TO DETERMINE THE PHYSICAL AND MECHANICAL PROPERTIES OF THE SOIL OF LANDSLIDE SLOPES FROM THE DEGREE OF POROSITY AND HUMIDITY

Abstract. The results of theoretical and experimental works devoted to the determination of the physical and mechanical properties of water–saturated soil are analyzed. On the basis of a comprehensive analysis, conclusions are formulated, and a method is proposed for determining...
the Young’s modulus and Poisson’s ratio for water-saturated soil, depending on humidity (degree of saturation) and porosity. Tables of data on the physical and mechanical properties of water-saturated soil are proposed. The study established the places of formation of local stress concentrations along the inclined layer. The values of dangerous stress concentrations found in various areas of the mountain slope that are vulnerable to collapse are shown in the tables.

**Keywords:** slope, ground, layers, erosion, denudation, landslide

1. **INTRODUCTION.** As in other mountainous regions of the world, landslides continuously occur on the slopes of the Northern Tien Shan. It is known that landslides are diverse, depending on the type, nature, scale, speed of movement, volume of the mass being moved, mechanism, and so on. During the landslide «Ak Kain» («Birch»), located between Almaty and its satellite city Talgar, in the spring of 2004, about a million tons of landslide mass moved from the mountain slope [1], [2]. Almost instantly overcoming the path length of 500 m with a serpentine, the tongue of the landslide «swallowed» a residential two-story house, burying 28 residents alive [3]. During the Kol Sai landslide in the spring of 2018, the landslide mass of about 50 million tons, 900 m wide, 177 m long, went continuously for 5 days [4].

The state of the mountain slope of Kok Tobe has always been alarming and today worries residents of the Eastern part of the city of Almaty because of the landslide danger. Not to mention the built modern high-rise buildings and structures located directly at the foot of Dostyk Avenue, and the western slopes are densely populated and built up [5].

The foothills and other slopes of the Trans-Ili Alatau mountains and the gorges between them around Almaty have long been inhabited. There are numerous buildings such as sanatoriums, recreation centers, sports bases, livestock farms, children’s camps, etc.

In order to take safety measures to strengthen the slopes of such populated foothill hills, it is necessary, first of all, to scientifically investigate the main patterns of landslide occurrence for specific cases, i.e., the mechanisms of occurrence for the purpose of forecasting.
The landslide state of this mountain has not yet been investigated by modern methods of mathematical modeling, computational mathematics, computer graphics, geomechanics and drilling of ultra-deep wells to bedrock. The height of the Kok Tobe Mountain is 250 m, and the height of the TV tower built on its western slope, on loose soils, is 372 m (Fig. 1) [6].

![Fig. 1. TV tower erected on top of the landslide dangerous Kok Tobe Mountain in Almaty, Kazakhstan [7]](image)

Back in 2005, in the early spring after heavy rains on Kok Tobe, significant cracks appeared, the ground began to slide and buildings began to collapse. There was a real threat of a landslide on residential areas located nearby.

For scientific research using geomechanics, mathematical modeling, and computer technology, the physical and mechanical properties that pass into a three-phase state before the start of a landslide are not yet known. Due to the penetration of thawed, atmospheric and communication water, the soils adjacent to the soil-plant layer become more water-saturated. Before starting any construction on the slope and under it, you need to calculate whether it will be strengthened or not. To do this, it is necessary to check its stability and moisture content. Over the years, all stingrays
become heavier due to humidity. This phenomenon shows the three-phase (solid, plastic and fluid) state of the cover soils, especially in the spring during the heavy rain season.

In 2017 alone, 64 cases of spontaneous landslides occurred in the eastern territory of Almaty in early spring. In the month of may because of a sharp rise in temperature, melting snow and heavy rains recorded 35 landslides. In this regard, it is necessary to solve the following tasks:

The review and analysis of the Kok Tobe data suggests that the process of dangerous accumulation of water in deep layers is taking place in the soils of its slopes. When it reaches the surface of the underlying rock, the probability of a sudden huge slip of the mass of soil on them will increase.

By their natural nature, the soils of mountain slopes are formed by layers of variable thickness, moreover, they have obliquely layered structures. Analyses of previous years works, except for the isolated works of Polubardinova-Kochina, show the paucity of studies of the cover soils of landslide slopes of anisotropic structure.

The cause of landslides on mountain slopes due to precipitation is also indicated [8] by Abid Ali, Jinsong Huang, A.V. Lyamin, S. W. Sloan, J. H. Li. (2014) The following authors Laura Longoni, Monica Papini, Davide Brambilla, Diego Arosio, Luigi Zanzi (2016) modeled the Ranko landslide on a deep gravity slope in Italy [9].

One of the places where a landslide occurs is cut sections of mountain slopes in order to pave the road. The work Slavka Harabinova (2017) [10] is devoted to assessing the stability of slopes on roads. Often, the cover soils of the slopes are formed by loess, which are found in places on Koktobe. Landslides occur from time to time on the bypass roads laid by undercuts of the north–western foot of Koktobe. The loess landslide of the Jangyang Plateau was investigated by Yanqiu Leng, Jianbing Peng, Qiyao Wang, Huang (2018) [11].

These reviews form the basis of theoretical preparation of scientific research by methods of geomechanics and mathematical modeling.

2. ON ONE DEVELOPED APPROACH FOR DETERMINING THE EQUIVALENT ELASTIC PROPERTIES OF WATER-SATURATED SOIL
To perform calculations to determine the stress-strain state of landslide-prone slopes with a water-saturated cover layer, for the accuracy of the calculations, it is necessary to set the physical and mechanical properties (FMS) of the soil corresponding to the specified humidity. The works of Z. G. Ter–Martirosyan [12] and for water-saturated two-phase soil, L. A. Eisler, etc. [13], [14] are devoted to the determination of the elastic properties of wet soil.

The value of the elastic modulus $E$ for water-saturated soil can be calculated using the usual expressions of the theory of elasticity, if experimental data on the shear modulus $G_0$ or volume deformation are known $K_0$, Z. G. Ter-Martirosyan gives some such dependences for water-saturated soil [12]. Figures 2a and 2b show the graphical dependencies from this work. As can be seen from the figure, with an increase in the value of humidity $W$, with different density of the skeleton, the values of the shear modulus $G_0$ and volumetric deformation $K_0$ and strength $C$ characteristics also fall.

For each step of increasing humidity, taking the values $G_0$ or from these graphs, the value $K_0$ of the Young’s modulus $E$ for moisture-saturated soil can be calculated using one of these formulas.

Between the elastic modulus and the shear modulus, as well as between the volume strain, there are the following dependencies.

$$E = 2G_0(1 + \nu), \quad E = 3K_0(1 - 2\nu)$$

(1)

Since the value of the Poisson’s ratio changes slightly and has almost no effect on the results of the elastic calculation, it can be left constant.

In addition to the single work of L. A. Eisler, there are virtually no explicit analytical expressions for determining the Young’s modulus $E$, Poisson’s ratio $\nu$, and $\gamma$, $1 \cdot 10^2 \text{Mh/m}^3$ volume weight for water-saturated soil [13], [14].

When experimentally determining the elastic properties of a multicomponent material, errors are introduced due to averaging in the form of a quasi–homogeneous material. Such errors are also unavoidable in theoretical consideration, which affect the result of the study of the regularities of the distribution and concentration of stresses in the object. Below are some considerations for an approximate consideration of this issue for water-saturated soil.
According to [13], [14] the volume compression modulus of the soil $K_V$ is calculated by the expression.

$$K_V = \frac{E_r}{3(1-2v_r)},$$

(2)

Where $E_r$, $v_r$ is the modulus of elasticity and the Poisson’s ratio for the soil. The reduced volume module for water-saturated soil is determined by combinations of modules for solid particles $K_T$ and water $K_B$ [13], [14]:

$$K_T = \frac{E_T}{3(1-2v_T)},$$

$$K_B = \frac{E_B}{3(1-2v_B)},$$

(3)

$$K^+ = \frac{K_T K_B}{K_T - K_B}.$$

For water, $K_B = 2000$MPa [15]. Based on the above relations, we will write down the expressions of elastic characteristics for an averaged material that simulates a water-saturated soil. In the quasi-one-component case, taking into
account the joint movement of the components, i.e. without taking into account the outflow of water from the soil pores, we have

\[ K^3_V = \beta K^*, \]  

(4)

Where \( \beta = 1 + \frac{nK_T}{K_T^*} \), \( K^* = \frac{K_T K_B}{nK_T + mK_B} \) is the volume compression modulus of the «ground mass», here \( n, m \) – is the fraction of the volume contents of the solid and liquid (gas-saturated) components in the soil, respectively.

Now the given elastic modulus \( E^3 \), Poisson’s ratio \( \nu^3 \), and shear modulus \( G^3 \) for water-saturated soil are calculated by the expressions:

\[ E^3 = \frac{9\beta K^* G}{3\beta K^* + G}, \]

\[ \nu^3 = \frac{3\beta K^* - 2G}{2(3\beta K^* + G)}, \]

\[ G^3 = G. \]

(5)

The degree of porosity of the soil is specified according to N. A. Tsytovich [6]:

\[ \eta = \frac{n}{m} \text{ or } \eta = \frac{n}{1-n}. \]

(6)

As you can see, \( n + m = 1 \). They are directly included in the expression for \( K^* \). By expression (6), you can set the type of soil. So, values equal to 0.2 1.5- correspond to the usual, 2 12-organ-mineral soil, or \( \eta <1 \) - defines the compacted, \( \eta >1 \) – loose soil.

3. PREPARATORY CALCULATIONS FOR DETERMINING THE FMS OF SOILS FROM THE DEGREE OF HUMIDITY AND POROSITY

According to formulas (1)-(6), we calculated the elastic properties for water-saturated runes composing landslide slopes with different variations in the ratio of solid and liquid components of soils. The results are given in Table 1.

| Type of soil                 | \( E_1, \text{MPa} \) | \( \nu_1, \text{MPa} \) | \( n, \% \) | \( m, \% \) | \( E^3, \text{MPa} \) | \( \nu^3, \text{MPa} \) |
|-----------------------------|------------------------|------------------------|------------|------------|------------------------|------------------------|
| Clay tape layered soft plastic | 8                      | 0.42                   | 90         | 10         | 7.99                   | 0.419                  |
|                             |                        |                        | 80         | 20         | 7.97                   | 0.418                  |
|                             |                        |                        | 70         | 30         | 7.92                   | 0.406                  |
Here $E_r$ – is the modulus of elasticity at natural soil moisture,

$\nu_r$ – Poisson's ratio in the natural moisture of the soil,

$n$ – share content in the soil solid components

$m$ – share content in the soil liquid components,

$E^3$ - reduced modulus of elasticity for water-saturated soil,

$\nu^3$ – the reduced Poisson’s ratio for water-saturated soil.

In the process of moving the landslide mass down the slope when meeting with an obstacle (irregularities, roughness, etc.), the phenomenon of buckling will occur. Buckling is also possible in the broad sense in the natural process of drainage of water-saturated soil and on a global scale in tectonic compression. In all these cases, the bulging occurs due to reverse compression or stretching. Therefore, it is appropriate to determine at least theoretically the value $\sigma_r$ of the Mohr circles

If you know the critical strength parameters—the force $C$ -of adhesion and the $\phi$ angle of internal friction $\tau 0 \sigma$, then applying them to the axes of the coordinate system, it is not difficult to determine the corresponding ones $\sigma_{max}$ and $\sigma_{min}$. According to D. H. Trollope, the latter with the opposite sign will correspond to the tensile stress, i.e. [17].

For the soils indicated in table 1, a complete table of physical and mechanical properties has been compiled (Table 2). In part I of the table, the values according

| Soil Type                      | $E_r$ | $\nu_r$ | $n$ | $m$ | $E^3$ | $\nu^3$ |
|-------------------------------|-------|---------|-----|-----|-------|---------|
| Hard sandy loam               | 0.32  | 0.32    | 0.32| 0.32| 0.32  | 0.32    |
| Loam                         | 0.31  | 0.31    | 0.31| 0.31| 0.31  | 0.31    |
| Flowing sandy loam           | 0.35  | 0.35    | 0.35| 0.35| 0.35  | 0.35    |
| Clay thin-layered solid      | 0.35  | 0.35    | 0.35| 0.35| 0.35  | 0.35    |
to N. S. Bulychev [18] are located, and the data of part II are calculated by us according to the formulas according to N. N. Maslov [19], as well $\sigma_r$- as the shear resistance tensile, $\sigma_{sc}$- shear resistance during compression and $\tau_{sh}$- the ultimate shear resistance is determined by us theoretically through the Mohr circles:

1) bulk weight of the soil skeleton:
$$\gamma_c = \frac{\gamma_f}{1+W},$$

2) specific gravity of the soil:
$$\gamma_s = \frac{\gamma_f}{1-W(\gamma_f-1)},$$

$$n = \frac{\gamma_s - \gamma_c}{\gamma_s - \gamma_c},$$

3) soil porosity:
$$\varepsilon = \frac{n}{1-n},$$

4) porosity coefficient:

5) moisture capacity (the moisture content of the soil that it would have at a given porosity in the case of complete saturation with water):
$$W_e = \frac{e \gamma_f \times 100\%}{\gamma_s}.$$ 

6) the volume weight of the soil corresponding to the total moisture capacity:
$$W_v = \frac{e \gamma_f \times 100\%}{\gamma_s}.$$ 

### Table 2

Values of physical and mechanical properties of mountain slope soils as a function of humidity

| № | Type of soil                 | I-part                  |
|---|------------------------------|-------------------------|
| 1 | Clay tape layered soft plastic | $W_e$, % | $\gamma_f \times 10^2$, MH/m$^3$ | $C \times 10^2$, MPa | $\varphi^0$, MPa | $v_f$, MPa | $E_r$, MPa |
| 1. | Clay tape layered soft plastic | 36      | 1.89      | 0.8  | 16     | 0.42     | 8         |
| 2. | Hard sandy loam             | 22      | 1.98      | 1.2  | 20     | 0.32     | 9         |
| 3. | Loam                        | 20      | 2.04      | 2.0  | 22     | 0.40     | 12        |
| 4. | Flowing sandy loam          | 15      | 2.28      | 2.0  | 26     | 0.31     | 18        |
| 5. | Clay thin-layered solid     | 12      | 2.15      | 20   | 25     | 0.35     | 300       |
Here \( W \) is the natural moisture content of the soil,

\( \gamma_s \) - volumetric weight of the soil,

\( C \) - coefficient of adhesion,

\( \varphi \) - angle of internal friction,

\( \nu_s \) - Poisson’s ratio,

\( E_g \) - modulus of elasticity,

\( n \) - porosity of the soil,

\( \varepsilon \) - porosity coefficient,

\( W_e \) - total moisture capacity,

\( \gamma_c \) - volumetric weight of the soil skeleton,

\( \gamma_{gc} \) - specific gravity of the soil,

\( \gamma_e \) - volumetric weight of the soil at full moisture capacity,

\( \sigma_r \) - tensile shear strength,

\( \sigma_s \) - resistance to shear during compression.

In table 3 the calculated volume of water required to achieve a given soil moisture in a single volume, the humidity was set in the range from natural humidity. Yes total capacity, calculations have been carried out also according to the formulas in Maslova [19]:

1) the volume weight of the soil corresponding to the specified humidity (Wz):

\[
\gamma_{s,\text{calc}} = \gamma_c \left(1 + \frac{W_z}{100}\right),
\]

2) volume weight of water:

\[
q_v = \gamma_c (W_s - W).
\]
Table 3

Values of the volume weight of slope soils depending on the degree of humidity

| Type of soil                        | \( W_v, \% \) | \( \gamma_{a,сл.} \times 10^2, \text{ МН/м}^3 \) | \( q_a, \text{ тонна} \) |
|------------------------------------|----------------|-----------------------------------------------|------------------------|
| Clay tape layered soft plastic     | 40             | 1,91                                          | 0,055                  |
|                                    | 45             | 1,99                                          | 0,123                  |
|                                    | 50             | 2,06                                          | 0,191                  |
| Hard sandy loam                    | 30             | 2,11                                          | 0,129                  |
|                                    | 35             | 2,19                                          | 0,210                  |
|                                    | 40             | 2,27                                          | 0,291                  |
| Loam                              | 25             | 2,13                                          | 0,085                  |
|                                    | 30             | 2,21                                          | 0,170                  |
|                                    | 35             | 2,29                                          | 0,255                  |
| Flowing sandy loam                 | 20             | 2,38                                          | 0,099                  |
|                                    | 25             | 2,48                                          | 0,198                  |
|                                    | 30             | 2,57                                          | 0,297                  |
| Clay thin-layered solid            | 15             | 2,21                                          | 0,057                  |
|                                    | 20             | 2,30                                          | 0,153                  |
|                                    | 25             | 2,40                                          | 0,249                  |

In the mountain gorges on the outskirts of Almaty there are a large number of sanatoriums and boarding houses such as Ak Kayyn, Ak Bulak, Koktem, Ak Kainar, Shym Bulak, Alma–Arasan, Almaly «in Turgen» Blue Mountains and so on. In addition, there are a large number of buildings and engineering structures for various purposes. Most importantly, at the foot of mostly steep slopes and in the inter-slope gorges, among the foothill hills, there are a myriad of settlements.

4. ALGORITHMS FOR NUMERICAL SOLUTION OF THE PROBLEM OF STABILITY OF SOIL DEPOSITS OF LANDSLIDE SLOPES

Conducting studies of the landslide process by finite element modeling allows us to predict the appearance of dangerous stress concentrations responsible for the
occurrence of new landslides in various areas of the water-saturated slope, taking into account the heterogeneous structure of the cover soils.

The analysis of the criteria for determining stability allows you to choose the most appropriate ones for determining the stability of landslide slopes using the finite element method (FEM).

The finite element equation of the static equilibrium of the slope soil has the form [20]

\[ [K][U] = [P], \] (7)

where \([K]\) is the stiffness matrix of the system; \([U], [P]\) - vectors of unknown displacements and known forces that are formed for the considered finite element from the weights of the overlying elements.

After solving the system of equations (7), the components of the displacement vector become known \([U]\). The strain and stress components are calculated using the following known FEM ratios.

\[ \epsilon = [B][U], \] (8)

\[ \sigma = [D][\epsilon], \] (9)

where \([\epsilon]^T = \{\epsilon_x, \epsilon_z, \gamma_{xz}\}\) - components of deformations; \([B]\) - gradient matrix; \([U] = \{u, \varphi\}\) - vector of components of displacements; \([\sigma]^T = \{\sigma_x, \sigma_z, \tau_{xz}\}\) - vector of components of stresses; \([D]\) - matrix of elastic characteristics.

After solving the system of algebraic equations (7), the components of the displacements at the nodal points of the computational domain become known. Then, based on the found displacements, the strain components are calculated according to expression (8), and the stress components according to (9) in each finite element. Using these stress components, the maximum and minimum main stresses in each element and the directions of the main sites are calculated \(\bar{\alpha}\)

\[
\sigma_{\text{max, min}} = \frac{1}{2} (\sigma_x + \sigma_z) \pm \sqrt{\frac{(\sigma_x - \sigma_z)^2}{4} + \tau_{xz}^2},
\] (10)

\[
\tau_{\text{max, min}} = \pm \frac{\sigma_{\text{max}} - \sigma_{\text{min}}}{2}.
\] (11)
To determine the ultimate equilibrium, we use the Coulomb-Mohr criterion for a disjoint soil, which has the form [20].

$$\tau_{npeo} = c + \sigma \tan \varphi,$$  \hspace{1cm} (13)

where $\varphi$ is the angle of internal friction, $C$ is the coefficient of adhesion, and $\sigma$ is the normal stress component. Strength tests are carried out by various methods (indentation, application of tangential load, uniaxial, biaxial compression, etc.). But the constant parameter is the angle of internal friction. Therefore, to assess the stability of the soil around the underground structure, a convenient measure of the criterion $\varphi$ is . Such criteria are written in the following expressions.

$$\frac{(\sigma_z - \sigma_x)^2 + 4\tau_{sc}^2}{(\sigma_z + \sigma_x)^2} = \sin^2 \varphi.$$  \hspace{1cm} (14)

For cohesive soil

$$\frac{(\sigma_z - \sigma_x)^2 + 4\tau_{sc}^2}{(\sigma_z + \sigma_x + 2C\cot \varphi)^2} = \sin^2 \varphi,$$  \hspace{1cm} (15)

Another type of criterion is written in terms of the main maximum and minimum stresses, which are determined by the expressions (12) and (14).

$$\frac{\sigma_{\text{max}} - \sigma_{\text{min}}}{\sigma_{\text{max}} + \sigma_{\text{min}} + 2C\cot \varphi} = \sin \varphi.$$  \hspace{1cm} (16)

In practice, the criterion of the occurrence of the ultimate equilibrium in the form of the Coulomb–Mohr condition is often used in the following form

$$C = (\sigma_{\text{max}} - \sigma_{\text{min}} - \sin \varphi(\sigma_{\text{max}} + \sigma_{\text{min}}))/2\cos \varphi$$  \hspace{1cm} (17)

The FEM algorithm and criteria for determining the destruction of the soil (7)-(17) allows you to automate calculations for determining the stability of the cover soils of landslide slopes.

Water saturation of soils can occur due to saturation with atmospheric precipitation (infiltration), rising ground water level (filtration), as well as as a result of man-made impacts. In studies related to the determination of the stability of landslide-prone slopes, the physical and mechanical properties of soils in a dry state
are often used, due to the lack of data on the elastic properties of fully water-saturated soil. The data from the tables we have compiled can restore this gap.

5. VAT CALCULATIONS OF ONE OF THE MOUNTAIN SLOPES OF THE NORTHERN TIEN SHAN – «KOK TOBE»

The calculated Kok Tobe area shown in Figure 1, using an automatic partitioning program, was broken down into NEL=11552 isoparametric end elements with a total number of nodal points: NB=11819. The order of the resolving system of linear algebraic equations with the deduction of fixed boundary nodes was NEQ=23369. The program modules are compiled in the Fortran algorithmic language. Multivariate calculations were performed with huge numerical results.

The VAT of one of the flat sections of the mountain from the Eastern foot to the foot of the Western slope is studied. The finite element model of this cross-section is shown in Figure 3. This cross-section corresponds to the place of the mountain that runs between the TV tower and the landing station.

The results of the study on the stress components $\sigma_x$, $\sigma_z$ and $\tau_{xz}$, $\sigma_{\text{max}}$, $\sigma_{\text{min}}$, the direction of the main sites are $\alpha$ shown in Table 4.

Fig. 3. Finite element model of cross-sections of old landslides The Eastern and Western slopes (the length of the base of the calculated area is 1100 m, the view of a flat cross-section from North to South)
Values of the calculated stresses corresponding to the first two layers from the day surface down the Eastern and Western slopes of Kok Tobe, assuming that the base is rigid

| № zones | № layers | № элемент | Components of stresses in elements, Mpa | № zones | № layers | № элемент | Stress components at the main sites, Mpa | The main floor, the degree |
|---------|----------|-----------|----------------------------------------|---------|----------|-----------|----------------------------------------|--------------------------|
|         |          |           | $\sigma_x$ | $\sigma_z$ | $\tau_{xz}$ | $\sigma_m$ | $\sigma_{min}$ | $\tau_{max}$ | $\alpha$ |
| I       | 1        | 18        | -42.50    | 30.70     | 11.54       | 1         | 84         | -44.09      | 27.5        | 41         |
|         | 2        | 16        | -18.20    | -50.07    | -17.47      | 2         | 17        | -57.33      | 27.0        | -72        |
| II      | 1        | 73        | -36.73    | -63.07    | -18.28      | 1         | 65        | -93.66      | 48.5        | 17         | -59        |
|         | 2        | 81        | -18.74    | -80.80    | -18.28      | 2         | 81        | -97.20      | 33.0        | 72         | -84        |
| III     | 1        | 13        | 40.18     | -46.17    | -14.34      | 1         | 13        | -49.92      | 33.7        | -71        | 80         |
|         | 2        | 13        | 31.16     | -80.15    | -13.32      | 2         | 13        | -86.39      | 52.1        | -80        | 83         |
rise buildings, that is, to the vertical load. And here the surface under study is inclined. Therefore, for the analysis, it is necessary to consider the strength of the soil for the separation stress by or by the maximum stress. All available experimental data for this reason relate to the separation stress of the software and are referred to as «ground resistance», «calculated values of ground resistance», and so on. The results of the study are obtained under the assumption that the base of the mountain, relative to the Eastern and Western foothills, is undeformable. That is, the cross-section of the Kok Tobe body relative to the base is studied.

6. ANALYSIS OF THE RESULTS AND CONCLUSION

These points under the action of their own weights are shifted asymmetrically, since the mass of the mountain at the top towards the South and West is asymmetric. The eastern side is deformed more, as the support from the south is smaller. Therefore, the vertical component on the east side is much larger. Now let’s assess the impact of tectonics. Since the tectonic force is directed from left to right, 3.2 cm more for point 33. The impact on the rest is about the same. Due to this, the vertical component of the movements is reduced. To the observer, of course, such a difference in voltage is not felt. But as the stress values of Table 4 show in the scientific and practical relations, it turns out to affect. Interestingly, such a difference in displacements does not cause a change in stresses. The stress components remain practically unchanged. If we determine the physical-mechanical and strength properties and the degree of water saturation of the soils of the Kok Tobe slope by drilling to the rock, then using the proposed approach, the calculation model

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