Prediction and stabilization of landslides based on their classification

A.M. Yagolnyk, S.V. Bida, I.I. Lartseva, M.O. Vovk *(National University "Yuri Kondratyuk Poltava Polytechnic")*

SUMMARY

Intensive urban development leads to the loss of large areas of agricultural land. Therefore, in recent decades, the efforts of designers are aimed at the development of areas with unfavorable engineering and geological conditions – soils that have the properties of subsidence or swelling, bulk and alluvial massifs etc. If the steepness of the slopes exceeds 5°, they are landslide-prone and special attention needs to be paid to ensuring the stability of the slopes, taking into account the anthropogenic impact. Given that landslides are common in almost 50% of Ukraine, the relevance of studying the stability of slopes is beyond doubt. Existing landslides classifications are based on various specific features that are not related to each other, which does not allow to qualitatively and fully assess the state of the slope and choose the most effective measures to prevent landslides or to combat their development. Therefore, the aim of the research was to develop a general classification of landslide processes, which would allow to comprehensively characterize the landslide process, predict the possibility of landslide development and wort out effective anti-landslide measures. We can identify five main features that researchers considered the most important: the genesis and nature of the development of landslide, the characteristics of the landslide mass, the shape of the sliding surface and the activity of landslide processes. As a result of the conducted researches the classification which allows to consider the influence of all factors and features of conditions on a possibility of development of landslide processes was comprehensively developed. The use of such a classification in the future will greatly facilitate the work to prevent the emergence of new or stabilize the development of existing landslides, as well as the design of engineering solutions for the protection of landslides.

Introduction

The need to develop areas with adverse engineering and geological conditions poses the task for scientists to ensure the operation of buildings and structures for the required time and minimize their harmful effects on the environment. One of the most difficult in this regard are the slopes, because if their steepness exceeds 5°, they are landslide-prone. The development of landslides is also facilitated by human activities, especially in areas with high population density and developed industry. Therefore, landslides are common in almost 50% of Ukraine (Velikodny et al., 2016). They are most widespread in Zakarpattia, Ivano-Frankivsk, Lviv, Chernivtsi, Mykolaiv, Odesa, Kharkiv, Dnipro regions and in the Republic of Crimea (Fig. 1).

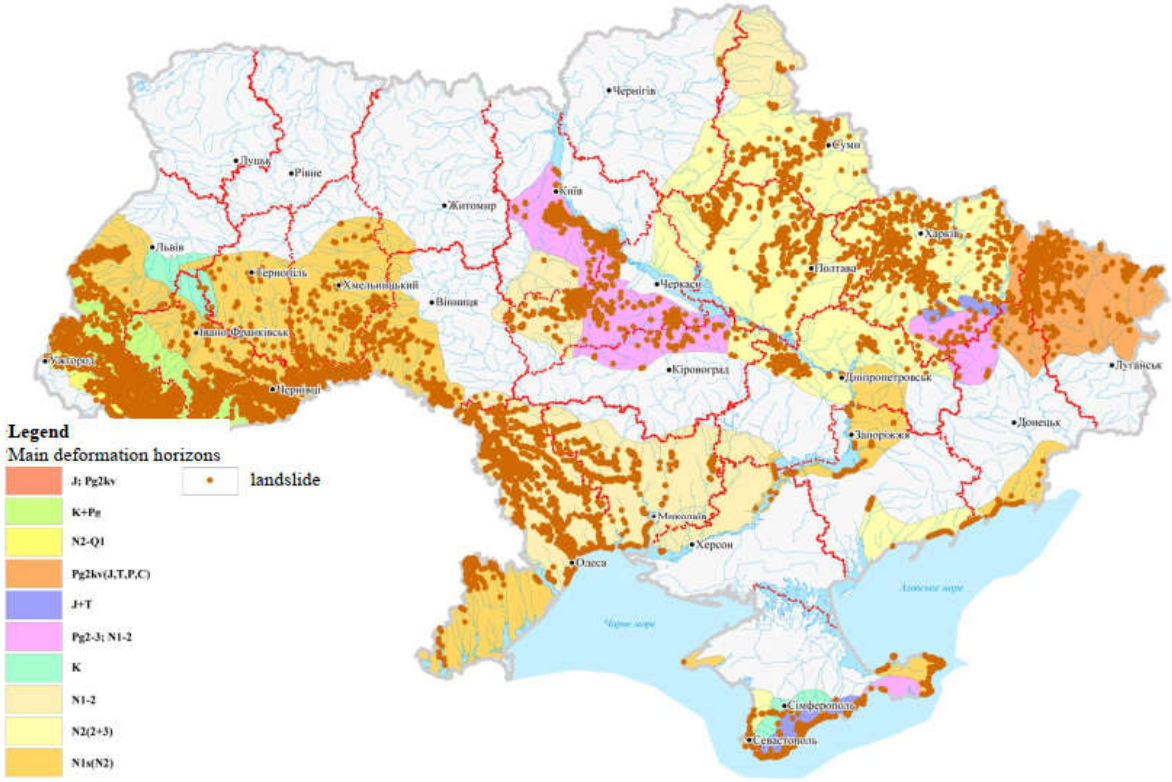

Figure 1 *Map of landslide distribution in Ukraine (according to the State Research and Production Enterprise "Ukraine State Information Geological Fund")*

Studying the origin and development of landslide processes, researchers have developed numerous classifications of landslides, which basically contain various specific features (Zotsenko et al., 2001; Maslov et al., 1997; Ginzburg, 2007). The most common and widely used are the classifications of landslides by F. Savarensky, A. Pavlov, I. Popov, and others. However, the lack of a generalized classification of landslides makes it difficult to choose the most effective measures to combat them.

Many works of both domestic and foreign scientists are also devoted to the development of methods for determining the stability of slopes (SBC, 2017; Bida et al., 2009). However, depending on the conditions of occurrence and development of landslide processes for the calculation of slopes it is necessary to use different calculation schemes. When choosing them, it is necessary to take into account a wide range of operating factors (Rudko et al., 2012), which would be much easier to do in the presence of a general classification of landslide processes. Therefore, the aim of the research was to develop a general classification of landslide processes, which would allow to comprehensively characterize the landslide process, predict the possibility of landslide development and develop effective anti-landslide measures.

Meted and Theory

After analyzing the existing classifications, we can identify five main features that researchers considered the most important. These include the genesis and nature of the development of landslide, the characteristics of the landslide mass, the shape of the sliding surface and the activity of landslide processes.

First of all, it is necessary to determine the causes of the landslide – to characterize its genesis. The causes can be both natural factors (influence of ground or surface waters, forgery of shores, weathering, temperature fluctuations, seismic, gravitational influence of the Sun and the Moon, etc.) and anthropogenic (pruning, overloading and flooding of slopes, felling, dynamic loads, reclamation work, etc.). Proper understanding of the causes of landslides will allow not only to make the most effective decisions to combat them, but also to take measures to prevent their occurrence, which is much cheaper and more effective.

If the development of the landslide could not be avoided, then its nature of development must be classified by place of origin (delapsive or detrusive shift), direction of development (progressive or regressive), the nature of landslides (sliding, flow, mixed movement), and recurrence of processes on site landslide development (single, periodic or permanent processes).

An important characteristic of landslides is the characteristic of landslide mass. We can distinguish the shape of the landslide (block, glacier, frontal shear), size (development area, volume of moving soil, depth of rock, etc.) and the speed of landslide mass movemen, the structure of the landslide body and its composition by material.

The choice of method for determining the stability of the slope depends on the shape of the sliding surface, which can also be characterized by several features. Thus, according to the ratio of the sliding surface and the structure of the slope, there are sequential, consecutive, sequential shifts. Characterizing the sliding surface in shape should be distinguished separately longitudinal and cross section. Considering the longitudinal section, it is necessary to distinguish the shape of the sliding surface, which may be due to the structure and features of the engineering-geological structure of the slope. In the cross section, it is especially necessary to emphasize the concave shape, which in most cases is the result of the presence of a coombe in the roof of the waterproof layer (Rudko et al., 2012). The ratio of the sliding surface and the ground-water level is also important, because the impact of ground-water is one of the main causes of landslides.

No less important feature in assessing the state of the slope is the activity of landslides. Usually in the literature there is a division of shifts into active and stabilized (inactive). Among the latter are recent, old and ancient landslides.

Having systematized the stated material, the general classification of landslide processes can be presented in the form of Table 1.

Calculations of landslide protection structures, as well as buildings and structures on the slopes should be performed taking into account the peculiarities of landslide processes, their classification and possible changes in physical, mechanical and strength characteristics of soils under natural or man-made factors, as well as changes in hydrogeological regime.

Implementation of a set of measures for engineering protection of the territory, taking into account the proposed classification is aimed at ensuring the stability of the slope and will create safe conditions for construction and further operation of the residential complex.

Table 1*Classification of landslide processes*

Classification feature	Type		Characteristic (reason)
Genesis	Anthropogenic		cutting of slopes
			loading of slopes
			flooding of slopes
			felling of plantings
			dynamic loads
			complex
	Natural		groundwater
			surface waters
			weathering
			forgery of shores
			mudding
			temperature fluctuations
			seismic
			sun and moon influence
Characteristics of landslide mass	By size	thickness	surface (< 1 m)
			shallow (1 – 10 m)
			deep (> 10 m)
			very deep (tens of meters)
		area	insignificant (up to 5 ha)
			small (5 – 50 ha)
			medium (50 – 100 ha)
			large (100 – 200 ha)
			very large (200 – 400 ha)
			enormous (over 400 ha)
		volume	small (up to 10 ths m^3)
			medium (up to 100 ths m^3)
			large (up to 1 m. m^3)
			very large (over 1 m. m^3)
	The speed of movement		inactive (up to 6 cm / year)
			very slow (1.5 m / year)
			slow (1.5 m / month)
			fast (1.5 m / day)
			very fast (30 cm / min)
			catastrophically fast (3 m / s)
	By the structure of the landslide body		massifs of rocks
			landslide blocks
			landslides-flows
			floats
			earthflow
			break-down
	By the material	solid rocks	separate solid blocks
			weathering products
		soft rocks	top soil
			deluvial-proluvial deposits
			bedrocks
		mixed rocks	rocks of different genesis
Characteristics of the sliding surface	By the ratio of the sliding surface and the structure of the slope		asequent
			consequent
			insequent
	By shape	longitudinal section	concave
			convex
			wavy
			zigzag
		cross section	concave
			wavy
	By the location of the sliding surface relative to the ground-water level		above the ground-water level
			lower the ground-water level
Activity	current (active)		modern
	stabilized (not active)		recent
			old
			ancient

Conclusions

The systematization of landslide processes covers most of the known classifications. It allows you to determine the features of landslides that develop or may occur on the slope. The use of such a classification in the future will greatly facilitate the work to prevent the emergence of new or stabilize the development of existing landslides. Its use will reduce to a safe level their negative impact on new construction and further safe operation of these facilities.

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