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Conceptual model of an experimental pile structure for stabilizing landslide processes

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Abstract. The paper considers a conceptual model of an experimental pile structure consisting of a vertical and inclined pile, which is proposed to be used to stabilize landslide processes. The operating principles of stud piles and anti-block pillars are described. A distinctive feature of the experimental pile structure under consideration is the combination of the advantages of known technologies for fixing landslide massifs using stud piles and anti-block pillars.

Key words: *pile, landslide, pile structure, landslide massif, anti-landslide measures*

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Концептуальная модель экспериментальной свайной конструкции для стабилизации оползневых процессов

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Аннотация. Рассмотрена концептуальная модель экспериментальной свайной конструкции, состоящей из вертикальной и наклонной свай, которую предлагается использовать для стабилизации оползневых процессов. Описаны принципы работы свай-шпилек и противообвальных колонн. Отличительной особенностью рассматриваемой экспериментальной свайной конструкции является сочетание преимуществ известных технологий закрепления оползневых массивов с помощью свай-шпилек и противообвальных колонн.

Ключевые слова: *свая, оползень, конструкция сваи, оползневой массив, противооползневые мероприятия*

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Introduction

Natural disasters have threatened the inhabitants of our planet since the beginning of civilization. There is no such thing as 100% safety anywhere. Natural disasters can cause enormous damage, the size of which depends not only on the intensity of the disasters themselves, but also on the level of development of society and its political system [*Fomichev, 2017*].

For example, landslides annually affect tens and hundreds of buildings and structures, destruction of road surfaces, collapse of slopes and embankments, collapse of structures and various accidents occur. And, of course, it should be noted that thousands of people become victims of landslides every year. This in itself is the most important factor indicating the relevance of this problem [*Simonyan, 2011*].

It is known that debris flows in mountainous regions cause significant damage to the economy and often lead to casualties among the population. To solve the debris flow problem, a comprehensive approach is needed, including monitoring, analysis, creation of maps of dangerous areas, development of mathematical models and modern methods of calculating landslide processes using software packages, conducting experimental studies, creating effective engineering structures to secure landslide masses, building debris flow protection structures, assessing the risk of debris flow disasters and mitigating the consequences of natural disasters.

Brief overview of the problem

Soil displacement in the form of landslides occurs when the shear forces exceed the forces that hold the soil. This can occur during periods of soil moisture. Landslide soil displacement occurs along a sliding surface that separates the sliding and stable soil massifs [*Maslov, 1977*].

The modern foreign classification of landslide flows identifies the following patterns of their movement: viscous flow; viscoplastic flow; sliding on a solid surface; mixed form of flow and sliding; spreading, as well as some types of debris flows with a pronounced sliding surface on a stationary underlying layer [*Cruden, 1996*].

Methods

Landslides of the "crash with shear and rotation" type can be calculated using the circular cylindrical sliding surfaces method or the equal-strength slope method, while cover landslides are calculated using the "horizontal forces" method. However, the choice of the calculation model for the flow of soil mass is largely influenced by its composition, moisture state, and the expected dynamics of movement [*Burmina, 2017*].

Therefore, it is advisable to use rheological models of viscous-plastic flow of a landslide, in the form of a structured medium, as one of the most catastrophic phenomena. From a rheological point of view, a structured medium is a medium with initial shear resistance. It is characterized by the fact that, unlike unstructured media, no flow occurs in it at stresses greater than zero but less than the initial shear resistance. Viscous flow of unstructured media is possible at any values of tangential stresses other than zero [*Buslov, 2018*].

In our case, the slope modeling was performed using elasticity theory methods and consisted of dividing the soil massif into a set of finite elements in the Plaxis software package. The calculation scheme of the massif is shown in Fig. 1.

Data

One of the possible methods of fixing landslide deluvium is the use of piles. To fix or prevent landslides, when there is a strong underlying layer in which the lower ends of piles or pillars can be embedded, retaining pile structures are used from one or two rows of reinforced concrete piles, usually bored, with a grillage or in the form of separate pile bushes, as well as reinforced concrete pillars constructed in thrust with the soil in shafts or in large-diameter boreholes. Numerous facts of the use of piles in this area indicate their effectiveness and stability as a means of combating landslides.

It is known to use pillars-nadolbs and piles-studs as a fixation of a landslide soil mass. Piles-nadolbs are a rigid element that takes up landslide pressure and works on bending. Piles-studs are similar to a flexible element that works on tension.

The pillars-nadolbs take on a colossal load from the sliding soil mass, and accordingly, the maximum bending moment occurs in these structures. To increase the bearing capacity of such a structure, to secure the sliding soil masses, it is necessary to use a significant number of pillars-nadolbs of large cross-section.

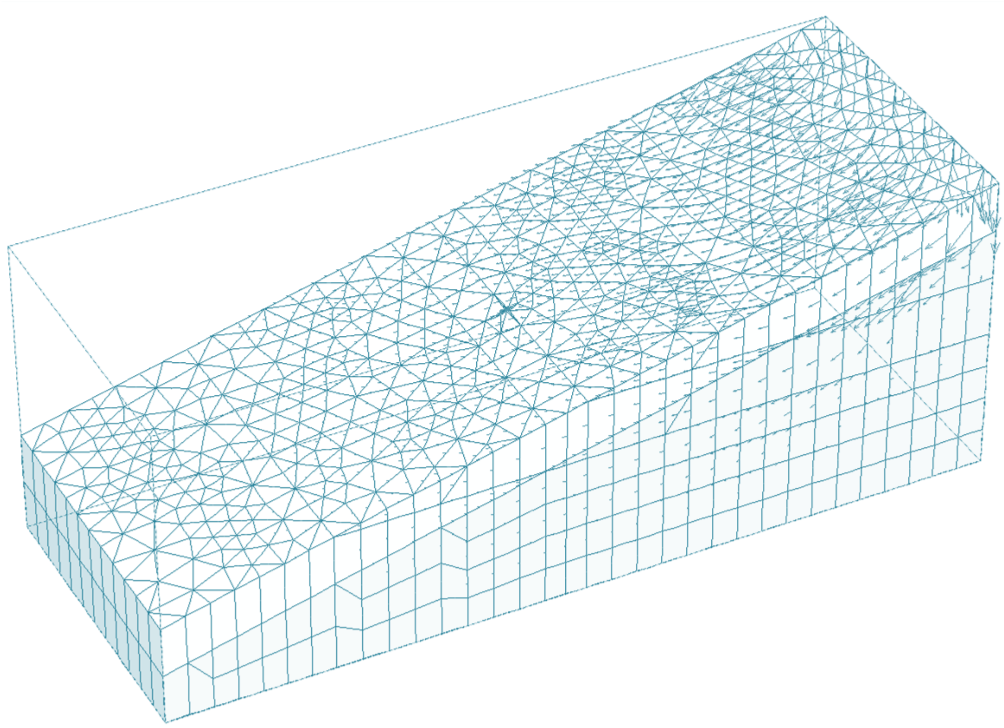

Fig. 1. Soil mass deformation diagram in the Plaxis software package

To ensure the fixing work of pile-studs in the soil massif, it is necessary that they could work in tension and were reliably fixed against tearing out both in the sliding and immobile thickness. We propose to use a conceptual model of a pile structure that combines the advantages of a pillar-nadolb and a flexible pile-stud.

This structure is a combination of two piles (Fig. 2), connected to each other by a hinge and embedded in the supporting layer of soil or bedrock, along which the sliding masses of deluvium slide.

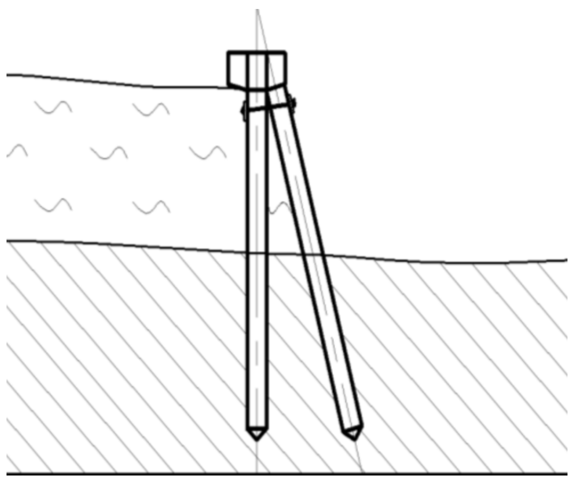

Fig. 2. Schematic diagram of the conceptual model of the experimental pile structure

Analysis

The hinged connection allows the vertical pile, which takes the pressure from the landslide movement, to work like a flexible stud pile, and the inclined pile to take the pressure from the landslide, due to its transfer through the hinge and its transfer to the foundation, performing the function of a thrust, due to which the vertical pile does not tear off. In general, the design is similar to the work of a pillar-thrust. The deformations and moment diagrams of this design can be determined by methods of structural mechanics or modeling in the LinPro software package, the calculation results are shown in Fig. 3.

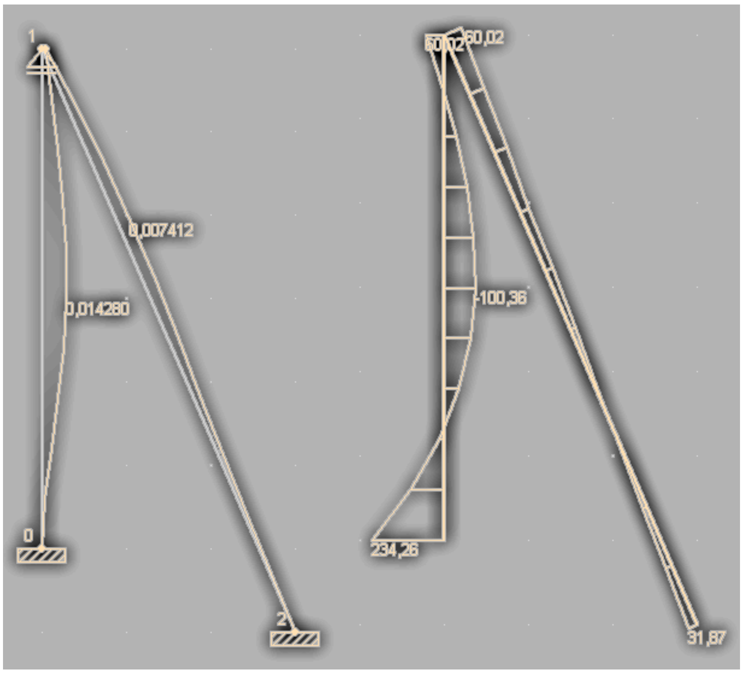

Fig. 3. Deformation and moment diagrams in the LinPro software package

It is advisable to arrange such structures in a staggered pattern, since such arrangement is justified when placing single piles, which allows slowing down the speed of movement of landslide masses. It is possible to connect the hinged heads of ordinary structures using a grillage or to introduce cross-shaped connections to impart greater rigidity and stability to the complex of proposed structures for fixing landslide masses.

Conclusions

The double pile structure allows for the strengthening of a soft soil massif with rheological properties, but in the surface zone the hinge head may "creep". As a result, it is necessary to take measures to reduce the landslide pressure that falls on each experimental structure. The fight against this phenomenon should be carried out with a simultaneous reduction in the distance between the pile rows and between the piles, the use of drainage surface measures and phytogenic measures.

The advantage of the proposed design is the simplicity of installation, the smaller depth of embedment of piles in the bearing layer in relation to the pillars-nadolbs and stud piles, as well as the smaller value of the cross-section of the reinforced concrete pile - this is due to the redistribution of forces in the paired structure of piles connected by a hinge. However, the issue concerning the dimensions of the cross-section of piles, the step in a row and between rows of paired pile structures requires additional study taking into account the angle of inclination of the additional support, which will depend on the nature of the landslide, the physical and mechanical properties of weak soils and bedrock, as well as engineering and geological conditions.

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