THEORETICAL BASES FOR THE ECOLOGIC RECONSTRUCTION OF THE LANDSLIDES

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Abstract. *Landslides are coherent land masses movements down slopes, along the so-called slide surfaces which separate the slide material from the stable surface of slopes, and play a very important role both in the evolution of the relief and for the security of anthropic works. These phenomena have a strong environmental and socio-economic impact raising important risks for inhabitants and constructions, as well as technical difficulties as regards the reconstruction of lands and extremely high costs for repair works for the damaged areas (2).*

Keywords: landslides, ecological reconstruction, environmantal, risk factors

INTRODUCTION

Landslide determinants. Taking into account the complexity level of these phenomena as well as the extremely varied ways of occurrence, it is very difficult to establish the causes of landslides as it depends on the determining factors and on the geological (lithologic and structural) features of the region where they occur.

Any factor disturbing the balance of the rocks at the land surface is a cause of landslides.

Most of the landslides occur after the simultaneous action of more factors. Moreover, one action, such as the presence of water, may have a double effect reducing the critical shear stress and increasing the lateral thrust by growing the weight of the land and by raising hydrostatic pressures in the crevices from above (5).

Landslides result from the change of internal or external forces which ensure the stability of the slopes and from the degradation of the resilience features of the land. Among factors triggering landslides we mention:

Gravitation is considered the main cause triggering and moving the masses of land down slopes. The influence of this natural factor is the result of the mountain weight and the movement of the land mass takes place according to the slope inclination and to the rock type which determines the stability conditions of a slope.

Water is a fundamental cause triggering landslides, regardless of its origin either surface or underground, influencing the mechanical characteristics of the land by damping. When water infiltrates into the soil, it takes the place of the air in the interstices, crevices and other holes. As water is heavier than the air, the land may become overloaded and this favours the gravitation to the cohesion force.

In coherent soils (when particles that compose the soil are interconnected and form a compact mass) such as clays, water causes their destabilization:
the more water infiltrates in the soil, the more particles composing it distance one another creating the effect of interstice pressure. As the pressure grows, the attraction force uniting particles diminishes and the particles begin to evolve gradually independently (4).

Sandy clays and marls though have a medium cohesion when dry, they bloat when water-logged and lose their cohesion, they become plastic and they even flow. Having these features, clays and marls are defined as potential sliding rocks. Claylike lands may

retain water naturally reaching 30% of their volume. Actually, the liquid limit is very close to this value and it is estimated that the water content ranges between 32 to 45%.

The type of the land is marked by bedding in layers, specific weight, cohesion, homogeneity etc and may trigger landslides because of cohesion forces and inner friction forces variations (6).

The most favourable rocks to landslides are clays and alternation between clays, marls, puddles and sands. The most frequent landslides occur on slopes with moderate inclination (10-30 degrees) formed mainly of broken and spoiled schist.

The **relief**, represented by the slope, the degree of remoulding, exposure, previous loses of balance, may trigger or activate the landslide; irregular relief – its negative forms – allows for the accumulation and stagnation of the water coming from outflows or precipitation and its infiltration in the sliding bed.

Human action. Human action may trigger landslides by irrational deforestation, clearance and breaking up the soil of the slopes with big inclination and light soils, the execution of some constructions or roads, railways which in many places requires cuts in the slopes that reduce the resilience and trigger landslides.

According to Royal Academy of Engineering (7), the causes of the landslides are classified into two categories:

External causes:

1. change of the slope geometry
2. gradient
3. height
4. slope length
5. discharge (natural, induced by man)
6. load (natural, induced by man)
7. chokes and vibrations (unique, multiple/continuous)

Internal causes:

1. progressive fall (as an answer to the discharge)
2. expansion, bloat
3. break
4. slow tension
5. stress concentration
6. spoil
7. change of physical properties, bloat
8. chemical changes
9. erosion caused by outflow/infiltration
10. removal/wash of binders

2. Landslide occurrence mechanism. The landslide occurs when gravitation exceeds the stabilization forces, the resilience to cuts and the weight of the slope foot. On slopes, the cause of the landslide may be the overpressure caused by water from heavy precipitation or precipitation over a long period, slope overload and reduction of the counterweight of the slope foot.

In the case of a rotational landslide, the slide surface is circular and concave. The surface of rupture is characterised by a sudden rupture of the slope and the presence of crevices (3).

The scheme showing the evolution of a rotational landslide and the distribution of forces is presented in Fig. 1.

The weight of the slide (Sb) and the friction (Fr) oppose to the mass in movement (stabilisation forces) while the weight of the slide head (Sa) exerts a driving force (3).

If **Sa – Fra > Sb + Frb** then the slide occurs.

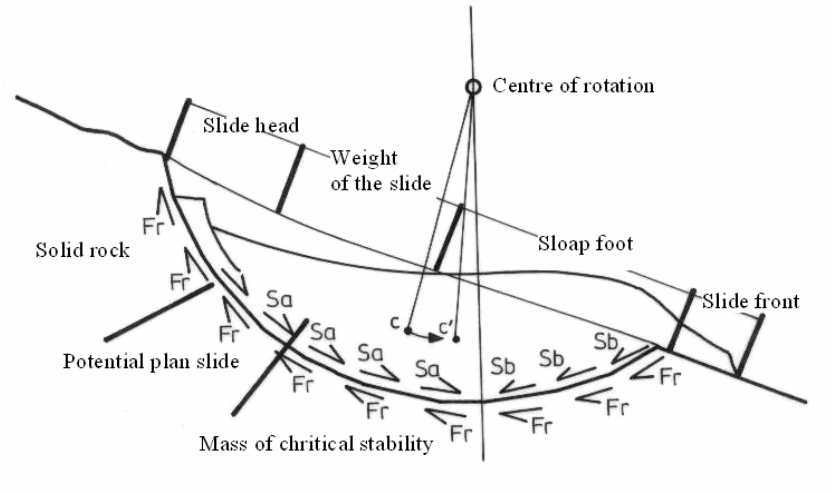

Fig.1. Scheme of the landslide

The process of landslide includes three phases: (4)

- Preparation phase, slow slide, initial slide (pre-threshold);
- The landslide (exceeds the geomorphologic threshold);
- Natural stabilisation (balance, post-threshold process)

According to Ferry, the resilience factors to landslide reflect in the Coulomb's equation: (1)

$S = C + (P-U) \operatorname{tg} \varphi$

S – critical shear stress
C - soil cohesion
P – normal pressure at surface due to gravity
U – interstice pressure of water in the soil
Φ - inner sliding angle

The landslide occurs when it is reached the mouldability limit or the liquidity limit and the friction force exceeds soil resilience.

3. **Morphology and forms of landslides.** A landslide has many elements that make up the morphology of the whole damaged land and is characterised by specific forms of manifestation defined by specific terms (Fig. 2) (8):

Landslides consist of a wide variety of process resulting from the descendent movement generated on the slope of different materials which include rocks, soil, artificial ballasting or combinations of them which may move by rockfall, topple, slide, spread or flow (image 3). (9)

Rockfalls Rockfalls are brutal movements of geological material masses containing rocks and blocks of cliffs that fall from abrupt slopes and rock-like brinks.

Topples Topples are characterised by the rotational movement around one point located above or under the land mass, under the action of gravity or of the forces exerted by the water from the crevices formed under the slide mass.

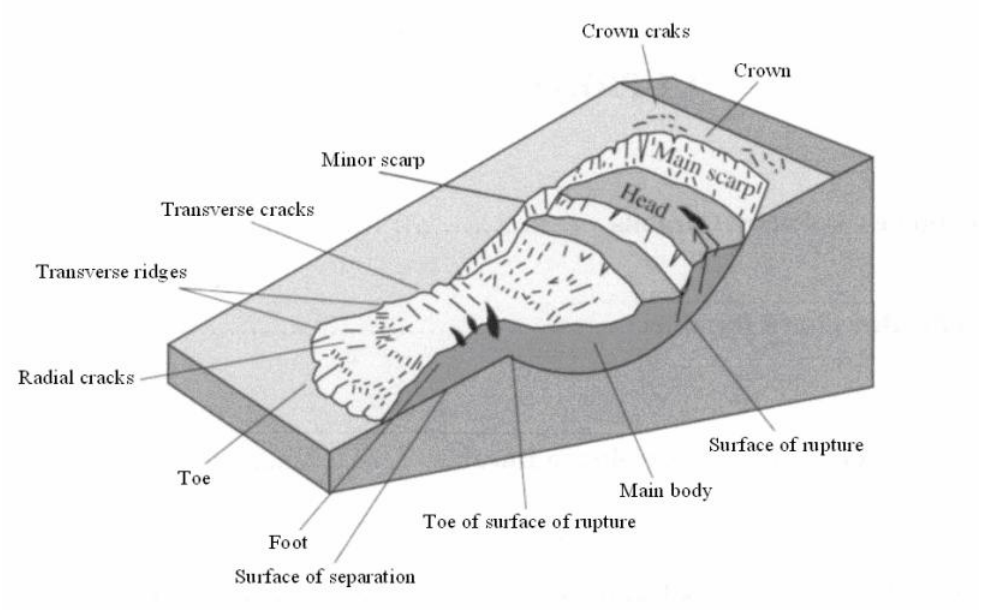

Fig. 2. Elements of a landslide

Debrisflows (flows of solid material)

Debrisflows are rapid movements of land masses characterised by a combination of loose soil, rocks, organic material, air, water that forms a muddy material (mud) which flows down the slope. This material contains less than 50% fines. This process is often caused by intense surface flows determined by heavy precipitation that erodes and damages the soil or the rocks forming abrupt slopes.

Debris avalanche

Debris avalanche is a rapid movement – very rapid movement of debris.

Earthflows

The material on the slope liquefies and flows forming upstream depression.

Mudflow

Mudflows are rapid flows of liquid earth which contains at least 50% sand, dust and clay. Sometimes, earthflows and mudflows are called mudslides.

Creep

The creep is a slow uniform movement of the soil and rocks. The movement is determined by the thrust which determines a permanent deformation. There are three types of creep: ***seasonal***, caused by the seasonal change in soil moist and temperature, ***continuous*** when the thrust is continuous and ***progressive*** when it is associated with other types of movements.

Lateral spread is a distinct form of slide which takes place on lands with small or plain slopes whose dominant movement is the lateral extension accompanied by thrust or rupture (10).

The rupture is generated by liquefaction as a result of soil saturation with water which damages sediments cohesion and transforms them in a mass with water in excess.

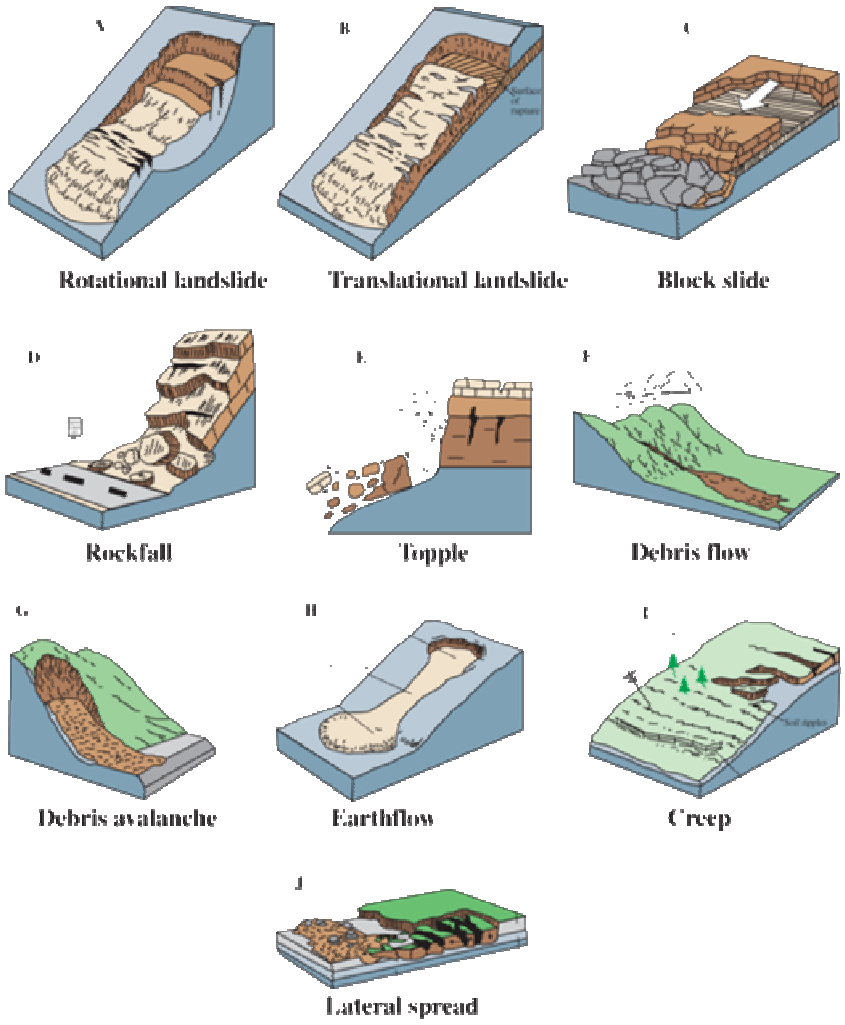

Fig. 3. Types of landslides

CONCLUSIONS

In order to solve landslide problems, it is necessary to be aware of the factors causing and conditioning landslides, of the landslide occurrence mechanism and of the types of landslides on the basis of a study on environmental engineering that should mention (5):

a) The age of landslides: contemporary or old landslides and fossil landslides.

b) evolution stage: potential landslides, active landslides and occurring landslides, recent landslides and temporary stabilised landslides and old stabilised landslides.

c) landslide direction: moving slides (regressive, sliding - they develop from the slope foot towards the ridge), detrusive (progressive, thrust - they develop from the ridge towards the slope foot) and mixed.

d) The formation of the slide surface as regards stratification: consistent slides (in the direction of the stratification inclination), inconsistent slides (the surface of the slide intersects the layers) and non-consistent (lands without stratification).

e) Inclination of the slope: slides on slopes with small inclination (up to 10^o), medium inclination (up to $10^o – 20^o$) and big inclination (over 20^o).

f) The position of the slide surface: slides inside the covering deposits, at the base of the deposits and inside the base rocks.

g) The depth of the slide surface: surface slide (up to 1m), low depth (1-2 m), medium depth (2-5 m), high depth (5-10 m) and very high depth (over 10 m).

h) The number of the slide surfaces: simple slide (with one slide surface) and complex slide (with 2 or more than 2 slide surfaces).

i) The degree of remoulding of the slide: softly remoulded lands (with rupture and relatively small crevices with unevenness smaller than 0,5 m), remoulded lands (frequent unevenness up to 2 m), very remoulded lands (unevenness bigger than 2 m with mixes of horizons and bedrocks)

j) Microrelief of the slide: slides in layers, lenticular, monticular (with hills) slides, slides in benches, in torrents, and combined slides.

k) The size of the slide surface: small slides (under 1 ha), medium slides (1- 5 ha), big slides (5-25 ha) and very big slides (over 25 ha).

l) The proportion between the surface of the slope affected by landslides and the undamaged surface: general slides down the slope, grouped in certain sectors of the slope or isolated.

m) Land stability: stable lands (undamaged by slides), lands with stabilised slides, lands with active slides and occurring slides, lands with potential slides and lands with mixed slides.

The characteristics mentioned above helps in explaining the landslide occurrence mechanism and in establishing concretely the measures and the planning and exploiting works for the damaged lands.

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