Training/workshop on  
“Earthquake Vulnerability and Multi-Hazard Risk Assessment: Geospatial Tools for Rehabilitation and Reconstruction Effort”

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AN APPROACH TO  
THE CLASSIFICATION OF SLOPE MOVEMENTS

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Landslide is defined as the movement of a mass of rock, debris or earth down the slope, when the shear stress exceeds the shear strength of the material.
Shear strength/Shear stress

Stability: stable/unstable
Factors contributing to an increase of shear stress

- removal of underlying support (erosion, road cuts and quarries)
- increase of load (rain/snow, fills, vegetation)
- increase of lateral pressures (hydraulic pressures, roots, swelling of clay)
- transitory stresses (earthquakes, vibrations of trucks, machinery, blasting)
- regional tilting (geological movements).
Factors related to the decrease of the material strength

- decrease of material strength (weathering, change in state of consistency)
- changes in intergranular forces (pore water pressure, solution)
- changes in structure (decrease strength in failure plane, fracturing due to unloading)
The factors contributing to trigger the landslide

The factors contributing to an increase of the shear stress are:

- removal of lateral and underlying support (erosion, previous slides, road cuts and quarries)
- increase of load (weight of rain/snow, fills, vegetation)
- increase of lateral pressures (hydraulic pressures, roots, swelling of clay)
- transitory stresses (earthquakes, vibrations of trucks, machinery, blasting)
- regional tilting (geological movements).

Factors related to the decrease of the material strength are:

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Landslide Activity Classes

1: active,
2: suspended,
3: reactivated,
4: dormant,
5: stabilized,
6: relict.
Classification of Slope Instability

**Discriminating factors for classification of mass-movements (slope instability)**

- Type of material
- Type of movement
- Water content in the material
- Velocity
- Morphology / morphometry
- Geology
- Climate
- Activity
Different authors have used in different discriminating factors for the classification of mass-movements (slope instability):

- Sharpe (1938):
  - material: earth ↔ rock
  - movement: flow ↔ slip
  - velocity: slow ↔ very rapid
  - content: water/ice
- Crozier (1973):
  Type of movement and Morphometry

- Sharpe (1938):
  - material: earth ↔ rock
  - Movement: flow ↔ slip
  - Velocity: slow ↔ very rapid
  - content: water/ice
Coates (1977):

Material: bedrock, regolith, sediment

Movement: slide, flow, fall

Secondary: size of material coherence
Varnes (1978):

Material: bedrock, debris, earth
Movement: fall, topple, slide, flow, complex
Secondary:
water content: dry ↔ wet
Velocity: slow ↔ rapid
<table>
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<tr>
<th>Velocity Classes</th>
<th>mm / sec</th>
<th>m / hour</th>
<th>m / year</th>
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<td>landslide</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>extremely rapid</td>
<td>$5 \times 10^3$</td>
<td>$10^4$</td>
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</tr>
<tr>
<td>very rapid</td>
<td>50</td>
<td>$10^2$</td>
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<tr>
<td>Rapid</td>
<td>5</td>
<td>1</td>
<td>$16 \times 10^3$</td>
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<tr>
<td>Moderate</td>
<td>$5 \times 10^{-3}$</td>
<td>$10^{-2}$</td>
<td>160</td>
</tr>
<tr>
<td>Slow</td>
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<td>$10^{-4}$</td>
<td>$1 \times 6$</td>
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<tr>
<td>very slow</td>
<td>$0.5 \times 10^{-6}$</td>
<td>$10^{-6}$</td>
<td>$16 \times 10^{-3}$</td>
</tr>
<tr>
<td>extremely slow</td>
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Mass Movements

- Classification based on Hutchinson (1988)
  - Rebound
  - Creep
  - Sagging
  - Landslides
  - Debris movement of flow like forms
  - Toppling failures
  - Falls
  - Complex slope movements
Rebound

A.

- Gulley parallel to main valley
- Raised valley rim
- Slough parallel to crest
- Drift
- Bedrock surface
- Flexural slip
- Valley flexure
- Valley Anticline
- Typically 800-1600 m
- Typically 250-750 m
- 1.5-3 m
- River
- Marker beds - Coal, Bentonite or Limestone layers
Sagging

Sagging is defined as large scale deep seated deformations, under influence of gravity, occurring in competent rocks and occurring in zones where erosion has created deep valleys and therefore an unstable situation (Hutchinson, 1988).
D1 Confined failures

(a) In natural slopes
- High or artesian G.W. pressure
- Tension crack
- Slight bulge
- Soft clay
- Sand/silt layer

(b) In man-made slopes
- Scarp and tension crack
- Slight bulge
- R.C. retaining wall
- Wall drain
- Soft backfill
- Slip surface
- Original firm ground
Landslides (contd.)

D2 Rotational slips
(a) Single

(b) Successive

(c) Multiple

Slope, toe and base failure
Slip surfaces
Cap rock
Stiff plastic clay
Competent sub stratum
Landslides (contd.)

D3 Compound slides
(a) Released by internal shears
(i) in slide of moderate brittleness

(b) Progressive compound slides
(ii) in slide of high brittleness
extremely rapid
Landslides (contd.)

D4 Translational slides

(a) Sheet slides

(b) Slab slides

(d) Rock slides

(i) Planar slides

(ii) Stepped slides

(iii) Wedge failures

(e) Slides of debris
    (i) Debris slides

(ii) Active layer slides

(f) Sudden spreading failures
Debris movements of flow like form

1/2 Mudslides

3 Flow slides
   (a) In loose cohesionless materials
   (c) In high porosity weak rocks

4 Debris flows
   (a) (i) Hillslope
   (a) (ii) Channelized

5 Sturzstroms
F  Toppling failures
1  Bounded by pre-existing discontinuities
   (a) Single
   (b) Multiple

Jointed cap-rock
weak sub-stratum

2. Released by tension failure
   at rear

Tension failure
intact till
wave-cut notch
beach
1. Primary; rock and soil falls

2. Secondary; stone falls
Complex slope movements

NB Not to scale. Camber slope frequently 800 - 1000 m long with valley 50 - 60 m deep. Depth from river to plane of décollement may be 50 m or more.
Complex slope Movements (contd.)
Complex slope

Movements (contd.)

5 Slides caused by seepage erosion

6 Multi-tiered slides

7 Multi-storied slides
Generalized Landslide types

Types of landslide based on movements are:

- fall,
- topple,
- slide,
- sagging,
- spread, and
- flow like forms.
Falls comprise a detachment of soil or rock from a steep slope and the more or less free and extremely rapid descent of the material. The movement is largely through the air, alternated with the bouncing or rolling on the slope.
A topple is a forward rotation out of the slope of a mass of soil or rock about a point below the centre of gravity of the displaced mass.

The process is, identically to fall, associated with very steep slopes. Topples may lead to the sliding of the displaced mass, but toppling is mostly occurring in combination with fall. The process in rock slopes is generally controlled by steep inclined discontinuities more or less parallel to the free toppling face.
A landslide in the restricted sense of the word is a generally rapid to very rapid downslope movement of soil or rock bounded by a more or less discrete failure surface which define the sliding mass.

An essential element of sliding is that the movement takes place as a unit portion of land, which implies that there are no movements within the slipped block.
Spread

Spread is defined here as an extension of a cohesive soil or rock mass combined with a general subsidence of the broken mass of cohesive material into softer underlying material. From the definition it is clear that the horizontal (lateral) component is more important than the vertical movement.

Common are block spreads, large joint controlled blocks are sliding into the valley.

Eg. liquefaction, which implies the abrupt lowering to zero of the cohesion and the effective stress and therefore a behaviour as a liquid of the underlying layer.
Flows or debris movements of flow-like form

- Large variety of mass movements of flow-like form exist and they grade into all other types of slope movements. Debris flows can be generated from debris slides.
- Earthflows are often originated by large slides whereby the more or less saturated sliding material disintegrates and continues its way down in flow-like form.
Block diagram of a rotational slide

Length
Width
Scarp
Body
Different types of slides

a: rotational rock slide;
b: rotational earth slide;
c: translational rock slide (upper portion is rock block slide);
d: debris slide;
e: translational earth slide (Varnes, 1978)
Examples of flows:
a: slow earth flow,
b: Loess flow,
c: dry sand flow (Cruden and Varnes, 1996)
Strurzstroms

are a rather exceptional form of dry rock flows originated by an enormous rock slide or fall, liberating an extreme high amount of kinetic energy. Due to this a dust cloud is formed of a high density which will move along the slope, through valleys over the ground surface. A sturzstrom is in this respect comparable to pyroclastic flows, where a enormous column of warm very hot volcanic tephra mixed with gases and water vapour collapses and flows down along the slopes of the volcano.