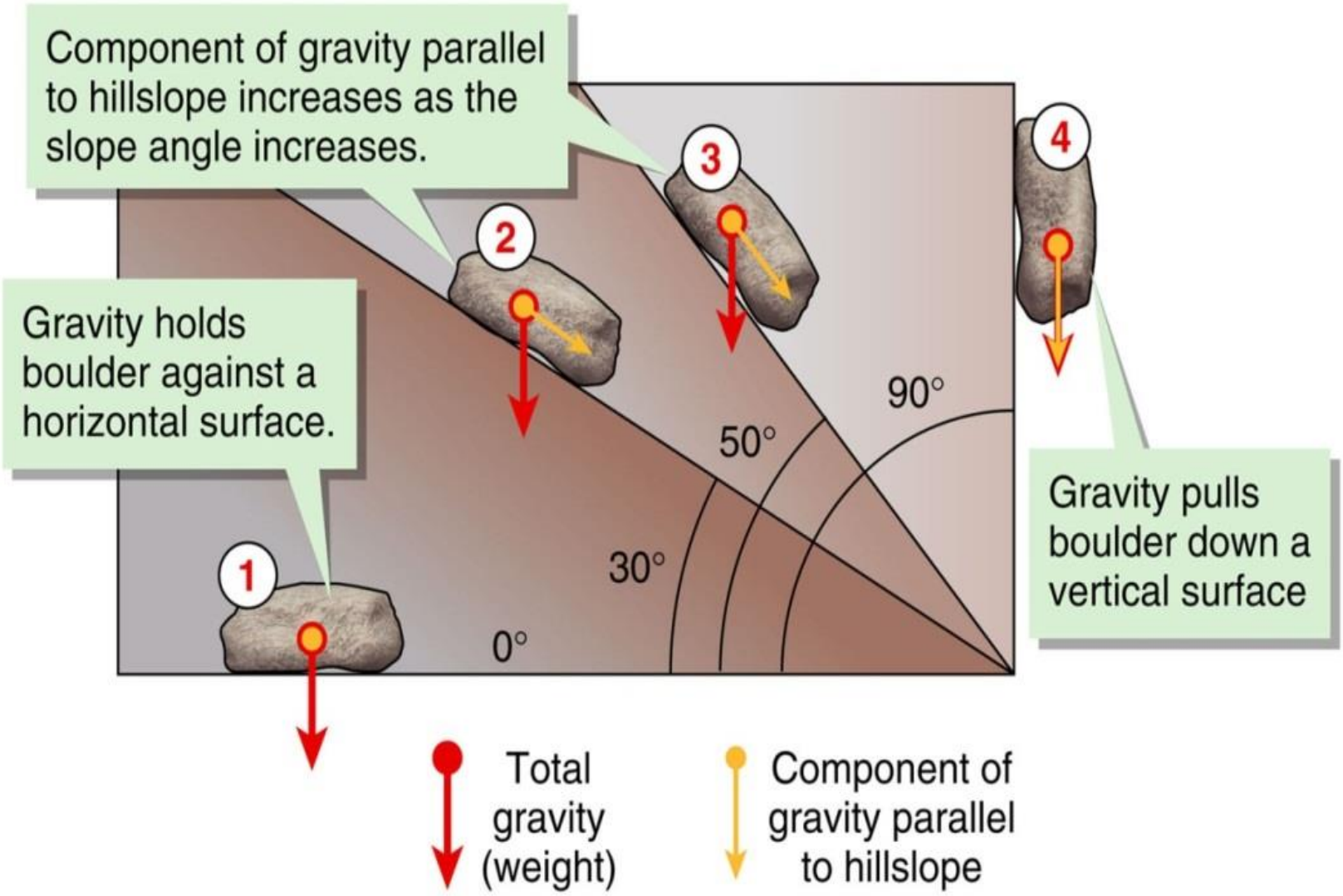
$S/A = N/A \tan \phi$

or

$\tau_f = \sigma \tan \phi$

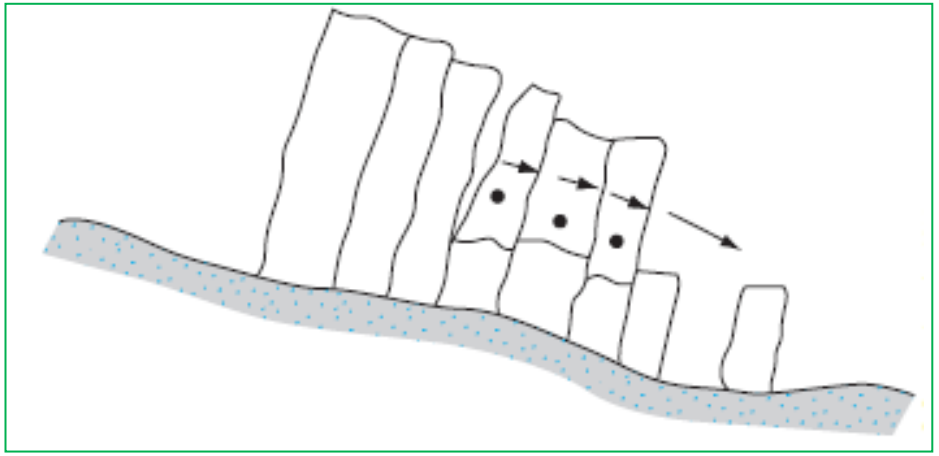
A = effective Base Area of sliding block

Falls


Component of gravity parallel to hillslope increases as the slope angle increases.
Gravity holds boulder against a horizontal surface.
Gravity pulls boulder down a vertical surface
1
2
3
4
0°
30°
50°
90°
Total gravity (weight)
Component of gravity parallel to hillslope

Topples

This is a forward rotation of soil and/or rock mass about an axis below the center of gravity of mass being displaced.

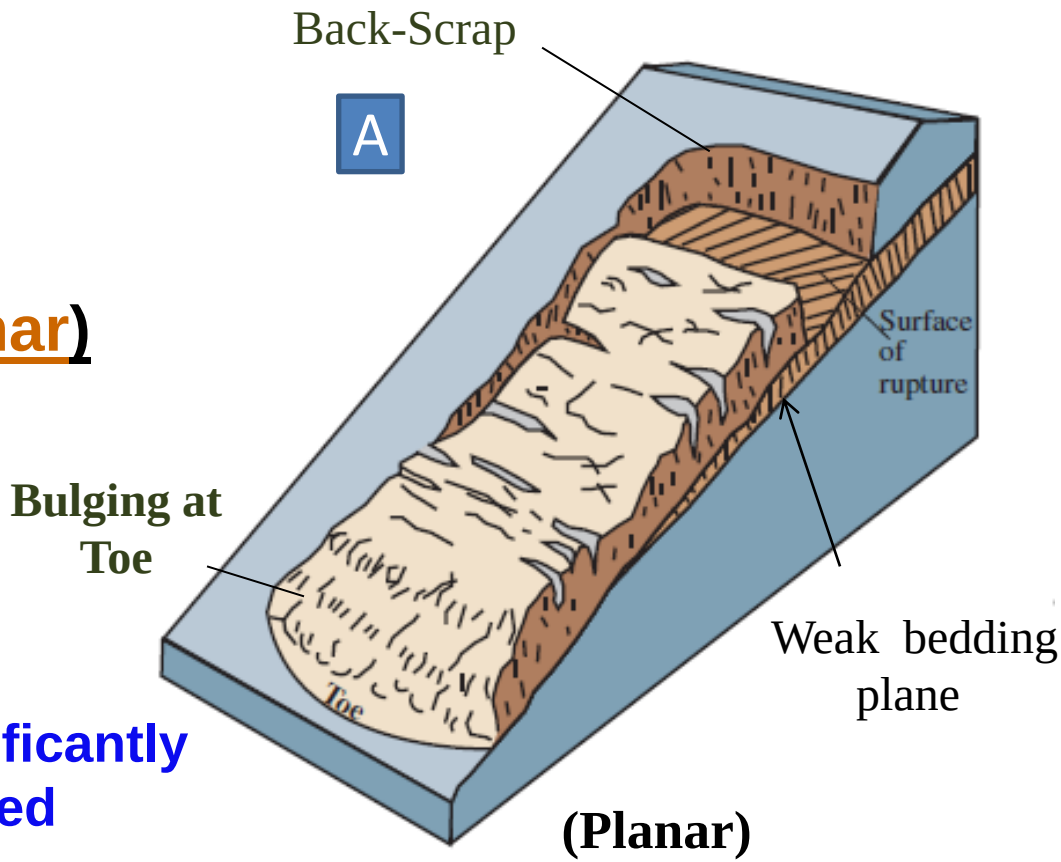


Slides

- Movements occur along planar failure surfaces that may run more-or less parallel to the slope. Movement is controlled by discontinuities or weak bedded planes.

Slides

A. Translational (planar)



(Planar)

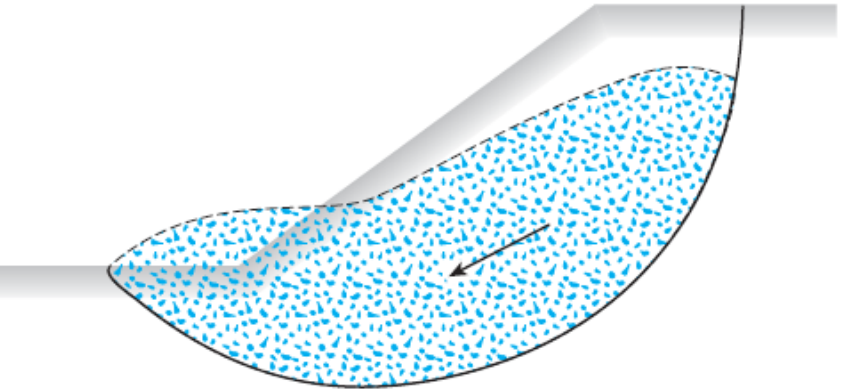
Translational landslide

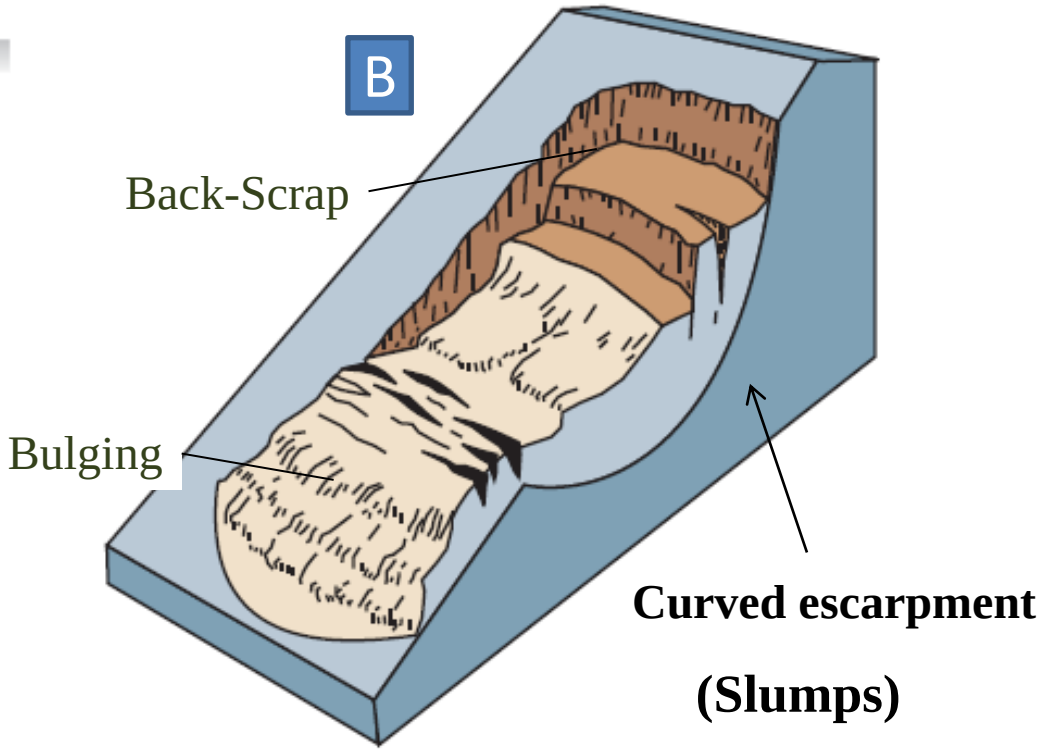
Occur when soil of significantly different strength is presented

Slides

B. Rotational (curved)

This is the downward movement of a soil mass occurring on an almost circular surface of rupture.

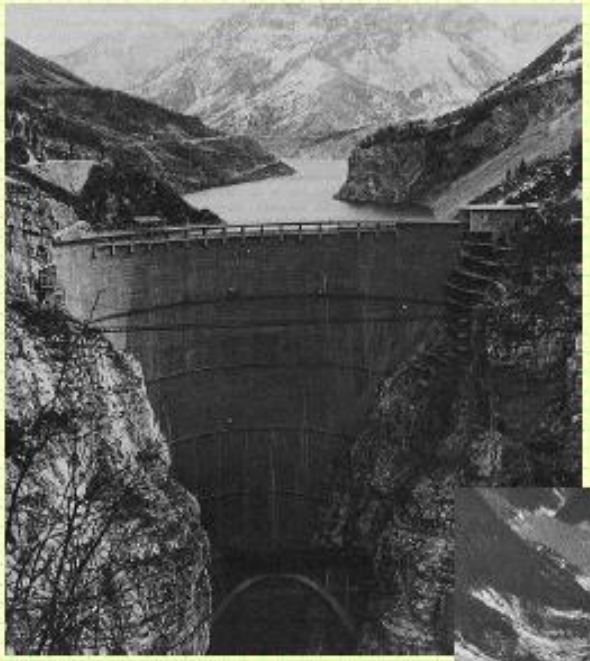




Rotational landslide

C. Compound (curved)

Slides

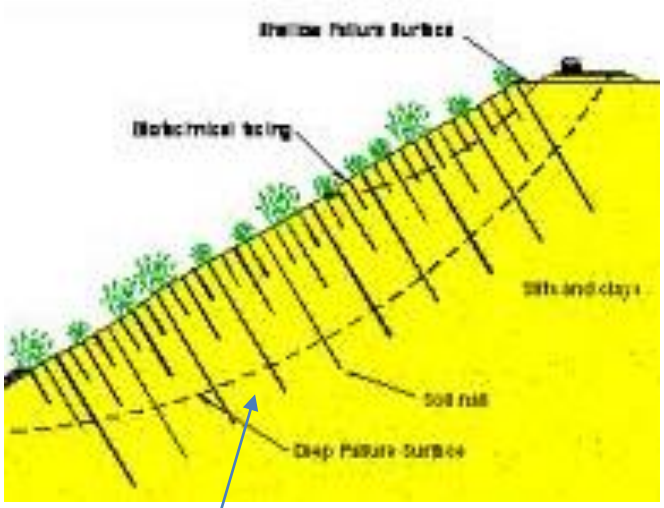


Vaiont dam disaster 1963

- Dam constructed 1957-60
- 276 m high. World's 2nd highest dam
- Slope started to creep as lake filled
- Accelerated to 80cm/day
- 9.10.63 275 millions tons of rock slid into lake
- 25 millions m^3 of water displaced over dam
- Three towns destroyed
- 2000+ killed

Slides

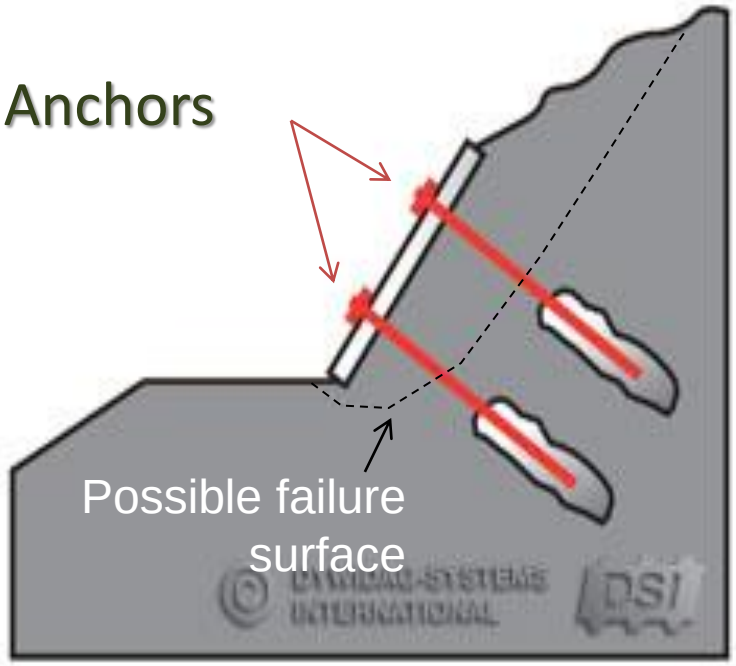
Reinforcement



Soil nails

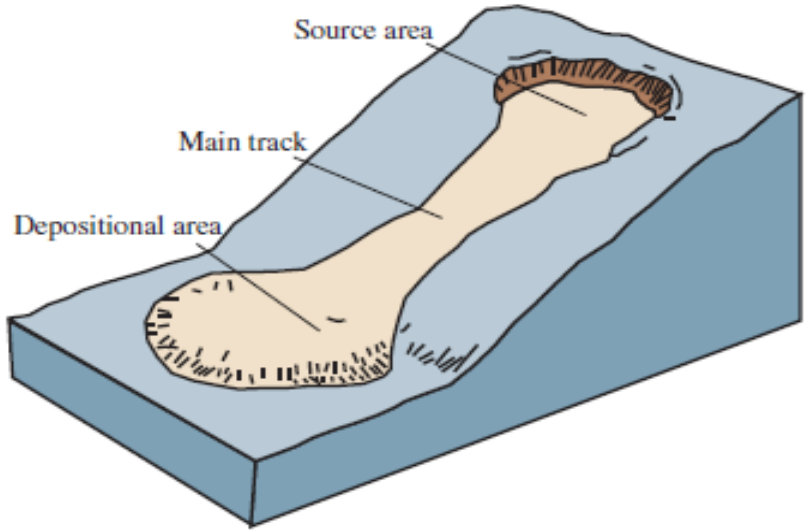
Slides

Reinforcement



Flows

- The materials moves like a viscous fluid. The failure plane here does not have a specific shape.

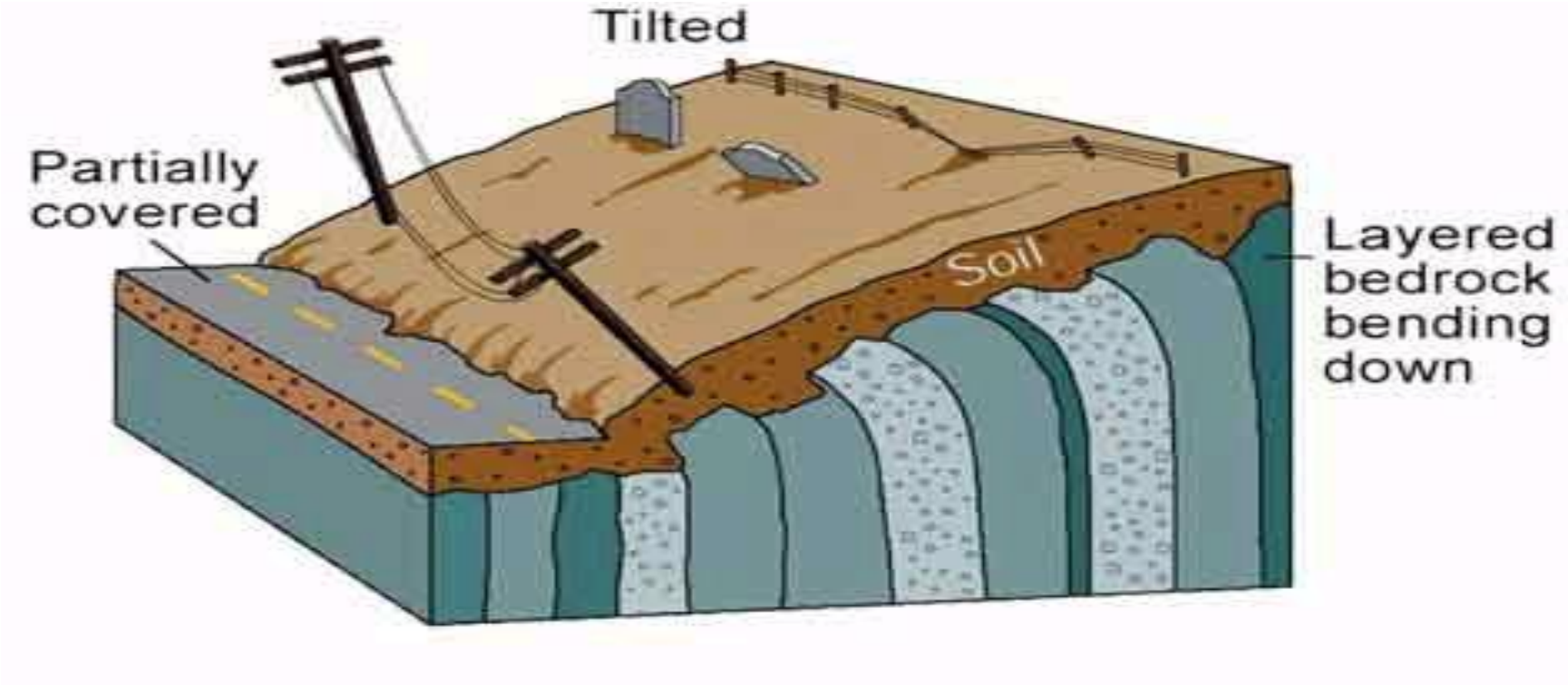


Earthflow

It can take place in soil with high water content or in dry soils. However, this type of failure is common in the QUICK CLAYS, like in Norway.

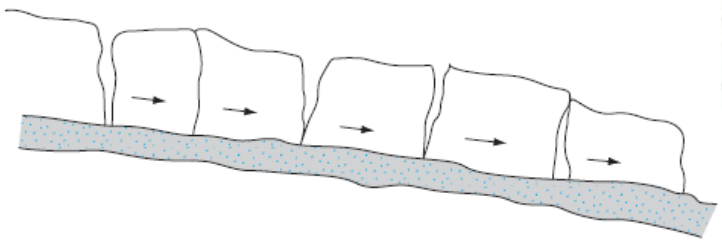
Creep

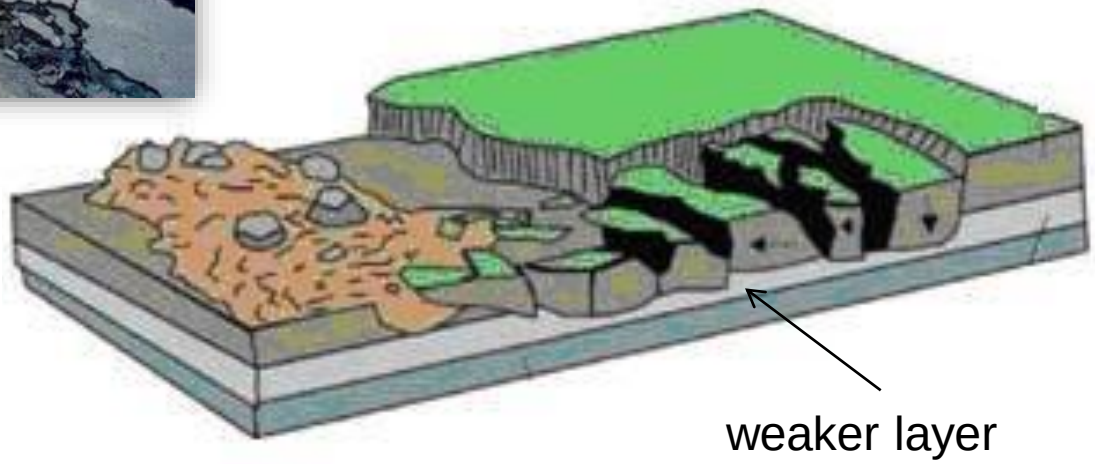
- **It is the very slow movement of slope material that occur over a long period of time**
- **It is identified by bent post or trees.**



Lateral spreads

- **Lateral spreads usually occur on very gentle slopes or essentially flat terrain, especially where a stronger upper layer of rock or soil undergoes extension and moves above an underlying softer, weaker layer.**

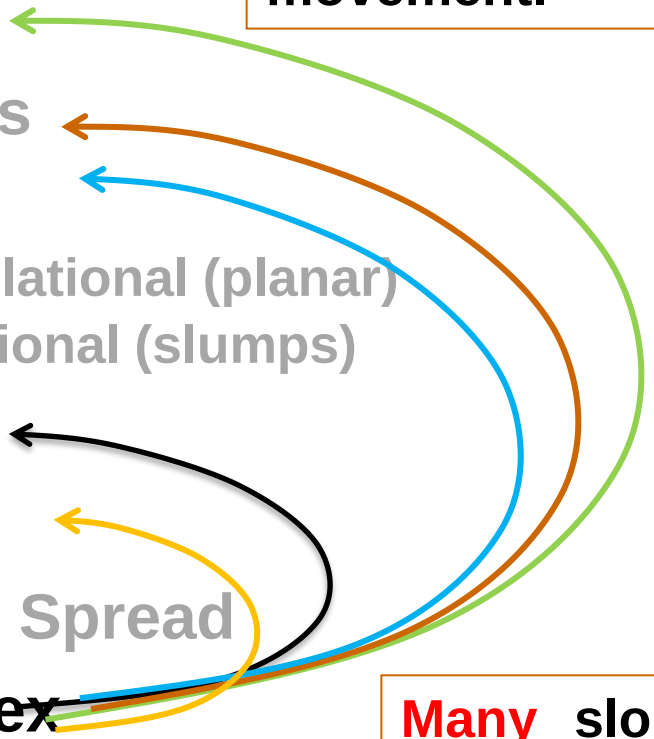




Complex

Complex movement is by a combination of one or more of the other principal types of movement.

1. Falls
2. Topples
3. Slides
   - A. Translational (planar)
   - B. Rotational (slumps)
4. Flow
5. Creep
6. Lateral Spread
7. **Complex**



Many slope movements are complex, although one type of movement generally dominates over the others at certain areas or at a particular time.

Types of Slope Failures

In general, there are six types of slope failures:

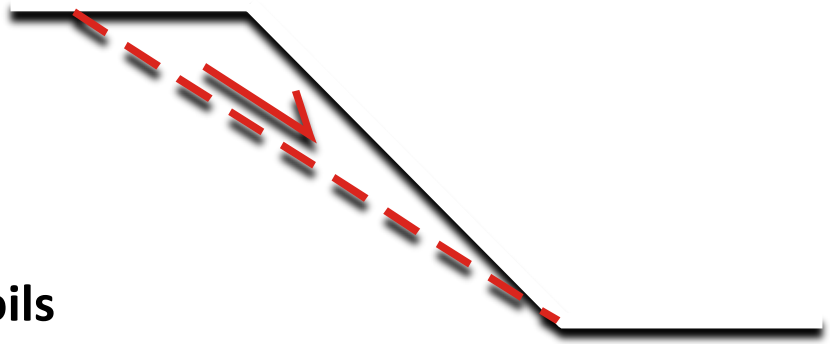
1. Falls
2. Topples
3. **Slides**
   - **Translational (planar)**
   - **Rotational (curved)**
4. Flows
5. Creep
6. Lateral spreads
7. Complex

Slide is the most common mode of slope failure, and it will be our main focus in this course

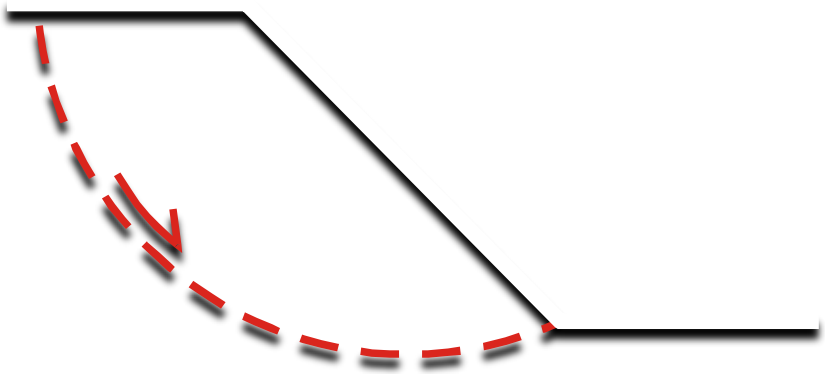
Types of Slide Failure Surfaces

- Failure of slopes generally occur along surfaces known as failure surfaces. The main types of surfaces are:

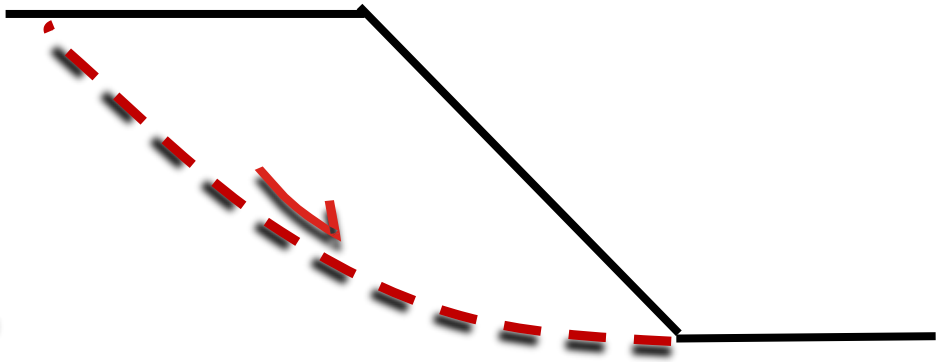
  - **Planar Surfaces:** Occurs in frictional, non cohesive soils



  - **Rotational surfaces:** Occurs in cohesive soils



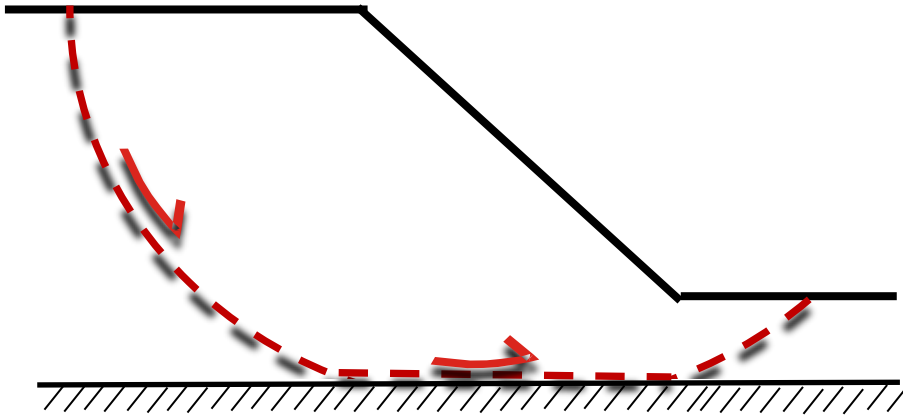
Circular surface (homogeneous soil)



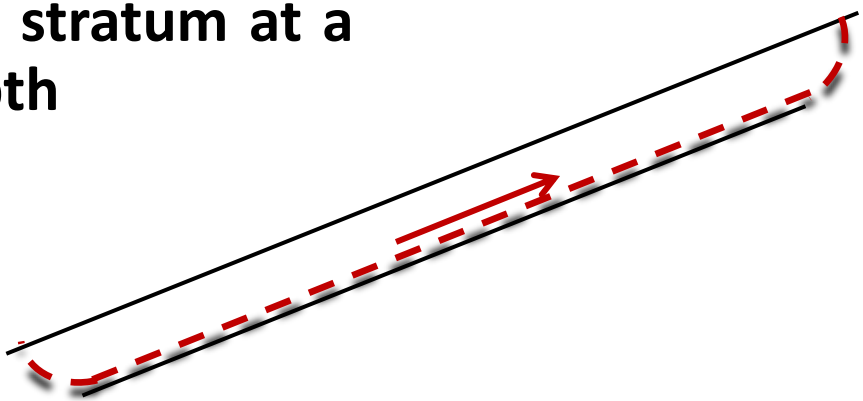
Non-circular surface (non-homogeneous soil)

Types of Slide Failure Surfaces

- **Compound Slip Surfaces:**
  When there is hard stratum at some depth that intersects with the failure plane



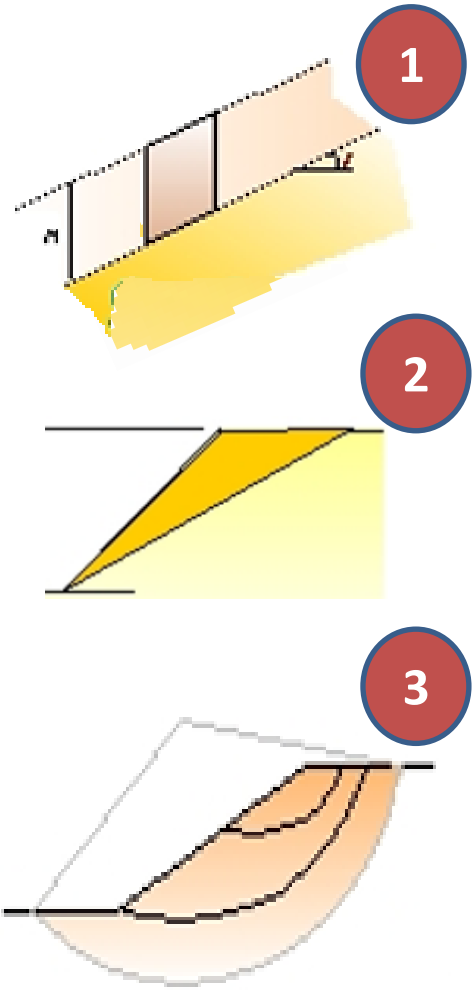
- **Transitional Slip Surfaces:**
  When there is a **hard** stratum at a relatively **shallow** depth



Types of Failure Surfaces

Failure surface

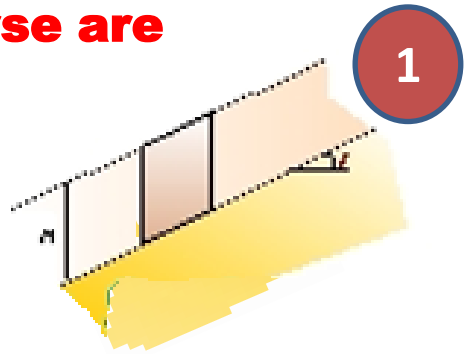
- **Slides**
  - **Translational (planar)**
    - **Infinite** — **Long plane failure surface**
    - **Finite** — **Plane failure surface**
  - **Rotational (curved)**
    - **Finite**
      - **Above the toe**
      - **Through the toe**
      - **Deep seated**



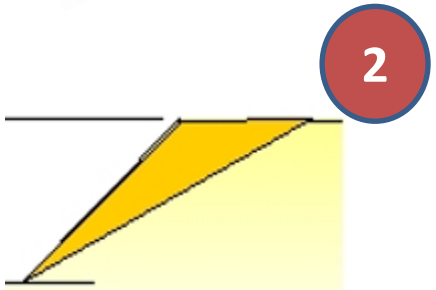
Types of Failure Surfaces

Types of Failure Surfaces Considered in this Course are

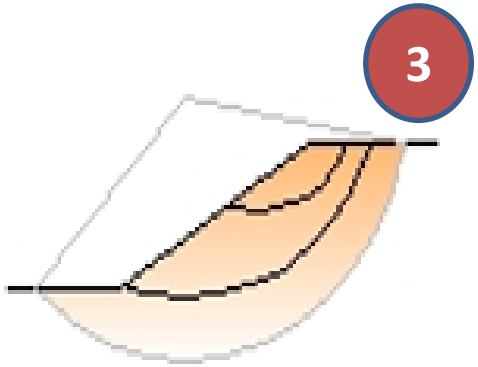
1. Stability of **infinite** slopes



2. Stability of **finite** slopes with **plane** failure surfaces



3. Stability of **finite** slopes with **circular** failure surfaces



The end