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Paper No. LF-19

Assessment and Prediction of Landslides in Slopes of Mountain-Folded Areas

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Abstract

Complex geological conditions, modern tectonic movements and close proximity of groundwater in southern Kyrgyzstan cause intensive development of landslide processes. The main cause of landslides in the area is the long rains and seismic impact on the slope, as the area refers to areas with high seismic risk. After years of observation and experience, has developed a methodology assessing the sustainability of the landslide dangerous slopes with the influence of humidity rock geomechanical parameters of the rock mass, taking into account the action of seismic forces and the groundwater level. The paper presents the methodology for assessing the stability of slopes in the mountain-fold areas, taking into account the special characteristics of overlying rocks, their moisture action of seismic forces and the groundwater level.

1. Introduction

Kyrgyzstan is located in the north-east of Central Asia, from the south-western part of the treat-folded mountain system of the Tien Shan and the northern parts of the Pamir mountain system. The whole country is at elevations of more than 400m above sea level, where almost 95% of the territory is covered by mountains at an altitude of more than 1000m above sea level. Intensive development of mountain and foothill areas of Kyrgyzstan is inevitably accompanied by the negative impact on the environment, change the steady natural balance. Of the 70 kinds known in the world of hazardous natural processes and events that cause significant damage to the population and the economy, more than 20 occur on the territory of Kyrgyzstan.

Kyrgyzstan is among the countries with developed landslide activity. In the mountain-fold areas feature formation and activation of landslide displacements are the geological structure of the slope, the active tectonics of the region, the height of slopes and disturbance constituent rocks. Complex geological conditions, modern tectonic movements and close proximity of groundwater in southern Kyrgyzstan cause intensive development of landslide processes. The greatest number of landslides occurs in the medium-and high-altitude areas are mainly formed in the cover formations lying on the rocks fundamental basics of mountain slopes, and often occur suddenly [1].

2. Landslides in Kyrgyzstan

Disturbance of the equilibrium state of the slopes is due to excess shear forces on retaining or otherwise - in excess of external forces on the strength of rocks. One should distinguish two main types of disequilibrium or slope stability: the landslide and collapse. If the resultant force of gravity on the selected slope of the lower block extends beyond the slip line or main deforming horizon and thus the force of gravity is greater tensile strength of rocks, it will block the gap and broken his connection with the slope. Such a mechanism disequilibrium slope leads to a collapse or collapse. If the imbalance occurs when the selected block, provided that the resultant force vector intersects the surface of the base gravity deformable horizon while gravity exceeds the shear strength of the rock, such mechanism leads to the development of a landslide. [2]

Landslide processes in Kyrgyzstan developed mainly in the area of distribution of mezo-cainozoic and mid foothill zone. It revealed a single and continuous development of landslides in eluvial-diluvial cover bedrock. Large number of them confined to the area of distribution of shale strata. The intensity of landslides due to the complex geology, precipitous terrain, composition and properties of soil and rock formations cover fundamental basics of mountain slopes, neotectonics, amount of rainfall and changes in groundwater levels.

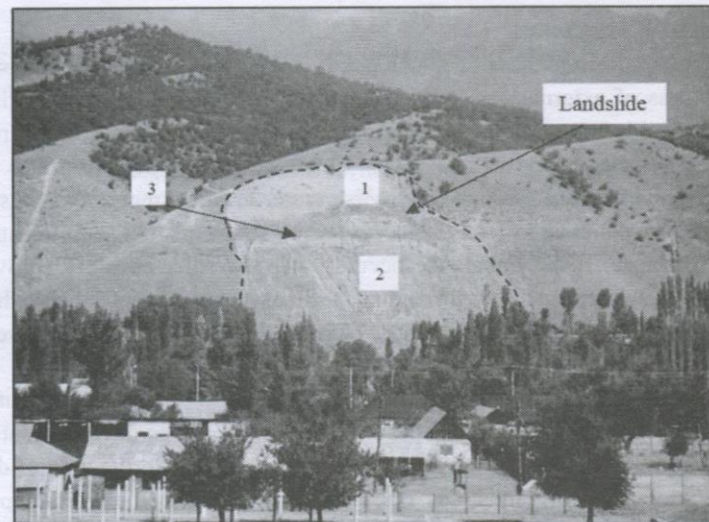
After many years of observing the manifestation of landslide processes in Kyrgyzstan found that mass manifestation of landslides observed in wet years and maximum position of groundwater level. Results in the south of Kyrgyzstan, there are more than 2,500 landslides.

Of which 98% is confined to the primary landslide slopes, with 59% of landslides developed on the slopes of the northern, northeastern and northwestern exposures. More than half of a landslide (63%) is formed on very steep slopes erosion. Of all the surveyed landslides, there are 50% of the surfaces, i.e. such that the length of the fall by far exceeds the power of the overburden. Of these landslides flow (flows) - 24%, landslide slip - 5% and landslides complex motion - 24%. While 56% have a depth of landslides capture from 1.5 to 10 m with the manifestation of groundwater is 20% landslide, 36% of them are formed at a constant level of groundwater. [3]

Landslide areas in Kyrgyzstan are mainly located along rivers and often have a linear distribution. The development of modern landslides occurs on the body of ancient landslides on the slopes and not yet affected by landslide processes, and new landslides formed more frequently than the old activated.

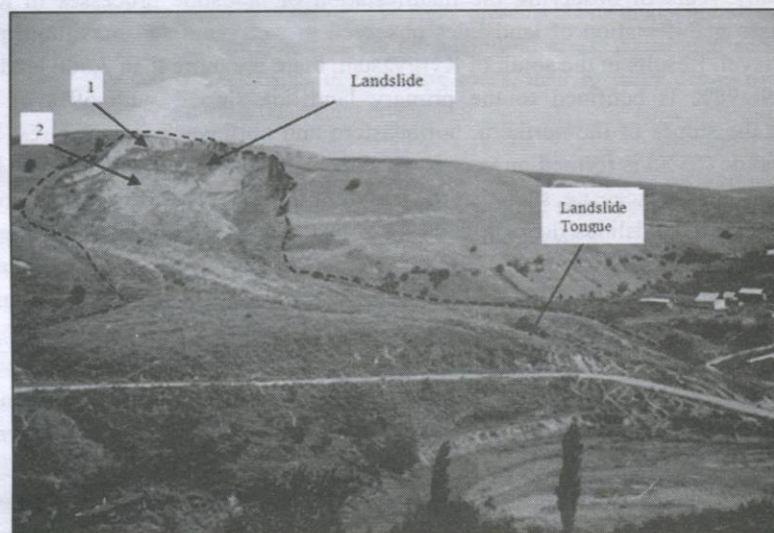
Consider the slope of the landslide in the village Oogan-Talaa Jalal-Abad region. Landslide formed in 1999, it re-activation was observed in 2004. (Fig. 1) Directly under the landslide slope is the village. When reactivate the landslide damaged three houses.

Another landslide site in the south of the country in the Osh region has two landslide steps that are clearly separated from each other. Language landslide slides to the river, which runs at the bottom of the slope. General view of a landslide is shown in Figure 2. Landslide body is very large; it has numerous cracks, many of spiny plants and reeds. Also there are ocean and gypsum deposits on the side.



1- first step landslide; 2-second landslide stage; 3 horizontal platform.

Figure 1. General view of the landslide slope Oogan-Talaa



1- first step landslide; 2-second landslide stage;

Figure 2. General view of the landslide slope Nichke-Sai

3. Landslide Stability Analysis

The main cause of landslides in the area is the long rains and seismic impact on the slope, as the area refers to areas with high seismic risk. Seismicity of the region according to BcaR 20-02.2004 is equal to 9 points.

A significant increase in precipitation in winter, increases moisture reserves in the soil and the soil and leads to activation of landslide processes. To meteorological factors play a significant role in the revitalization of landslide processes relates moisture regime terrain. Average rainfall according to Weather-500mm is per year with variations of 200-600 mm/year.

Assessment of slope stability within which power formations cover commensurate with the length of the slope, made by Bishop's methods in a combination to a method of Jambu. In this case, the results of geological and geomechanical studies calculated the location of the main deformable horizon. Within this horizon should calculate retention and shear forces and the relation and calculate the stability factor

$$K_{STAB} = \frac{P \cos \alpha \operatorname{tg} \varphi' + C' S}{P \sin \alpha} \quad (1)$$

where, P - mass of the entire prism possible collapse;

S - area of potential surface collapse;

C' , and φ' - calculated adhesion and calculated angle of internal friction of the potential slip surface;

α - surface attenuation angle at which might collapse.

The slope should be considered stable if the stability coefficient $K_{STAB} \geq 1,3$.

Provided that the power formations cover much less than the length of the slope, slope stability assessment and slopes were determined by horizontal forces (Maslov-Berrer method).

In this case, the stability coefficient should be calculated according to the chart

$$K_{STAB} = \frac{\sum_1^n T_i}{\sum_1^n (\pm H_i)} \quad (2)$$

where, $T = H - R = Q[\operatorname{tg} \alpha - \operatorname{tg}(\alpha - \psi_p)]$, T - part of the thrust perceived friction clutch and soil along the sliding surface;

$H = Q \operatorname{tg} \alpha$ - thrust (pressure on the wall of the underlying block) in the absence of ground friction forces between the blocks and clutch;

R - outstanding (active) part of the thrust;

Q - weight calculation unit, $Q = \gamma h l$,

γ - strength of the soil;

h - power coating formations on the slopes within the design block,

l - length calculated block;

ψ_p - angle of shearing resistance at the sliding surface, $\psi_p = \arctg\left(\operatorname{tg} \varphi + \frac{C}{\gamma h}\right)$,

C - adhesion of soil, φ - angle of internal friction

On the basis of long-term observations of materials and experience in the landslide-prone slopes, a technique was developed sustainability assessment landslide dangerous slopes with the influence of humidity rock geomechanical parameters of the rock mass, taking into account the action of seismic forces and the groundwater level.

It is known that soil moisture is crucial in assessing landslide hazard slopes.

With increasing soil moisture from 15% to 25% decrease in grip 5.5-6 times. When the humidity is 28% soil cover formations pass into a state of fluidity. On the slope is actively developing the landslide process. Figure 3 shows the change in the clutch cover soil formations on the slopes of the humidity. [4]

Landslide-prone slopes considered sustainable if the value of the safety factor $K_{STAB} = F_y - F_c > 0$. [5] Restraining forces on the elementary area taking into account the seismic action are of the form:

$$F_y = P(\cos \alpha - R_c \sin \alpha) \operatorname{tg} \varphi + Cl \quad (3)$$

where, P - weight species within the block possible collapse of the pit on the hillside;

α - slope angle;

R_c - the coefficient of seismicity;

C - adhesion;

l - probable length of the sliding surface.

Shear forces are equal:

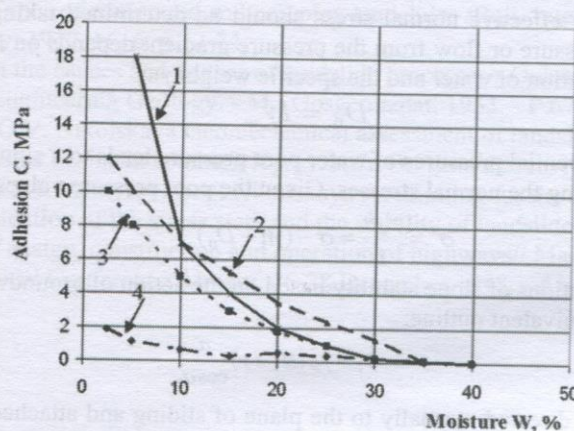
$$F_c = P(\sin \alpha + R_c \cos \alpha) \quad (4)$$

With regard to (3) and (4) the stability coefficient of road excavation on the slope of the form:

$$K_{STAB} = \frac{\int_A^B [P(\cos \alpha - K_c \sin \alpha) \operatorname{tg} \varphi + C] dL}{\int_A^B [P(\sin \alpha + K_c \cos \alpha)] dL} \quad (5)$$

In the calculations of stability should be the clutch C and internal friction angle φ in the array, using the specified part of the rock mass stability factor K_{STAB} , i.e.

$$\begin{aligned} C_m &= \frac{C_o}{K_y} \\ \varphi_m &= \frac{\varphi_o}{K_y} \end{aligned} \quad (6)$$



1 - loess with the content of the clay fraction more than 60%
2 - fine-grained loams with clay fraction containing 40%
3 - medium-loam with content worm fractions from 20 to 30%
4 - coarse loamy Contains worms fraction less than 20%
Figure 3. Adhesion dependence on moisture in the soil

In order to ensure the stability of geotechnical systems "slope- road- excavation" in seismically active regions of the stability coefficient values should be not less than 1.3.

Determining value in ground water has flooded arrays. When calculating the stability of slopes watered should take into account the nature of groundwater, i.e. they take into account the pressure or non-pressure and position of the groundwater level on the potential slip surface, estimated or natural.

In the case of unconfined groundwater, it is necessary to consider the amount of water flowing directly into the coating formation on the slope and the magnitude of this increase the weight of potentially unstable blocks provided that breed easily soak. Stability factor in this case is calculated as follows, provided that the sliding surface is above the groundwater level:

$$K_{STAB} = \frac{\sum [(P_1 + P_2 - \gamma_w h_w) \cdot \tan \varphi + Cl]}{\sum (P_1 + P_2) \sin \alpha} \quad (7)$$

where, P_1 and P_2 - the weight of the rocks above and below the groundwater level, respectively;

γ_w - strength of water,

h_w - lifting height of groundwater levels;

α - slope angle;

a - empirical coefficient depending on the strength characteristics easily soak rocks;

φ and C - adhesion and angle of internal friction of rocks

In case of pressure horizons of groundwater, slope stability calculation scheme complex geological structure, add values of the effective stress. It should be borne in mind that the effective shear stresses are almost independent of pore pressure and shear stresses are acting in

the array, and the effective normal stress should be determined taking into account the pore pressure. Pore pressure or flow from the pressure gradient depends on I , which in turn depends on the rate of filtration of water and the specific weight γ_w ,

$$D_0 = I\gamma_w \quad (8)$$

At high differential pressures of water pore pressure leads to a significant decrease in slope stability by reducing the normal stresses. Given the pore pressure values are effective stresses

$$\sigma' = \frac{\gamma_w h}{I} = \sigma - (\gamma h + D_0) \quad (9)$$

In the calculations of slope stability based on the action of groundwater body forces should be replaced by equivalent outline:

$$\Phi_i = \gamma_w (H_i - y) \frac{a_i}{\cos \alpha_i} \quad (10)$$

Power Φ_i is directed normally to the plane of sliding and attached to a midpoint between the i -th estimated units. Stability of the slope coefficient in this case is defined by the chart

$$K_{STAB} = \frac{\sum [(N_i - \Phi_i) \tan \varphi_i + C_i l_i]}{\sum T_i} \quad (11)$$

Given that the chart (11) can be written as:

$$K_{STAB} = \frac{\sum_{i=1}^n [(P_i \cos \alpha_i - \Phi_i) \tan \varphi_i + C_i l_i]}{\sum_{i=1}^n P_i \sin \alpha_i} \quad (12)$$

where, P_i - estimated weight block rocks with water enclosed therein;

α_i - angle potential sliding surface

φ_i и C_i - adhesion and angle of internal friction rocks calculated block

4. Concluding Remarks

Based on the analysis of the works found that among a variety of factors of landslides in Kyrgyzstan, the main features are:

- altitude, geology, tectonics, age rocks indigenous base coating composition of soil formations;
- landslide processes are actively developing on steep slopes at an altitude of 20-300m to 1000-2500 meters above sea level in the mezo-cainozoic rocks, mainly in mantle loams, lying on the rocks indigenous;
- formation of landslides directly related to the tectonics of the region, and landslide body formed within the fractures. The most dangerous are water-bearing fractures, which migrate to groundwater;
- maximum number of landslides is activated when an earthquake measuring 5.3 points. Large landslides are formed after the earthquake of 6-8 points in 1.5-2 years.

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