Basic of Mass Movement

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Overview of Presentation:

A. Background
B. Classification of Mass Movement
C. Causes
D. Mechanism
Background
Mass Movement

- Mass of earth materials (e.g. soil, fractured or weathered rock) which moves along the slip surface **downward under the influence of gravity** is termed as Mass Movement (Landslide). The term landslide is widely used for almost **all slope movements**.

The **driving force** of the movements is **gravity**, which is assisted by rain, erosion, water pressure, expansion & contraction forces, earthquake human interference & Local Geology.
Landslides are frequently occurring hazards but highly neglected, undermining the development, environment, ecosystem services, most often losses of lives & properties.

Causal & Triggering Factors of Landslides:
The elements which play the Major Role to the Mass Movement (Landslide): the Triggering Factors

- **Rainfall**, (Surface and Ground water);
- **Local Geological & Geomorphologic condition** (Weathering, erosion, toe cutting);
- **Earthquake**;
- **anthropogenic activities** (e.g. mining, road excavation, etc.).
Classification
Two types of Classification:

- VARNE’s Classification of Mass Movement;
- Preventive Classification (Field disaster oriented)
Classification of Mass Movement (Landslide)
<table>
<thead>
<tr>
<th>Type of Movements</th>
<th>Type of material</th>
<th>Engineering soil</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bed Rock</td>
<td>Predominantly Coarse</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Falls</td>
<td>Rock Fall</td>
<td>Debris Fall</td>
</tr>
<tr>
<td>2. Topples</td>
<td>Rocks Topple</td>
<td>Debris Topple</td>
</tr>
<tr>
<td>3. Slides</td>
<td>Rock Slump</td>
<td>Debris Slump</td>
</tr>
<tr>
<td>a. Rotational</td>
<td>Rock Slides</td>
<td>Debris Slides</td>
</tr>
<tr>
<td>b. Transnational</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Lateral Spreads</td>
<td>Rock Spread</td>
<td>Debris Spread</td>
</tr>
<tr>
<td>5. Flows</td>
<td>Rock Flow</td>
<td>Debris Flow</td>
</tr>
<tr>
<td>Complex</td>
<td>Combination of two or more principal types of movement</td>
<td></td>
</tr>
</tbody>
</table>

(Varnes 1978)
• Falls are masses of rock and/or soil that move down slope by falling or bouncing through the air. They are most common on steep road cuttings.

• The slope is generally more than 45°

• The movement is very rapid to extremely rapid. The velocity is more than 3 m/second.
**Topple**

- **Topple** denotes the **overturning or tilting** of a block of rock **on a pivot or hinge**. Finally, it separates from the main mass resulting in a fall or slide.

- Fractal** toppling** occurs most notably in **Slate, Phyllite, and Schist**.
• The slide is a mass movement process in which a presence of distinct surface of rupture or slip surface is available.

• There are two types of slides:
  • Rotational, &
  • Translational
Rotational Slide

- **Rotational slide** moves along the surface of rupture that is **curved concave or spoon shape slip surface**.

- **Rotational** landslides generally occur in **homogeneous materials**.
Translational Slide

• Translational slide is non-circular movement on planner slip surface.

• It is relatively shallower than rotational slide.
Lateral Spreading

- The spreads are failures caused by *liquefaction*, the process whereby water-saturated sediments transform into a liquid state.

- Spreads may result from *liquefaction* or flow of the soften material.
Flow (Debris flow)

- The movement is similar to flow of a viscous fluid.

- In this case, slip surface is almost absent.

- Due to high slope, the movement of debris flow may be extremely rapid (upto 40-50Km/hr in speed)

- Generally debris flow occurs near the foothill along the rivulets
Complex

- The combination of two or more types of mass movement (landslides).

Cross section of a complex landslide characterized by slumping at the top and earthflow at the base.
## Preventive Classification (Field Disaster Oriented)

### Mass Movement

<table>
<thead>
<tr>
<th>Slope failure</th>
<th>Landslide</th>
<th>Debris Flow (Debris, Earth &amp; Peat)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Movement of weathered surface soil layer / rock of steep slope. (Small dimension and rapid movement).</td>
<td>Movement of large sediment block which has clear slide surface. Large Dimension, slow and continuous movement mainly affected by ground water.</td>
<td>Movement of deposited or eroded sediment along the stream flow. Rapid movement including large volume of water through the stream.</td>
</tr>
</tbody>
</table>
Types of Mass Movement: Preventive Classification
Landslide and Slope Failure: Differences

1. Slope Failure
   - Weathered Soil (or Rock)
   - Rapidly thinning
   - Steep slope
   - Small scale

2. Landslide
   - Sliding area
   - Continuously slowly
   - Ground Water
   - Gently sloping
   - Slide surface (clayey soil)
## Landslide and Slope Failure: Differences

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Landslide</th>
<th>Slope Failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relation to Geology and Geological Structure</td>
<td>Much related</td>
<td>Not much related</td>
</tr>
<tr>
<td>Gradient of slope</td>
<td>Takes place in gently slope (5-20°)</td>
<td>Take place in steep slope over 30°</td>
</tr>
<tr>
<td>Causes of movement</td>
<td>Influenced by ground water</td>
<td>Heavy Rainfall, Earthquake</td>
</tr>
<tr>
<td>Scale of Dimension</td>
<td>Large (1-100ha)</td>
<td>Small</td>
</tr>
<tr>
<td>Rate of Movement</td>
<td>Generally low 0.001-10 mm/day</td>
<td>Extremely high over 10 mm/day</td>
</tr>
<tr>
<td>Condition of Movement</td>
<td>Continuous and recurrent</td>
<td>Occurs suddenly</td>
</tr>
<tr>
<td>Condition of Soil mass</td>
<td>Disturbance of the soil mass is small</td>
<td>Soil mass is disturbed</td>
</tr>
<tr>
<td>Sliding Surface</td>
<td>Mainly in Clayey Soil</td>
<td>in weathered surface of soil (sandy soil)</td>
</tr>
</tbody>
</table>
### Description of Movement with relation to Speed and Type

<table>
<thead>
<tr>
<th>Speed</th>
<th>Rate</th>
<th>Water Content</th>
<th>Material</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extremely rapid</td>
<td>3.0m/second</td>
<td>Dry</td>
<td>Rock</td>
<td>Fall</td>
</tr>
<tr>
<td>Very Rapid</td>
<td>0.3m/minute</td>
<td>Moist</td>
<td>Soil</td>
<td>Topple</td>
</tr>
<tr>
<td>Rapid</td>
<td>1.5m/day</td>
<td>Wet</td>
<td>Earth</td>
<td>Slide</td>
</tr>
<tr>
<td>Moderate Slow</td>
<td>1.5m/month</td>
<td>Very wet</td>
<td>Debris</td>
<td>Spread</td>
</tr>
<tr>
<td>Slow</td>
<td>1.5m/year</td>
<td></td>
<td></td>
<td>Creep</td>
</tr>
<tr>
<td>Very slow</td>
<td>0.3m/5year</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extremely slow</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*(After Bell, 1993)*
Causes
Landslides & Slope Failure: Causes

- **Intrinsic Causes** &
- **Direct causes**
Causes of Mass Movement (Landslide)

Intrinsic Causes

- Geographical factors
  - Geological weak zone
    - fault, fracture, joints, fissures
  - Weathered soil layer
  - Debris deposit

Topographical characteristics

- Erosion, Slope, deforestation
  (Secondary landslide)

Direct Causes

- Rainfall
  - Ground Water
  - Pore water Pressure
- Erosion by river
  - Toe erosion
- Earthquake
- Human Interference

- Cutting
- Loading
- Back Water at reservoirs
- Water leak from irrigation Channel etc.
Mechanism
Mechanism of Mass Movement (Landslide)

- **Driving force or, Shear Stress (T)** is down slope movement of material due to gravity, (The slope angle, slope material, climate,, chemical weathering and ground water contribute to the effect of gravity).

- **Resisting force or, Shear Strength (S)** stops or prevents the movement.

when *driving forces overcome resisting forces*, the slope is unstable and results mass wasting.
**Mechanism of Mass Movement (Landslide)**

**Factor of Safety (FS)**

The ratio of **resisting forces** to **driving forces**

\[
\text{Stability of the landslide} = \frac{S}{T}
\]

- \(FS > 1.5\) : Stable
- \(FS = 1 - 1.5\) : Marginally stable
- \(FS < 1\) : Unstable
Factor of Safety (FS): Physically based infinite slope stability model (Chae et al. 2015):

\[ FS = \frac{(c_z + c_r) + \cos^2 \theta [A] \tan \phi}{D \rho_i g \sin \theta \cos \theta} \]

where,

\[ A = \left[ \rho_i g (D - D_{wf}) + (\rho_i g - \rho_w g) D_{wf} \right] \]

\( c_z \) is the plant roots cohesion (N/m²), \( c_r \) is the soil cohesion (N/m²), \( \theta \) is the slope gradient (°), \( \rho_i \) is the soil density (kg/m³), \( \rho_w \) is the density of water (kg/m³), \( g \) is the acceleration due to gravity (9.81 m/s²), \( D \) is the depth of the soil layer (m), \( D_{wf} \) is the vertical height of the water table (m) and \( \phi \) is the internal friction angle of the soil (°).
Landslide Features
Thank You !!!