WG4: Identification & classification of exposure events.

Exceptional or infrequent event scenarios.

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Introduction

- **Accidental actions**: **fires, internal explosions, seismic events**, +/- covered by Eurocodes.
- The other exceptional hazards are **not** considered.
- **EN 1991-1-7** *"does not specifically deal with accidental actions caused by external explosions, warfare and terrorist activities, or the residual stability of buildings or other civil engineering works damaged by seismic action or fire,* ***etc.****"*
- This presentation deals with some actions hidden behind this **"etc."**

Introduction

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  - **avalanches**

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  - **erosion**

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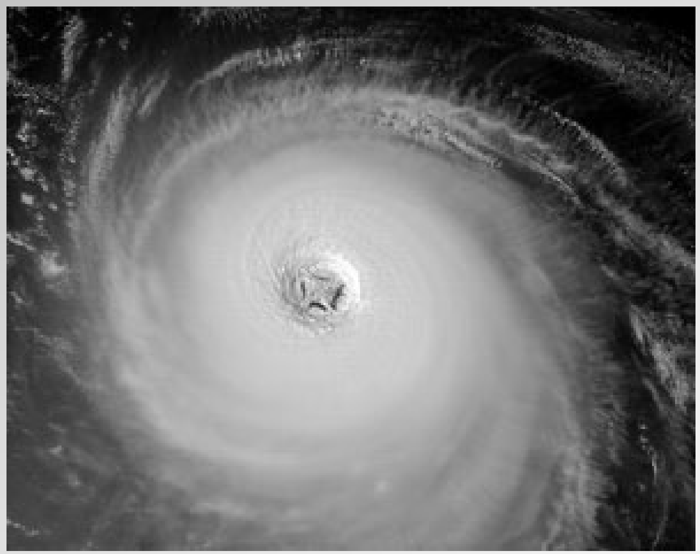
  - erosion
  - **extreme winds**



Introduction

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  - erosion
  - extreme winds
  - **landslides & rockfalls**

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  - **tsunamis & floods**

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- **Infrequent natural actions** not specified in Eurocodes are:
  - avalanches
  - erosion
  - extreme winds
  - landslides & rockfalls
  - tsunamis & floods
  - **volcanic eruptions**

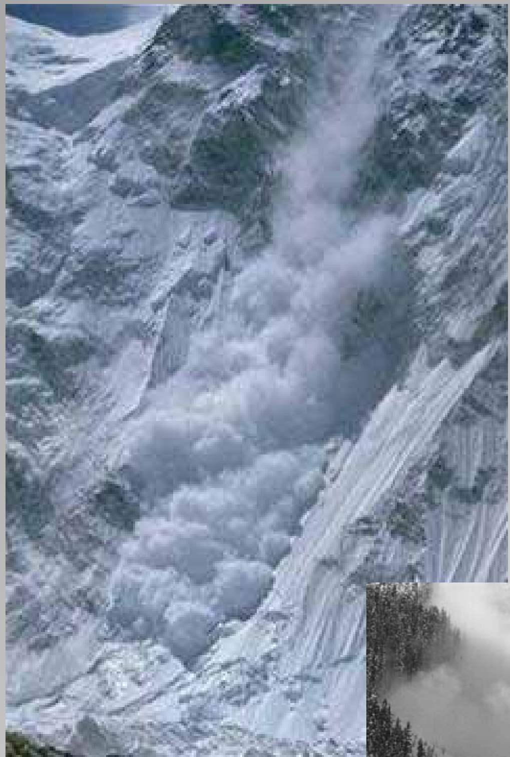
Introduction

- **Characterized by large fluid masses moving with a different degree of velocity** according to their density and viscosity.

Content

1. Snow: avalanches
2. Wind: tropical cyclones & tornados
3. Water: erosion & tsunamis
4. Volcanic eruptions
5. Landslides & rockfalls

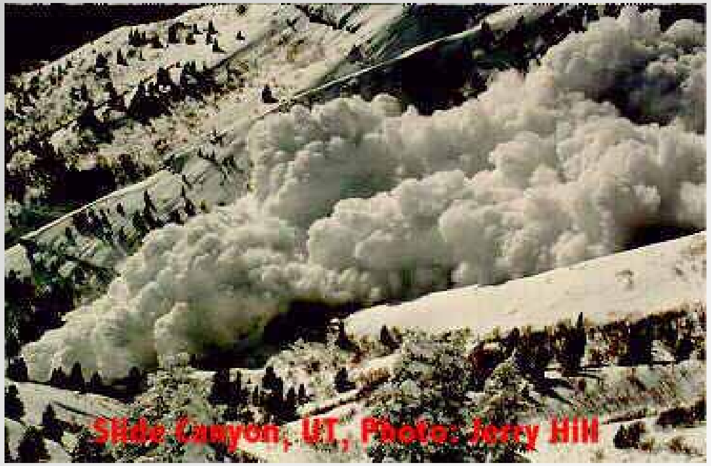
1. Snow



1. Snow – Avalanches

2 main types:

– dry snow or powder avalanche



– wet snow avalanche

1. Snow – Avalanches

- **Mode of failure**, **way of displacement** and **relative power** are different.

	Dry snow avalanche	Wet snow avalanche
Displacement speed	**Fast** to very fast: up to 100 m/s or 360 km/h	Relatively **slow**: < 30 m/s or 108 km/h
Pressure	**May be higher than 1000 kPa**	
Unit weight	**≈20 kg/m³**	**Up to 500 kg/m³**
Height of influence	Currently 30 to 40 m but may be **higher than 100 m**	Generally **less than 8 to 10 m**

1. **Snow** – Avalanches

- **Wet snow avalanches:**
  - slower than **dry snow avalanches**,
  - the runout distance is shorter,
  - high density of wet snow ⇨ important impact on obstacles,
  - the speed reduces with the slope,
  - less dangerous for humans, more for constructions.
- **Dry snow avalanches:**
  - not really affected by the site topography.

1. **Snow** – Avalanches

– In the **Alps**, **3 categories of hazard**:

- **Red zone**: it is forbidden to build any kind of new constructions;
- **Blue zone**: it is possible to build constructions but with special requirements;
- **White zone** is expected to be without danger.

1. **Snow** – Avalanches

- **Approximation of the reference dynamic pressure:**

$$P_d = 1/2\ \rho\ V^2$$

  - ρ average snow unit weight (kg/m³)
  - **V** displacement speed of the avalanche (m/s)

	Dry snow avalanche	Wet snow avalanche
Unit weight	*10 kg/m³*	*400 kg/m³*
Displacement speed	*77.5 m/s ≈ 280 km/h*	*12.25 m/s ≈ 44 km/h*
Pressure	***≈ 30 kPa***	***≈ 30 kPa***

1. Snow – Avalanches

– An **avalanche loading** is **very high**.

– **Blue zone: 30 kPa** is a reference value used in many European countries for a **wet snow avalanche**.

This value comes from **Switzerland**, the reference country in Europe.

1. Snow – Avalanches

– **Trees**, **stones**, **ice blocks** amplify the effect of **wet snow avalanches** by adding an **impact load.**

- The value depends on the reference dynamic pressure:
  - In Switzerland:
    - ⇨ **100 kN** is used with $\mathbf{P_d = 30\ kPa}$;
    - ⇨ **33 kN** is used with $\mathbf{P_d = 10\ kPa}$;
  - Surface of application: **500 $\mathbf{cm^2}$** at any level of the avalanche.

1. Snow – Avalanches

Combination:

– **wet** and **dry snow avalanches** are **never combined** (due to their different origin).
– **Avalanches** are **never combined** with **earthquakes** (they don't occur in the same time).
– **Winds** and **avalanches** are **never combined** (wind actions included in the avalanche load case).
– **Snows** and **avalanches** are **combined** (heavy snow is a creating factor).

2. Wind

2. Wind – Extreme winds

Cyclones, hurricanes, tornados & typhoons

- Dynamic action ⇨ Severe damages to constructions.
- Often associated with **torrential rains** creating **floods** ⇨ amplification of the damages.

2. Wind – Extreme winds

- Their **name** depends on the geographical location and on the maximum speed:

  – **Tropical cyclones** above seas or oceans:
    - **Hurricanes** in the Atlantic Ocean;
    - **Typhoons** in the Pacific Ocean.

  – **Tornados** above the earth.

2. Wind – Cyclones

- Three types of **cyclonic perturbations**:
  - tropical depressions,
  - tropical storms,
  - tropical cyclones.

Name	**Sustained winds speed (km/h)** (a 10-minute average)	
	Atlantic & East Pacific	**West Pacific**
Tropical depression	≤ 62	≤ 62
Tropical storm	63-117	63-88
Severe tropical storm		89-117
Cyclones or typhoons	Tropical cyclones ≥ 118	Typhoons ≥ 118

2. Wind – Cyclones

- The **Saffir-Simpson hurricane scale**

Category	Wind speed (km/h)
1	119-153
2	154-177
3	178-209
4	210-249
5	≥ 250

2. Wind – Cyclones

- A **tropical cyclone**:
  - an eye at the centre (a warm and calm zone),
  - surrounded by an area about 16-80 km wide where strong thunderstorms and winds circulate around.

- **Extreme wind speed** measured:

≈ 305 km/h

2. **Wind** – Cyclones

- **Tropical cyclones**: initiated and sustained over large unstable volumes of warm water (>26°C over 60 m in depth)
  - ⇨ Strength decreases over land because of the lack of water;
  - ⇨ Coastal regions more affected than inland regions.

2. Wind – Cyclones

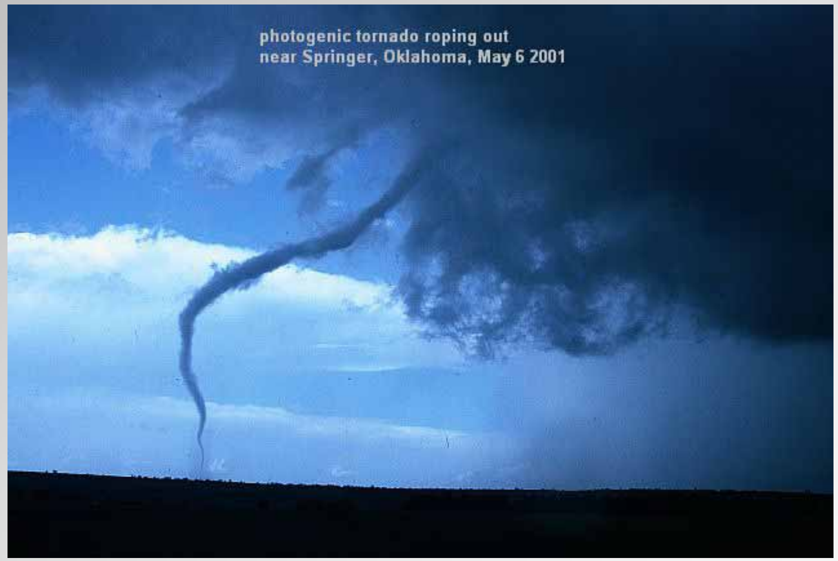
- **Tropical cyclones** often combined with **torrential rains**, **high waves** and **storm surges**:
  - **Strong wind** ⇨ high pressure + debris (flying objects) ⇨ damages on structures;
  - **Heavy rains** create:
    - river and stream floods,
    - Landslides;
  - **Storm surges** ⇨ increasing of the sea level, Extensive coastal floods up to ≈ 50 km inland.

2. Wind – Cyclones

– **Damages to constructions**:

Wind speed	Damages
< 150 km/h	Negligible. Some coastal flooding.
150-180 km/h	Minor damages to roofs and openings. Significant flooding damages.
180-210 km/h	Some structural damages to small constructions. More important flooding damages near the coast: small structures destroyed and larger structures damaged by floating debris.
210-250 km/h	Significant structural damages. More important curtain wall failures with some complete roof structure failures on small constructions. Important erosion of coastal areas.
> 250 km/h	Complete roof failures on most constructions and industrial buildings. Some complete building failures. Flooding causes major damage to lower floors of all concerned structures

2. Wind - Tornados



- **Smaller** than **tropical cyclones.**
- **Violent rotating column of air** in contact with the earth and starting from a cumulonimbus.
- Different shapes: typically a visible condensation funnel whose narrow part moves on the earth.

2. Wind - Tornados

– **Localised damages** but very important (high speed of rotation) on the path of the displacement.

– In most cases, a **cloud of debris** moves around: damages ⬀.

2. Wind - Tornados

Radial action combined with a **vertical suction** amplifying damages.

- A powerful tornado may extract light constructions from foundations.

2. Wind - Tornados

- **Localised strong wind**: speed ≈175 km/h.
- **Lower part ≈100 m.**
- Travel on **small distances** (≈10 km) before dissipation.

More powerful tornados have been observed:

- Wind speed ≈ 500 km/h,
- Base diameter ≈ 1.5 km,
- Travel > 100 km.

2. Wind - Tornados

- **Tornados** are common and frequent in the U.S. plains.
- **Some** tornados are **observed in Europe**:
  - Netherlands (> 20/year),
  - U.K. (≈ 50/year),

  but with a much smaller power than in the US:
    - ➢ up to now, in Eurocodes, the damages are considered to be so localised and with such a small probability of occurrence that **they are not taken into account**.

3. Water

3. **Water** - Erosion

- **≈20% European coasts +/- affected by coastal** erosion.
- Most impact zones (15100 km) are retreating in spite of the coastal protection (2900 km).
- Another 4700 km have become artificially stabilized.

3. Water - Erosion

- **Dynamical variability** of sandy beaches when sediment transport is controlled by:
  - **waves**,
  - **currents**,
  - **wind**,
  - **water level**,
  - **sediments**.

⇨ **Erosion situations** ⇨ construction risks.

3. Water - Erosion

- **Main causes** for coastal erosion:
  - the **generalized sea level rise** due to climate changes,
  - **coastal interventions** ⇨ some negative effects,
  - **littoral occupation**,
  - **exterior interventions in harbours**,
  - **river sediment supply reduction**.

3. Water - Erosion

- **Solutions:**
  - **beach artificial nourishment** ⇨ very expensive,
  - **to mitigate** coastal erosion processes in specific locations,
  - **hard coastal defences** are needed.

3. **Water** - Erosion

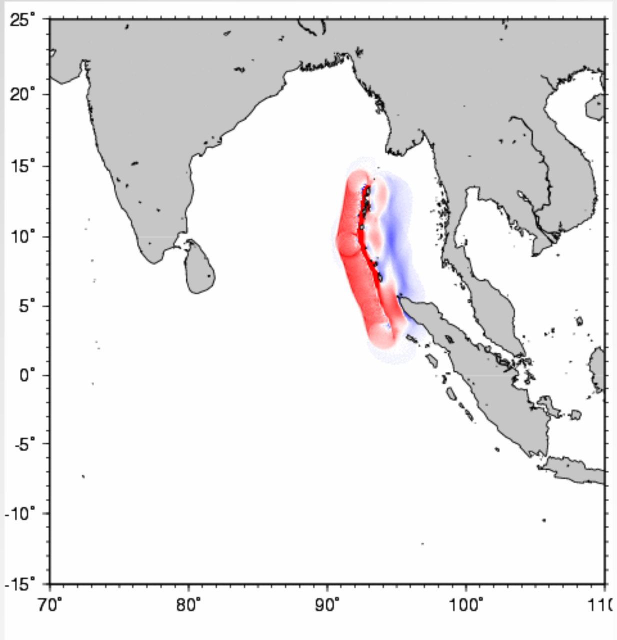
- It is crucial:
  - **to regulate** urban seafront extension,
  - to identify **new lines of defence** and to **re-settle the populations** in the interland.
- **Compromises** between passive acceptance of erosion, beach nourishment and coastal intervention for urban front protection.

3. Water - Tsunamis

- **Tsunami**: waves created by the fast displacement of very large volumes of water due to a huge natural phenomenon.
- Can be **initiated by**:
  - **earthquakes**,
  - **submarine volcanic eruptions**,
  - **seabed landslides**,
  - not by strong winds.

3. **Water** - Tsunamis

- The effects can be classified from insignificant to catastrophic regarding coastal population and constructions.



3. Water - Tsunamis

- **Waves:**
  - growing circles from the raising location to surrounding coats,
  - high speeds (mean value: 700 km/h in the Pacific Ocean),
  - a large wavelength (hundreds of kilometres).
- They travel great transoceanic distances with small overall energy loss.

3. **Water** - Tsunamis

- Far from coasts, a tsunami has wave heights <1 m. In its motion, its involves the water column from surface to sea bed.
- Approaching the coast, the sea bottom becomes less deeper :
  - ⇨ the wave front becomes higher: it can reach 20 m or +,
  - ⇨ the residual energy creates a violent displacement.

3. **Water** - Tsunamis

- Most of the damages are due to the enormous mass of water accompanying the initial wave front.

- They are originated by:
  - the wave impact on obstacles,
  - the flood resulting from the sea level rising.

3. Water - Tsunamis

- Sufficient energy to **project objects** found on its path and far from the coast.
- Able:
  - **to shear** weak constructions at their base,
  - **to submerge** and to create **bending actions** on high constructions.
- The influence area depends on the relief. It can act several kilometres far from the coast which can be strongly affected.

4. Volcanic eruption

4. Volcanic eruption

- An **eruption** may be characterized by:
  - explosions,
  - projections of magma or pre-existing solid rock,
  - lava flows,
  - +/- dense clouds of ash-laden gas,
  - dust and steam.
- **Eruption may occur** from the crater or from fissures or fractures.

4. Volcanic eruption - Lava

- **Lava** may flow in a viscous mass from the crater.
- It can be **blown away** in fragments creating avalanches whose speeds may be 150 km/h.
- It creates great destructions if it occurs in constructed areas.
- The **engineering behaviour** is:
  - to avoid any kind of constructions in such areas,
  - to survey the volcano in order to predict likely eruptions.

4. Volcanic eruption - Ashes

- **Eruptions** may send ashes into the stratosphere to heights of 10-30 km above the earth's surface.
- Combined with the wind, they can spread more or less heavy materials far from the volcano.

4. Volcanic eruption

- Most building damages: when the load exceeds the strength of the roof-supporting structures or its covering.
- Ash:
  - Dry weight ≈ 4-7 kN/m^3,
  - Amplified by rain: 50-100% ⇨ >20 kN/m^3.

  - Dry layer 10 cm ⇨ extra load ≈ 0.4-0.7 kN/m^2,
  - Wet layer ⇨ 1.0-1.25 kN/m^2.

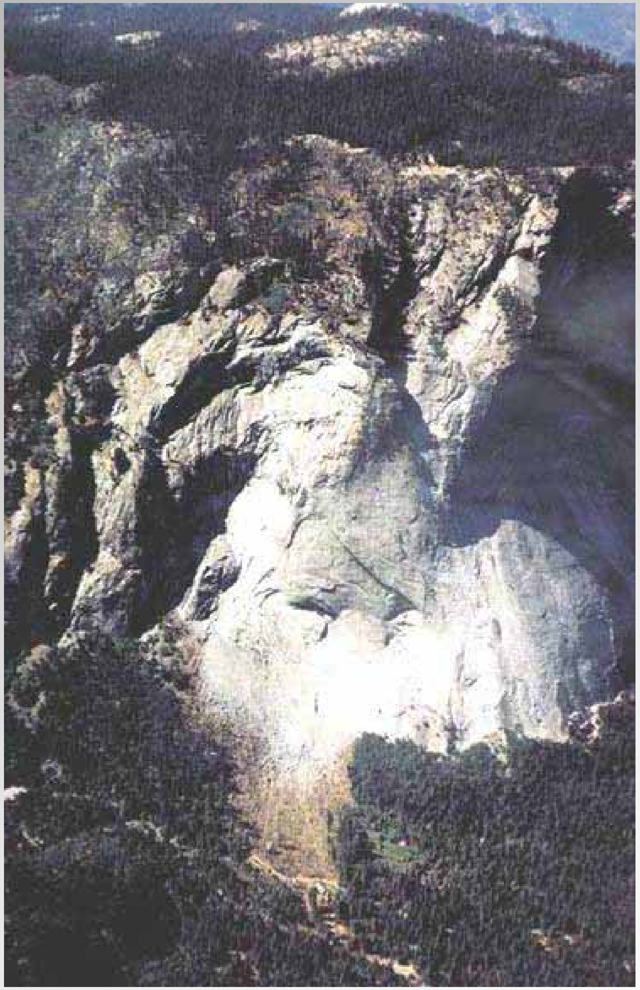
4. Volcanic eruption

Ash loading: similar to a snow load.
Differences:

- heavier, much more severe loading case,
- ash does not melt,
- ashes fill gutters and draining pipes ⇨ collapse after rainfalls.

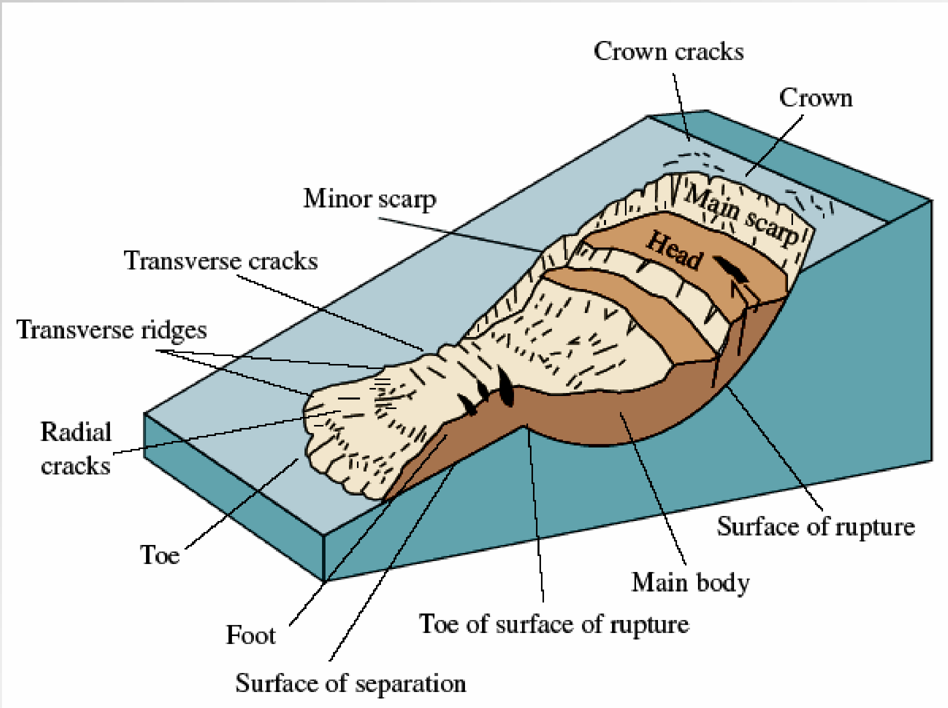
- If snow load cases exist, expected protection against ash falls: depends on the location: altitude and geographical position.

5. Landslides

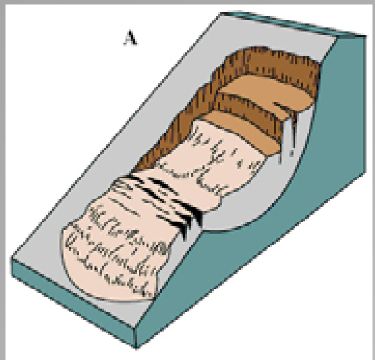


5. Landslides

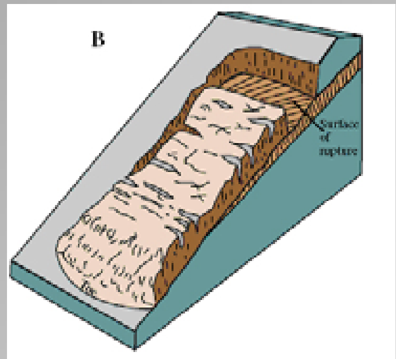
- Landslide:
  - Results in the downward and outward movement of slope-forming materials including:
    - **rock,**
    - **soil,**
    - **artificial fill,**
    - **combinations.**



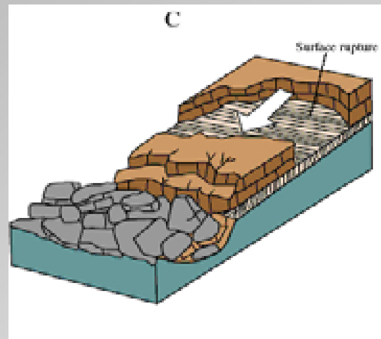
5. Landslides – Most common types



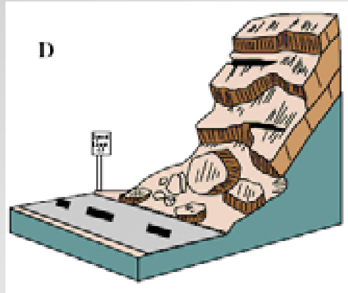
Rotational landslide



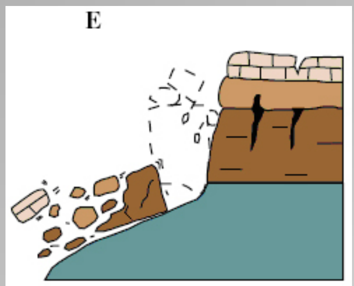
Translational landslide



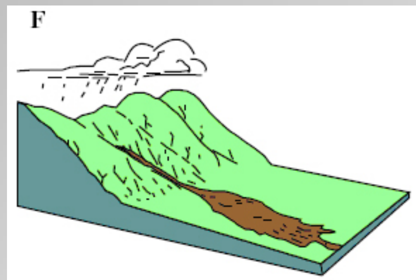
Block slide



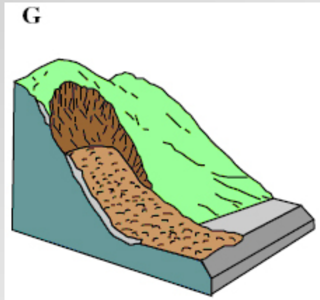
Rockfall



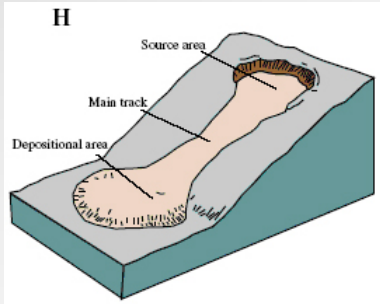
Topple



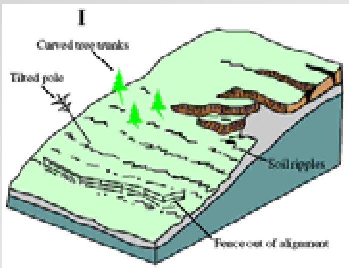
Debris flow



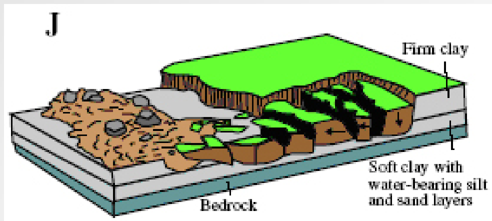
Debris avalanche



Earthflow



Creep



Lateral spread

5. Landslides – Causes

- There are many causes but **3** create most of the damages:
  - **water,**
  - **seismic activity,**
  - **volcanic activity.**

5. Landslides - Water

- **Slope saturation** by water: a **primary cause** of landslides.
- Landslides can cause **flooding** by forming dams blocking valleys and stream channels.
- Solid landslide debris can cause channel blockages and diversions:
  - ⇨ flood conditions
  - ⇨ localized erosion.

5. Landslides - Seismic activity

- The occurrence of earthquakes in steep landslide-prone areas increases the probability of landslides due to:
  - ground shaking alone
  - shaking-caused dilation of soil materials: allows rapid infiltration of water.

5. Landslides - Volcanic activity

- Landslides due to volcanic activity are **some of the most devastating** types.
- Volcanic lava rapidly melt snow ⇨ deluge of rocks, soil, ash, and water.
- Volcanic debris flows reach great distances damaging structures in flat areas close to the volcano.

5. Landslides - Stability analysis

- The conventional stability analysis of slopes is carried out by calculating the safety factor (i.e. by comparing the shearing resistance available along the failure surface).
- Several techniques are currently available to assess the post-failure velocity and travel distance of the moving mass.

5. Landslides - To reduce the effects

- How to reduce the effects of landslides:
  - to investigate the hazard history of a site,
  - to require an engineering analysis,
  - to avoid constructions on steep slopes and existing landslides,
  - to stabilize the slopes.

5. Landslides - To reduce the effects

- Slope stability is increased:
  - if ground water is prevented from rising by:
    - covering the landslide with a membrane,
    - directing surface water away,
    - draining ground water away,
    - minimizing surface irrigation;
  - when a retaining structure is placed at the toe of the landslide;
  - when mass is removed from the top of the slope.

Conclusion

- **Avalanches**, **erosion**, **extreme winds**, **landslides**, **tsunamis** and **volcanic eruptions** have been identified and briefly described according to their mechanical effects on constructions.
- Not covered by the Eurocodes, a study of the vulnerability or robustness of constructions under exceptional loading needs this preliminary phase to propose a realistic relevant modelling

WG4: Identification & classification of exposure events.

Exceptional or infrequent event scenarios.