DESIGN STUDY OF GEOSYNTHETICAL MATERIAL SYSTEM PROTECTING HIGHWAYS FROM STONE FALL

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The project was done for the Lidoga-Vanino motorway distance (Russian Far East) due to designing and construction of rational and effective structure made of modern geosynthetic materials protecting motorway from stone fall from slopes.
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1. GOALS AND AIMS OF THE RESEARCH

The main goal of the researches done is to develop protecting structure methods to provide safety for people, facilities and transport from stone falls on motorways.

Modern developed structures provide safety from falling out products of erosion keeping their spread off the motorway territory in complex geological and technological conditions.

2. CONDITIONS AND GEOLOGICA STRUCTURE OF THE OBJECT UNDER RESEARCH

Geological and technological prospecting results showed that the slope consisted of stone bedrocks covered with weathering crust of lithosphere in a form of crushed rock on the top and clod material of 2.7m capacity.

The object under research is a motorway distance laid at the curve of the Anuy River in the Khabarovsk territory. The configuration of the slope is of two layers. The upper part of the slope is 45° to contour line; the lower one is 79°. The total height of the slope to construct the protection from falling out erosion rock products is 42.5m. The motorway of 700m long passes the slope which is characterized by rock exposures with steep sides of 20-50m high. This part of motorway is a subject for dangerous gravitational processes widely spread in this area and represented by falls. A half-pit design, which is slope facing and removing of the weathering crust, produced exposure of bedrocks. Thus, as the result of weathering, unprotected rocks provoke the falling processes and can be a threat to the transport structure within their limits. An engineering protecting design of the transport structure must prevent both screes from the upper part of the slope and fallouts of weathering products from the low part.

3. DEVELOPMENT OF PROTECTING DESIGN AND FIXING THE ELEMENTS ON THE SLOPE

In current conditions at the distance under research, all traditional ways of remodeling and protective methods (slope compaction, construction of anti-falling structures, galleries, catching facilities, distance detour, a tunnel) are labor consuming and expensive. In this particular situation the intersection method is proposed. The essence of it is installation of a screen made of polymeric or metallic net that is not fixed at the bottom of the slope. Thus, the fall of weathering material is controlled. The fallen down material is stored in the bottom trench, its cleaning up following.

The use of polymeric net is preferable. It is four times lighter than a metallic one and durable enough. It doesn't corrode and is protected from ultraviolet sun rays. A two-axis geogrid made of polypropylene of high strength is more technologically reliable and inexpensive.

Anchors and ropes are supposed to strengthen the protecting net structure on a natural slope preventing the spree movement. Later, along the slope, at the point of its transition into the pit, the net structure should be installed so, that it doesn't get close to the slope, anchors and a system of vertical and horizontal ropes being used. Anchor fittings are installed in the lower part of the slope to keep the protecting structure at the distance from the slope surface. It prevents falling rocks from storing up at the lower part and doesn't produce additional loading on the anchor fittings.

At the upper part of the slope the anchors are installed at every 3.7 meter and through them a metal rope is drawn. The polymeric geogrid is fixed to the rope. For better load spreading the geogrid is fitted with seizers at the vertical ropes that are fixed at intermediate and lower anchors with the step of 1.85m at the profile bending (Figure1).

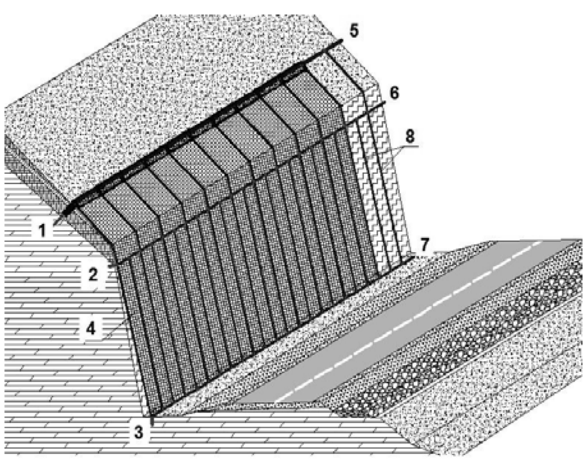

Fig.1 Engineering slope protecting structure.
1 - upper anchor; 2,3- intermediate and lower anchors; 4- SSLA-30 geogrid; 5- upper rope; 6- middle rope; 7- lower rope; 8- vertical rope

3.1. Determining pre-work parameters of structure elements

When determining parameters of the upper anchors in a first approximation, the soil resistance under the influence of horizontal pressure Rz is calculated according to the formula as a difference between the stresses of active and passive pressures calculated according to the Coulomb formula

$$R_Z = \frac{4}{\cos\varphi}(\gamma \cdot z \cdot tg\varphi + 0{,}6c) \quad (1)$$

where φ -is the angle of internal friction of soil, c- intercept cohesion, γ -unit weight of soil, z- depth from ground surface to Rz measurement level.

Horizontal pressure condition of ultimate strength of soil on an anchor is Rz

$$\sigma_z \leq R_Z \quad (2)$$

Considering the stiffness of a cross-section element being ultimately great EI=∞, and, the lower anchor end is loose (this condition creates allowance), the formula for determining stresses in soil is the following

$$\sigma_z = \frac{6 \cdot z}{bh^2}\left[\left(3 - 4\frac{z}{h}\right)Q + \left(4 - 6\frac{z}{h}\right) \cdot \frac{M}{h}\right] \quad (3)$$

where b is the width of the anchor, Q is the cutting force, M is the bending moment.

The maximum values of the applied structure loadings are used to determine the parameters of the structure working in the extreme regime: snow loadings, a mass of rock debris in the lower part and the weight of the structure itself.

The upper part of the anchor is supposed to be filled with concrete to the depth h to increase the compression area of a spongy part of the slope surface.

The capacity of the upper anchor and the amount of concrete filling are determined by calculation according to Figure 2.

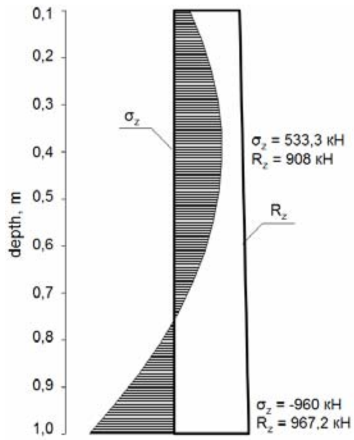

Fig.2 Epure of stresses in soils (R2) and in anchors (Ơz)

The conditions of initial parameters of the anchors installed in strong rock in the middle part of a slope are determined by calculation and are shown on Figure 3.

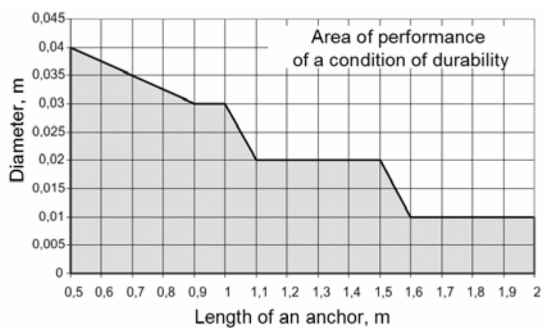

Fig.3 Conditions for performing durable behavior in rocks by an average-sized anchor

3.2. Geotechnical modeling of behavior of protecting structure elements in extreme conditions

The geotechnical modeling of behavior of protecting structure to determine more rational parameters of the elements was carried out using "FM models" programming complex developed by geotecnicians under leadership of professor V.M.Ulitsky in St.Perterburg. The complex allows to solve 3-demensional tasks of stress-deformed conditions of designs and their elements.

The elastic plastic model of Coulomb-Moor ultimate surface was used to research structure behaviors. Initial data and parameters were taken from the materials of engineering and geological surveys and from the specification of standards. The design model of the geological structure with the protecting design made of a geogrid is shown on Figure 4.

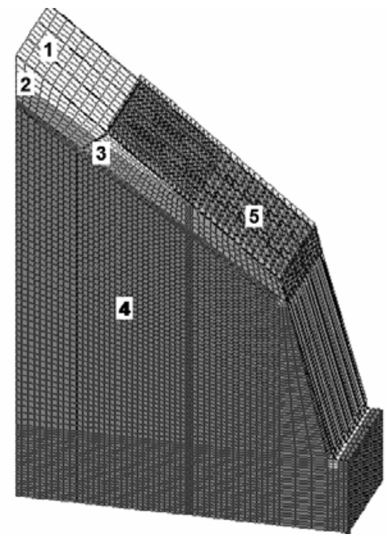

Fig.4 Design model of geological structure
upper slope; 2- crushed rock; 3- rock; 4- firm shale;
5- geogrid

The horizontal forces in ropes and anchors were determined in the process of geotechnical modeling of protecting structure behavior (Figure 5), as well as tensile stress in the geogrid and structure deformations from its weight and snow loadings.

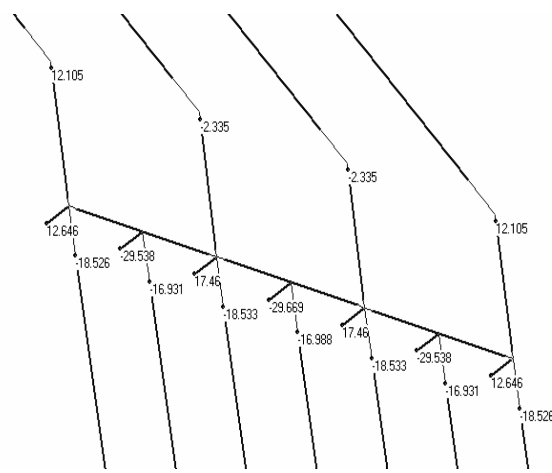

Fig.5 Horizontal forces N in ropes and anchors, kH

The results of the geotechnical modeling done allowed confirming the effectiveness and rationalism of the chosen protecting design of the structure as well as determining more rational parameters of its elements.

ACKNOWLEDGMENT:

1. The analysis of the protecting structure parameters and the results of numerical geotechnical modeling of particular element behavior carried out for different variants show that the calculated values of forces, stresses and deformations are not in the direct relationship of slope height or extreme loading values.

2. Crucial influence on the values of calculated parameters are made by: the length of the slope, its angle to the horizon and the values of extreme loadings determined by natural conditions.

3. Tensile stresses in a geogrid and its deformations generally depend on the length of the slope.

4. The greatest stresses are applied to the upper anchors.

5. Tensile stresses appearing in the protecting geomaterial are only of 15.53 kN/m that provides the geomaterial's safety margin of 48% and its work in an elastic stage.

6. Deformations of the geomaterial achieve 275mm at the greatest loadings, but its work in the elastic stage provides safety and durability of the structure.

7. The parameters of horizontal ropes accepted according to pre-calculations were confirmed by numerical geotechnical modeling providing the margin of 40%.

8. A geotechnical modeling of the protecting structure behavior allowed adjusting precalculated values taking into account the received parameters that were accurate enough.

9. Estimation of the received deformation values of the structure under loadings in the worst conditions allows confirming a good quality of the given structure and its long-term exploitation reliability.

10. The theoretical calculation study of the protecting geogrid structure carried out on the basis of the results of engineering calculations and numerical geotechnical modeling showed that the developed elements of the protecting structure are able to provide the necessary reliability and safety of the system with a certain margin in general.

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