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Satbayev University

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РЕСПУБЛИКИ КАЗАХСТАН
Satbayev University

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Қазақстан Республикасы Ұлттық ғылым академиясы "ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы" ғылыми журналының Web of Science-тің жаңаланған нұсқасы Emerging Sources Citation Index-те индекстелуге қабылданғанын хабарлайды. Бұл индекстелу барысында Clarivate Analytics компаниясы журналды одан әрі the Science Citation Index Expanded, the Social Sciences Citation Index және the Arts & Humanities Citation Index-ке қабылдау мәселесін қарастыруда. Webof Science зерттеушілер, авторлар, баспашылар мен мекемелерге контент тереңдігі мен сапасын ұсынады. ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы Emerging Sources Citation Index-ке енуі біздің қоғамдастық үшін ең өзекті және беделді геология және техникалық ғылымдар бойынша контентке адалдығымызды білдіреді.

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E. E. Gasanov, V. V. Mammadova, A. J. Mammadov, V. H. Salimova, K. B. Salaeva

Azerbaijan University of Architecture and Construction, Baku, Republic of Azerbaijan.
E-mail: gasanov5089@uoel.uk

FORMATION OF ROCK SLOPES DURING WORK TO REDUCE THE EROSION ACTIVITY

Abstract. The formation of anti-erosion procedures is based primarily on achieving an equilibrium state that affects the state of the soil or constituent rocks of the slope. In this regard, the formation of a model that can demonstrate the processes of slope destruction, which can be represented not only by soil, but also by rocks or other formations, becomes relevant. In particular, it should be relevant for urban soils and technologically transformed landscapes. The novelty of the study is determined by the fact that all possible materials that form both slopes of natural origin and technological origin are considered as objects of potential erosion activity. The authors of the article are considering the possibility of applying reclamation measures that will reduce the maximum erosion activity within not only natural, but also urban landscapes. The article developed a model for analyzing the potential of erosion activity in combination with the physical parameters of the slopes and their mechanical composition. The practical significance of the study is determined by the fact that the proposed measures and the developed model for countering erosion activity can reduce technological costs for reclamation activities and thus increase the economic and technological efficiency of the project.

Key words: slope stability, destruction of rocks, rock mass, model of stability, erosion activity.

Introduction. The destruction of rocks is described in mechanics as the result of breaking of their structural bonds due to the application of external forces [1]. The study of this process is always done by analyzing the corresponding physical models. They include either structural models, which consider the object of study at the atomic-molecular level, or structureless model, in which a solid body is considered as a continuous homogeneous medium [2, 3]. Combined probabilistic-statistical models are also known, where the medium is presented in the form of a solid body consisting of randomly arranged elements with their own low-level microstructure [4, 5].

Theories of Strength are the most applicable in solving elastoplastic problems in geomechanics. Studies of rock fracture under severe load conditions made it possible to formulate a number of strength theories that take into account the heterogeneity of materials, which is exposed in the process of controlled fracture [6, 7]. The authors of strength theories proceeded from the assumption of an ideal structure that is solid, that is, has a homogeneous structure [8]. Real construction materials and rocks are far from being perfect. Consequently, strength theories do not always match laboratory test results. Particularly substantial discrepancies arise if the material under study contains sufficiently large defects – inclusions, pores that differ significantly in their physicomechanical properties. These materials with an imperfect structure include rocks.

For inhomogeneous solids, the deterministic model of continuous medium is insufficient [9, 10]. As the places of stress concentration are local and are observed mainly near inhomogeneities that are randomly placed in the material, the interpretation of rock strength taking into account probability-statistical models gains pronounced importance [11]. To describe the critical state of soils and soft rocks, such as clays and loams, the most commonly used criteria are the destruction of Mohr-Coulomb, Drucker-Prager, Hoeck-Brown, Cam-Clay, which are based on the classical concepts of natural destruction of solids [12, 13].

Since in soft rocks the main factors affecting the strength of the massif are porosity and moisture saturation of the massif, these criteria can describe the fracture process using a different set of initial data [14]. Thus, in the criterion for the destruction of Mora-Coulomb, based on determination of the conditions of stress-strain state and described by a curved tangent to the limit circles of the main stresses, there is an angle of internal friction and adhesion, as well as tensile strengths for uniaxial compression R_c and tension R_p.

The Drucker-Prager criterion was initially proposed to describe plastic deformations in soils and soft rocks, and later to assess the strength of polymers and other materials [15, 16]. The Hoeck-Brown criterion takes into account the physic mechanical properties of the intact and unharmed rock mass, which is subjected to external loads of both natural and technological origin [17].

Materials and methods. For brittle materials, the physical model was initially proposed, which shows the dependence of strength on the presence of microdefects. Failure criterion has the form:

$$(\delta_1 - \delta_3)^2 + 8R..(\delta_2 + \delta_1) = 0, when\ 3\delta, +\delta_1 > 0 \quad (1)$$

$$\sigma_3 = R_p, 3\sigma_3 + \sigma_1 < 0 \quad (2)$$

When $\sigma_3 = 0$ the expression (1) implies the relationship between the ultimate tensile strength on uniaxial compression R_c and the ultimate tensile strength on uniaxial tension R_p:

$$R_C = -8R_p \quad (3)$$

This is consistent with soft rock test results. In the coordinate system "$\tau - \sigma$", the basic equation can be expressed as follows:

$$4\tau^2 - 2R_c\sigma - 0.25R_c^2 \quad (4)$$

Based on other physical premises, a fracture criterion was proposed, the basic formula of which has the form (5) or (6):

$$4\tau^2 - 2\sigma(1-\psi)R_c - \psi R_c^2 = 0 \quad (5)$$

$$(\sigma_1 - \sigma_3)^2 - (1-\psi)R_c(\sigma_1 - \sigma_3) - R_c^2\psi = 0 \quad , \quad (6)$$

where $\psi = \frac{R_p}{R_c}$ – is the fragility coefficient, σ_1 and σ_3 are the largest and smallest values of the principal tensions.

To take into account the factor, which is shown in the form of falling section of the curve on the deformation graph, the so-called strength reduction function is usually introduced into the strength condition. Then the strength condition (5) can be described as follows:

$$F(\sigma_1, \sigma_2, \sigma_3) \leq k(x, y, z) \quad (7)$$

where $k(x, y, z)$ – is the strength criterion, the value of which is different at different points in the fracture area.

As a rule, in soils and soft rocks, a significant part of massif is represented by cavities filled with air or water. As a result, massif deformations are accompanied by significant and often irreversible volume changes. The main advantage of the classic and modified Cam-Clay models is the most suitable description of the volumetric changes in the massif. The critical state of the rock mass is characterized by three parameters: effective average tension p', deviation tension (shear tension) q', specific volume ν. In conditions of widespread compression, the average tension p'can be calculated from the main tensions $\sigma_1, \sigma_2, \sigma_3$:

$$p' = \frac{1}{3}(\sigma_1, \sigma_2, \sigma_3) \quad (8)$$

A triaxial shear tension can be defined as:

$$q' = \frac{2}{\sqrt{2}}\sqrt{(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2} \quad (9)$$

Therefore, the processes of destruction of solids, in particular rocks, are described by various phenomenological theories and criteria. The selection of the most appropriate criterion for rock destruction facilitates reliable analysis of the stability of geotechnical objects and engineering systems.

Results and discussion. Let us consider the Mohr-Coulomb criterion for a model of stability of soil slope. Adhesion C and angle of internal friction φ are the main parameters for assessing the strength and fracture of soft rocks using the Mohr-Coulomb criterion, which is most widely used in geotechnical practice. In generalized form, the criterion can be written like this:

$$\tau = c + \sigma_n tg\rho \tag{10}$$

where τ – is the shear tension, σ_n – is the normal tension. The soil model, which is usually used in the study of slopes, consists of six parameters: calculated adhesion c', calculated angle of internal friction φ', dilution angle (expansion) ψ ', Young's modulus E', Poisson's ratio ν', specific weight γ. The destruction of the array can be expressed in terms of existing tensions:

$$F = \frac{\sigma_1' + \sigma_3'}{2} \sin\varphi' - \frac{\sigma_1' - \sigma_3'}{2} - c' \cos\varphi' \tag{11}$$

where σ_1', σ_3' – is the maximum and minimum effective tension.

The elastic modulus (Young's modulus) and Poisson's ratio characterizing the elastic characteristics of the material with respect to external stresses can be determined experimentally in odometers or by formula:

$$E' = \frac{(1+\nu')(1-2\nu')}{m_\nu(1-\nu')} \tag{12}$$

where m_ν – is the compression coefficient.

The value of Poisson's ratio for non-irrigated soils lies in the range $\nu' = 0{,}2 \ldots 0{,}35$. The most important parameters for analysis of slope stability using the finite element method (FEM), as in traditional methods of limiting equilibrium, are specific weight γ, shear resistance characteristics c' and φ', and geometric parameters of the slope [18, 19].

Safety factor (SF) of the slope is a value on which we should divide the output parameters of soft rock shear resistance for the phenomenon of destruction to take place. This definition of SF is similar to traditional methods of limiting equilibrium, characterized by the ratio of the moments of holding forces to the moments of forces causing a shift in the slope:

$$F = \frac{\text{Resistance of the material (rock,soil) to shear}}{\text{Resistance of the shear that is necessary for the balance}} = \frac{t}{t^*} \tag{13}$$

the same for the traditional analysis of limit equilibrium. The characteristics of shear strength c_f' and φ_f' can be written as:

$$c_f' = \frac{c'}{KZ}\,;\ \varphi_f' = arctam\left(\frac{tan\varphi'}{KZ}\right) \tag{14}$$

RSR is used for calculations of SF, depending on the c_f' and φ_f'. With regard to assessing the stability of slopes, the method consists in phased calculation of the coefficient of reduction in shear resistance (CRSR), which is equivalent to CRSR for given soil strength characteristics.

RSR provides for the application of the Mohr-Coulomb criterion for the analysis of slope stability. A unique feature of this linear model is that it can be simply and explicitly expressed both in units of principal stresses $(\sigma_1 - \sigma_3)$and in the form of the mutual dependence of tangential and normal stresses $(\tau - \sigma_n)$. Factorized value of soil strength in terms of reduction of resistance to shift criterion Mohr-Coulomb can be expressed as:

$$\frac{\tau}{F} = \frac{c'}{F} + \frac{tan\varphi'}{F} \tag{15}$$

This equation can be transformed to:

$$\frac{\tau}{F} = c^* + tan\varphi^* \tag{16}$$

where $c^* = \frac{c'}{F}$ and $\varphi^* = arctan\left(\frac{tan\varphi'}{F}\right)$ are factored parameters of shear resistance of Mora-Coulomb.

Let us consider the Hoeck-Brown criterion, which is the most suitable model for predicting rock failure to assess the stability of slopes. The generalized Hoek-Brown criterion expresses the strength of the massif through the principal stresses:

$$\sigma_1' = \sigma_3' + \sigma_{ci}\left(m_b \frac{\sigma_3'}{\sigma_{ci}} + s\right)^a, \tag{17}$$

where σ_1 and σ_3 are the maximum and minimum tensions in the array, m_b is a constant of Hoeck-Brown for rock mass, S and a are the constant values considering the genesis and the state (quality) of a rock mass, σ_{ci} is a tensile strength for uniaxial compression of rock mass intact.

The characteristics of the rock mass can be calculated by the formulas:

$$m_b = m_i exp\left(\frac{GSI-100}{28-14D}\right) \tag{18}$$

$$s = exp\left(\frac{GSI-100}{9-3D}\right) \tag{19}$$

$$a = \frac{1}{2} + \frac{1}{6}\left(e^{-GSI/15} - e^{-20/3}\right) \tag{20}$$

where GSI (Geological Strength Index) is the coefficient of geological strength, taking into account the geological features of the rock mass, in particular its structure and the presence of cracks (5≤GSI≤100); D is a parameter depending on the degree of disruption of the mass due to blasting and the effect of stress relaxation varies from 0 (for intact) to 1 (for severely disrupted) rock mass. Normal and shear stresses relate to principal stresses in accordance with these equations:

$$\tau = (\sigma_1' - \sigma_3')\frac{k}{k^2+1} \tag{21}$$

$$\sigma_n' = \frac{\sigma_1'+\sigma_3'}{2} - \frac{\sigma_1'-\sigma_3'}{2}\frac{k^2-1}{k^2+1} \tag{22}$$

where

$$k^2 = \frac{d\sigma_1'}{d\sigma_3'} = 1 + am_b\left(\frac{m_b\sigma_3'}{\sigma_{ci}} + 1\right)^{a-1} \tag{23}$$

Using the equations for shear tensions (23), we can calculate the factorized strength indices as follows:

$$\frac{\tau'}{F} = (\sigma_1' - \sigma_3')\frac{\sqrt{1+am_b\left(m_b\frac{\sigma_3'}{\sigma_{ci}'}+s\right)^{a-1}}}{2+am_b\left(m_b\frac{\sigma_3'}{\sigma_{ci}'}+s\right)^{a-1}} \times \frac{1}{F} = (\sigma_1' - \sigma_3')\frac{\sqrt{1+am_b^*\left(m_b^*\frac{\sigma_3'}{\sigma_{ci}^*}+s^*\right)^{a-1}}}{2+am_b^*\left(m_b^*\frac{\sigma_3'}{\sigma_{ci}^*}+s^*\right)^{a-1}} \tag{24}$$

For the Hoeck-Brown and Mohr-Coulomb criteria most commonly used in engineering practice, a parallel can be drawn by constructing an envelope curve to display the destruction of the rocks. This approach lets us obtain equivalent parameter values and make a mutual transition between the criteria [20]. Thus, from the envelope of Mora's circles, one can determine not only the adhesion and the angle of internal friction, but also the equivalent parameters of the Hoeck-Brown criterion. The method also brings the straight line enveloping the Mohr-Coulomb circles to the curved Hoeck-Brown contour. Geometrically, it can be expressed in the equality of the sums of the positive regions above the Mohr-Coulomb line and the negative regions below the line. The final formulas for calculating the equivalent Mohr-Coulomb parameters are as follows:

$$\varphi' = sin^{-1}\left(\frac{6am_b\left(s+m_b\sigma_{3n}'\right)^{a-1}}{2(1+a)(2+a)+6am_b\left(s+m_b\sigma_{3n}'\right)^{a-1}}\right) \tag{25}$$

$$c' = \frac{\sigma_{ci}(1+2a)s+(1-a)m_b\sigma_{3n}'\left(s+m_b\sigma_{3n}'\right)^{a-1}}{(1+a)(2+a)\sqrt{\frac{1+\left(6am_b(s+m_b\sigma_{3n}')^{a-1}\right)}{(1+a)(2+a)}}} \tag{26}$$

where $\sigma_{3n}' = \frac{\sigma_{3max}'}{\sigma_{ci}}$. The matching procedure takes place through a range of stresses from tensile strengths σ_t to maximum compressive stresses σ_{3max}'.

The maximum compression resistance can be calculated from the equation:

$$\sigma_{3max}' = 0.72\sigma_{cm}'\left(\frac{\sigma_{cm}'}{\gamma H}\right)^{0.91} \tag{27}$$

where γ is the specific weight of the rock,$H$is the slope height, σ'_{cm} is the rock strength coefficient. This coefficient is calculated by the formula:

$$\sigma'_{cm} = \sigma_{ci} \frac{(m_b+4s-a(m_b-8s))\left(\frac{m_b}{4}+s\right)^{a-1}}{2(1+a)(2+a)} \tag{28}$$

Let us consider a slope composed of homogeneous rock with the following geometric characteristics: height H = 30 m, angle of inclination $\alpha = 37^{\circ}$. To comply with the boundary conditions, we set the following parameters: 60 m from the lower edge and 60 m from the upper edge to the horizontal boundaries of the model; distance from the top edge to the lower border of the model is 80 m.

The force of gravity acts on the slope. The initial physical and mechanical characteristics of the rock mass, as well as the calculated equivalent parameters are provided in table 1. We use the RocLab engineering program (from Rocscience Inc.), which implements the capacity to convert the parameters of the Hoeck-Brown criterion to the equivalent parameters of the Mohr-Coulomb criterion. As a result, we obtain equivalent values of adhesion C = 0.011 MPa and the angle of internal friction $\varphi = 9{,}45^{\circ}$. Further, according to the obtained parameters of equivalent strength by Mohr-Coulomb we can calculate SF in Phase2 software.

Table 1 – Physical and mechanical characteristics of rocks

Properties	Values	Properties	Values
Young's E modulus, MPa	20	Parameter m_b	0.5
Poisson's ratio ν, dimensionless.	0.3	Parameter s	8e-5
Specific gravity γ, MN / m^3	0.01764	Parameter a	0.6
Uniaxial compressive strength σ_{ci}, MPa	0.8	Dilation angle ψ, Degrees	0
Geological Strength Factor, GSI	15	Adherence C, MPa	0.03
Intact breed parameter m_i	10	Angle of internal friction φ, degrees	17.3
Massif intact Factor	0		

Rocks of various genesis stay in a state of unequal comprehensive compression. Their destruction under these conditions proceeds, both as for brittle for rocky materials and plastic for soft sedimentary rocks. In addition, the massif, depending on genesis, has a certain texture, and is broken by systems of randomly oriented cracks of the appropriate degree of disclosure, different parts of it have an excellent degree of flooding, inclusion, emptiness, etc. These circumstances result in that the characteristics of the rock strength in the sample and massif have a substantial difference, which is estimated by coefficient structural weakening – k_c, which is numerically equal to the relative values of the specific carrier characteristics in the massif R_m to its value obtained by testing samples of standard linear dimensions M (R):

$$k_c = \frac{R_m}{M(R)} \tag{29}$$

As this characteristic is associated with level limiting stresses and elastic parameters of the rock mass state, then setting the value of the objective structural weakening coefficient is a complex task involving both rational design geotechnical structures, and evaluating stability of natural and man-made slope. The structural attenuation coefficient for a rock mass weakened by a system of cracks depends on the average distance between cracks, the size of standard rock sample, and coefficient of variation of the test results of rock samples.

For a perfectly homogeneous environment $\eta_0 = 0$ and $k_c = 1$. As the heterogeneity increases, the value k_c tends to a value 0.4. Accounting for irregularities and planes of weakness in the rock mass is an important research step for quantifying the scale effect in massive statistically inhomogeneous medium.

The approaches to estimation of the scale effect make it possible to evaluate the strength of rock and semi-rock massif taking into account the coefficient of structural attenuation k_c and, accordingly, calculate the slope stability. In this case, the most significant factors are the strength of the rock mass genesis, lithology of rocks, the presence of weakening and fracture surfaces.

There is suggested and investigated probabilistic and statistical model of strength for monolithic undisturbed and cracked rock massifs. Such massifs are represented by various soft rocks of sedimentary genesis, in particular, loams, clays, and loamy soils. In such a rock mass strength is conditioned by adhesion forces that are primarily dependent on factors such as lithology, porosity and moisture saturation.

With regard to evaluating the stability of natural and artificial slopes, increasing of humidity in massif of argillaceous rocks and filling the pore space with water tends to reduce adhesion forces and the massif turns to viscoelastic state, which promotes such sliding processes as floods and landslides. The inverse process of loss of moisture in the mass due to opening of slopes and climatic influences causes development of fracturing in the surface layers of loams with subsequent destruction of the slopes.

Variations in the strength properties of the massif determine the natural heterogeneity of the structural elements and the variability of the physical and mechanical characteristics even within the same lithological difference. Thus, determining the strength of soft rocks by testing laboratory standard samples is a difficult engineering task. Due to the changing values of the adherence C and the angle of internal friction φ as the basic characteristics of the massif strength, tensile strength and testing process taking samples of random values constituting the statistical array. Due to the natural heterogeneity of the rock environment, the strength of structural elements is a random variable and follows one or another law of probability distribution with a distribution density $f(R)$.

Probabilistic and statistical studies of the model of strength of monolithic rock mass using the normal law distribution of adhesion and the angle of internal friction. Based on the algorithm, the strength of the massif should be estimated by value R_m, so that the strength of its structural elements with a given reliability is less than this value. Based on the normal distribution law, a formula is obtained for calculating the structural attenuation coefficient under the assumption that the strength of the structural elements of the massif is distributed according to the normal law:

$$k_c = \eta arg F_0(1-P) + 1 \tag{30}$$

Therefore, the structural attenuation coefficient depends, firstly, on the relative variation η, which, in fact, characterizes the degree of heterogeneity of the medium; secondly, from the probability Pthat characterizes the level of significance of the object.

We completed analysis of the physicomechanical characteristics of light yellow loess and yellow-brown dense loams to assess the landslide in dangerous natural slopes. Hence, the values of the angle of internal friction for light yellow loesslike loams vary in the range of 13-18 °, for yellow-brown loams – 16-26 °, and the variation relative to the average is 34-36%. The value of adhesion for light yellow loess loams varies in the range of 14-31 kPa, for yellow-brown loams of 20-50 kPa, and spread of values relative to the average is 38.5–39.5%. Let us determine, for example, the calculated value of adhesion and the angle of internal friction in the massif of loams, taking into account the variation of values. From equation (30) it follows that:

$$R_{rozr} = R_m = \overline{R_c} k_c \tag{31}$$

We shell set the probability P=0.95, we determine the value of the argument t for normal function $F_0(t)$ with its value equal to 1-0.95=0.05. We establish, that the values of integral function $F_0(t) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{t} e^{-\frac{t^2}{2}} dt$, that is equal $F_0(t) = 0{,}05$, it corresponds to the value of the argument $t = -1{,}64$, i.e. $F_0(0{,}05) = -1{,}64$. The calculated strength parameters and the structural attenuation coefficient k_s in the soft rock mass are summarized in table 2.

Table 2 – The calculated strength parameters in the massif of soft rocks

Class	Array Strength Characteristics	The average value in the sample $\bar{x}^*$	Relative variation η^*	Structural attenuation coefficient k_s	The calculated value in massif
Light yellow loess loam	Adhesion C	19.61	0.385	0.369	7.23
	Angle of internal friction φ	13.39	0.341	0.441	5.90
Yellow-brown loam	Adhesion C	29.58	0.395	0.352	10.42
	Angle of internal friction φ	18.24	0.364	0.403	7.35

Cohesive soils have a certain resistance to both compression and strain. The compressive $R_c$and tensile $R_p$strengths of soft rocks and soils are related to the angle of internal friction φ and adhesion C. Let's consider a separate element of the soil mass, which is affected by tensions σ_1 and σ_2. Under the condition of uniaxial compression $(\sigma_2 = 0, \sigma_1 > \sigma_2)$. The tension σ $_1$ corresponding to the destruction of the element is defined as:

$$R_c = 2Ctg\left(45 + \frac{\varphi}{2}\right) \tag{32}$$

In case of equilibrium of tensile element $(\sigma_1 < \sigma_2)$, we indicate the tensile strength R_p by:

$$R_p = -2Ctg\left(45 - \frac{\varphi}{2}\right) \tag{33}$$

From the above formulas it can be seen that on condition $C = 0$ for disintegrated loose soils $R_c = R_p = 0$. The ratio of the final resistance of cohesive soil to compression and tension is determined by the expression:

$$\frac{R_c}{R_p} = -\frac{tg\left(45+\frac{\varphi}{2}\right)}{tg\left(45-\frac{\varphi}{2}\right)} = -tg^2\left(45 + \frac{\varphi}{2}\right) \tag{34}$$

It should be mentioned that this ratio does not depend on the amount of adhesion, but only on the angle of internal friction. This relationship can be turned into the following:

$$\frac{R_c}{R_p} = -tg^2\left(45 + \frac{\varphi}{2}\right) = -\frac{1+sin\,\varphi}{1-sin\,\varphi} \tag{35}$$

where we get:

$$R_c(1 - sin\,\varphi) + R_p(1 + sin\,\varphi) = 0 \tag{36}$$

$$sin\,\varphi = \frac{R_c+R_p}{R_c-R_p} \tag{37}$$

If we assume, that the average value for the yellow-brown loams selected from the ravine-beam networks is R $_c$= 0.5 kgf / cm ^{2} (49 kPa) and R $_p$= 0.2 kgf / cm ^{2} (20 kPa), we get:

$$sin\,\varphi = \frac{0,5-0,2}{0,5+0,2} = \frac{0,3}{0,7} = 0,428 \tag{38}$$

$$\varphi = arc\,sin\,0,428 = 25,4^{\circ} \tag{39}$$

Adhesion can also be determined through $R_c$and R_p. Transforming the equations, we obtain

$$C = \frac{1}{2}R_c tg\left(45 + \frac{\varphi}{2}\right) \qquad C = -\frac{1}{2}R_p tg\left(45 - \frac{\varphi}{2}\right) \tag{40}$$

where we get:

$$C = \frac{1}{2}\sqrt{-R_c R_p} \tag{41}$$

For example, for the above values: R $_c$= 0.5 kgf/cm^2 (49 kPa) and R $_p$= 0.2 kgf/cm^2 (20 kPa) we have: C = 0.16 kgf/cm^2 (16 kPa). The above calculations of the angle of internal friction φ and adhesion C are not perfect, since they have certain error. In laboratory testing of soft rock landslide devices typically determine the physical and mechanical characteristics of the samples at different loadings to provide a family of Mohr circles and build tangent curve l_t on the received points that correspond to a certain moment stress-strain state. But the use of plausible values φ and C obtained in laboratory tests, depends on the way we build a line tangent to the Mora circles.

If Mora circles are being used, starting from the first circle that corresponds to the value R_c, then there is a possibility of obtaining overestimated values of adhesion C_{max} at the intersection of straight line l_{max} with the axis of tangential tensions τ. If the calculation scheme to include a circle, which corresponds to the limit in the tensile strength R_p, the result of drawing the line l_{min} tangent to the circles R_c and R_p provides the minimum value of the adhesion C_{min} at the intersection with the axis of the shear stresses τ. We also offer a different approach to determination of calculated values φ^* and C^* analytically:

$$\varphi^* = \frac{1-\psi}{\sqrt[2]{\psi+2(1-\psi)\frac{\gamma H}{R_c k_c}}} \tag{42}$$

$$C^* = R_c k_c \frac{1-\sin\varphi^*}{2\cos\varphi^*} \tag{43}$$

where $\psi = R_p/R_c$ is the fragility coefficient; k_c is the coefficient of structural attenuation. Consequently, the Mohr-Coulomb criterion can be rewritten in modified form:

$$\tau = C(W_0) + \sigma_n tg\varphi(W_0) = R_c k_c \frac{1-\sin\varphi(W_0)}{2\cos\varphi(W_0)} + \sigma_n tg\left(\frac{1-\psi}{\sqrt[2]{\psi+2(1-\psi)\frac{\gamma H}{R_c k_c}}}\right) \tag{44}$$

The above equations indicate the element of uncertainty during laboratory tests that require using probabilistic statistic methods for determining strength properties of soft materials and their application in geotechnical calculations. Having the calculated indicators of the physicomechanical properties of rocks $tg\varphi_p, C_p, \gamma_p$, we can calculate the potential erosion activity of the slope, if its geometric parameters (height $H$and angle of slope α) are given:

$$F_s = f\left(tg\varphi_p, C_p, \gamma_p, \alpha, H\right)$$
$$H = f\left(tg\varphi_p, C_p, \gamma_p, \alpha\right) \tag{45}$$
$$\alpha = f\left(tg\varphi_p, C_p, \gamma_p\right)$$

The degree of reliability of the final calculation results and the error of the functions presented above (45) are suggested to be estimated using the well-known error theory formula:

$$\sigma_{F_s}^2 = \left(\frac{\partial F_s}{\partial\varphi}\right)^2 \sigma_\varphi^2 + \left(\frac{\partial F_s}{\partial C}\right)^2 \sigma_c^2 + \left(\frac{\partial F_s}{\partial\gamma}\right)^2 \sigma_\gamma^2 \tag{46}$$

where $\sigma_{F_c}^2, \sigma_\varphi^2, \sigma_C^2, \sigma_\gamma^2$ are dispersions, respectively, of the safety factor of the slope, the angle of internal friction, adhesion and density of rocks.

Nevertheless, this approach is appropriate only for independent random variables, while the values of the random φ and C are correlated. We suggest using a probabilistic-statistical approach with respect to estimating the limiting parameters of the slope, based on the theory of linear regression. Using the diagram of the shear resistance for normal pressure $\tau = f(P)$ in laboratory test samples have shown that the maximum verisimilitude obtained line represents the locus of points corresponding to the average values of the random variables $\bar{\tau}(P)$distributed according to the normal law. That is, the expression of the linear regression equation $\bar{\tau} = a_0 + a_1 P$ is the equation of "random" line on the plane, and the average value is provided by the "true" line $\tau = a_0 + a_1 P$. The random line may deviate from the mean, depending on the deviations of the point (a_0, a_1) and the average $(\bar{a}_0, \bar{a}_1)$. Confidence boundaries form a band that, with a given probability, refers to the graph of unknown true dependence $\tau = f(P)$.

Accepting the confidence probability, we can also calculate the limiting parameters of the slope height H and its angle of inclination α, i.e., the slope with a safety factor $Fs = 1{,}0$, the value of which corresponds to the lower boundary of the confidence interval. Variability is an inherent property of rocks and effect caused by various factors in the formation and transformation of rocks, which have separate effect on their mechanical properties and characteristics. To solve the variability of input parameters in calculating the slope stability in various engineering analysis programs, for example in Phase2 (RocScience Inc.), statistical tools based on probabilistic method of point estimates (MPE) are used.

MPE principle consists in calculating the final function of SF in the range of two different values of physico-mechanical characteristics of rocks in changing conditions. To optimize the effort to reduce erosion activity, accurate calculations were carried out to determine the optimal geometric parameters of the slope in changing mining and geological conditions. Covering rocks are represented by layers of greenish-gray clay, Quaternary red-brown clay and forest light yellow loams with total thickness of 60...65 m. Excavation slope as a model consists of two layers: the upper layer of light yellow loesslike loams and the lower layer of red brown clay. A geomechanical assessment of stability of the slope is performed with two probabilistic input variables, namely, adhesion and angle of internal friction.

The calculation results demonstrate that the use of fixed values of the physical and mechanical characteristics of the rocks gives deterministic values of the safety factor. In changing geological conditions, the adhesion indicators and the angle of internal friction, that are parts of Mohr-Coulomb strength condition, vary within wide range depending on the humidity of soft soils.

Conclusion. The analyzed probabilistic-statistical model of strength of structurally heterogeneous undisturbed rock mass with crack systems has demonstrated that it is necessary to develop formulas for the coefficient of structural attenuation, which allow us to estimate the strength of a statistically heterogeneous rock mass. A comparative analysis of the deterministic and probabilistic approaches to determine the stability and limit parameters of slopes was performed, which helps to make more reliable assessment and prediction of stability of natural slopes and man-made slopes for optimal engineering decisions to reduce erosion activity.

Э. Э. Гасанов, В. В. Мамедова, А. Д. Мамедов, В. Г. Салимова, Х. Б. Салаева

Азербайджанский архитектурно-строительный университет, Баку, Азербайджан

ФОРМИРОВАНИЕ ОТКОСОВ ПОРОД ПРИ ПРОВЕДЕНИИ РАБОТ ПО СНИЖЕНИЮ ЭРОЗИОННОЙ АКТИВНОСТИ

Аннотация. Формирование противоэрозионных мероприятий основывается прежде всего на достижении равновесного состояния, которое затрагивает состояние почвы или слагающих пород склона. В этой связи актуальным является формирование модели, которая может выявить процессы разрушения склонов, которые представлены не только почвой, но и горными породами или иными образованиями. В частности, это становится актуальным для урбоземов и техногенно трансформированных ландшафтов. Новизна исследования определяется тем, что в качестве объектов потенциально эрозионной активности рассматриваются все возможные материалы, которые формируют не только склоны природного происхождения, но также и техногенного генеза. Авторы статьи рассматривают возможность проведения рекультивационных мероприятий, которые позволят снизить максимально эрозионную активность в пределах не только природных, но и урболандшафтов. В статье разработана модель анализа потенциала эрозионной активности в сочетании с физическими параметрами склонов и механическим составом. Практическая значимость исследования определяется тем, что предлагаемые мероприятия и разработанная модель противодействия эрозионной активности позволяет снизить технологические издержки от проведения рекультивационных мероприятий и тем самым повысить экономическую и технологическую эффективность проекта.

Ключевые слова: устойчивость откосов, разрушение горных пород, породной массив, модель устойчивости, эрозионная активность.

Э. Э. Ғасанов, В. В. Мәмедова, А. Д. Мәмедов, В. Г. Сәлімова, Х. Б. Салаева

Әзірбайжан сәулет және құрылыс университеті, Баку, Әзірбайжан

ЭРОЗИЯЛЫҚ БЕЛСЕНДІЛІКТІ ТӨМЕНДЕТУ БОЙЫНША ЖҰМЫСТАРДЫ ЖҮРГІЗУ КЕЗІНДЕ ЖЫНЫСТАРДЫҢ ЕҢІСТЕРІН ҚАЛЫПТАСТЫРУ

Аннотация. Эрозияға қарсы шаралардың қалыптасуы, ең алдымен, топырақтың күйіне немесе көлбеу тау жыныстарының құрамына әсер ететін тепе-теңдік күйіне жетуге негізделген. Осыған байланысты тек топырақпен ғана емес, сонымен қатар тау жыныстарымен немесе басқа түзілімдермен ұсынылған еңістердің бұзылу үдерістерін анықтай алатын модельдің қалыптасуы өзекті болып табылады. Атап айтқанда, бұл қалалық топырақтар мен техногендік түрлендірілген ландшафттар үшін өзекті болады. Зерттеудің жаңалығы ықтимал эрозиялық белсенділік объектілері ретінде тек табиғи беткейлерді ғана емес, сонымен қатар техногендік генезді де құрайтын барлық мүмкін материалдар қарастырылатындығымен анықталады. Мақала авторлары тек табиғи ғана емес, сонымен қатар урболандшафт шегінде ең жоғары эрозиялық белсенділікті төмендетуге мүмкіндік беретін рекультивациялық іс-шараларды өткізу мүмкіндігін қарастырады. Мақалада беткейлердің физикалық параметрлерін және механикалық құрамымен бірге, эрозия белсенділігінің әлеуетін талдау моделі жасалды. Зерттеудің практикалық маңыздылығы ұсынылған іс-шаралар мен эрозиялық белсенділікке қарсы іс-қимылдың әзірленген моделін қалпына келтіру, технологиялық шығындарды азайтуға және сол арқылы жобаның экономикалық және технологиялық тиімділігін арттыруға мүмкіндік беретіндігімен анықталады.

Түйін сөздер: еңістердің тұрақтылығы, тау жыныстарының күйреуі, жыныстық массиві, тұрақтылық моделі, эрозиялық белсенділік.

Information about authors:

Gasanov Elgiz E., PhD, Head of the Department of Amelioration and Water Management Construction, Azerbaijan University of Architecture and Construction, Baku, Republic of Azerbaijan; gasanov5089@uoel.uk; https://orcid.org/0000-0002-5214-6162

Mammadova Vusale V., PhD, Senior Lecturer, Department of Amelioration and Water Management Construction, Azerbaijan University of Architecture and Construction, Baku, Republic of Azerbaijan; mammadova.v.v5089@murdoch.in; https://orcid.org/0000-0002-2469-8306

Mammadov Akhad J., PhD, Senior Lecturer, Department of Amelioration and Water Management Construction, Azerbaijan University of Architecture and Construction, Baku, Republic of Azerbaijan; mammmadov5089@kpi.com.de; orcid: https://orcid.org/0000-0001-7171-3268

Salimova Vefa H., PhD, Senior Lecturer, Department of Amelioration and Water Management Construction, Azerbaijan University of Architecture and Construction, Baku, Republic of Azerbaijan; salimova5089@ubogazici.in; https://orcid.org/0000-0003-3597-4537

Salaeva Khadija B., Head of Laboratory, Department of Amelioration and Water Management Construction, Azerbaijan University of Architecture and Construction, Baku, Republic of Azerbaijan; salaeva5089@kpi.com.de; orcid: https://orcid.org/0000-0002-3628-2914

REFERENCES

[1] Abrahams, A.D., Howard, A.D., Parsons, A.J. (1994). Rock-mantled slopes. In A.D. Abrahams & A.J. Parsons (Eds.), *Geomorphology of Desert Environments*. P. 173-212. Dordrecht: Springer Netherlands.

[2] Miščević, P., Cvitanović, N.Š., Vlastelica, G. (2020). Degradation processes in civil engineering slopes in soft rocks. In M. Kanji, M. He, & L. Sousa (Eds.), *Soft Rock Mechanics and Engineering*. P. 335-371. Cham: Springer International Publishing.

[3] Kyryliuk, V., Krychkivskyi, V., Kovalchuk, N. (2020). Influence of protracted application of systems of basic till and fertilizer is on structure of soil. *Scientific Horizons,* Vol. 8, Issue 93. P. 119-124.

[4] Wang, Z.-Y., Lee, J. H.W., Melching, C.S. (2015). Vegetation-erosion dynamics. In *River Dynamics and Integrated River Management*. P. 53-122. Berlin, Heidelberg: Springer Berlin Heidelberg.

[5] Gennadiyev, A.N., Golosov, V.N., Chernyanskii, S.S., Markelov, M.V, Kovach, R.G., Belyaev, V.R., Ivanova, N.N. (2006). Comparative assessment of the contents of magnetic spherules, 137Cs, and 210Pb in soils as applied for the estimation of soil erosion. *Eurasian Soil Science.* Vol. 39, Issue 10. P. 1100-1115.

[6] Velasco, A., Úbeda, X. (2015). Runoff generation and soil erosion after forest fires from the slopes to the rivers at a basin scale. In A. Rowiński Pawełand Radecki-Pawlik (Ed.), *Rivers – Physical, Fluvial and Environmental Processes*. P. 443-458. Cham: Springer International Publishing.

[7] Khusanov, B., Rikhsieva, B. (2019). Thickness dimensions of the contact layer of soil-rigid body interaction. *E3S Web of Conferences,* Vol. 97. P. 1-7.

[8] Schmid, T., Mueller, U., Tognini, F., Meyer, J. (2007). Comparison of revegetation techniques on alpine slopes prone to avalanches and erosion. In A. Stokes, I. Spanos, J.E. Norris, & E. Cammeraat (Eds.), *Eco-and Ground Bio-Engineering: The Use of Vegetation to Improve Slope Stability*. P. 433-438. Dordrecht: Springer Netherlands.

[9] Kraushaar, S. (2016). Erosion features and measurement methods on the slope. In *Soil Erosion and Sediment Flux in Northern Jordan: Analysis, Quantification and the Respective Qualitative Impacts on a Reservoir Using a Multiple Response Approach*. P. 33-76. Cham: Springer International Publishing.

[10] Shevchyk-Kostiuk, L., Romaniuk, O., Banya, A. (2020). Improving the efficiency of phytoremediation technologies of oil-contaminated soils with the participation of natural sorbents-meliorants. *Scientific Horizons,* Vol. 23, Issue 10. P. 7-16.

[11] Šlezingr, M., Pelikán, P., Marková, J., Gernešová, L. (2015). Protection of slopes against erosion by flowing rain water. In P. Hlavínek & M. Zeleňáková (Eds.), *Storm Water Management: Examples from Czech Republic, Slovakia and Poland*. P. 137-155. Cham: Springer International Publishing.

[12] Lee, J. M., Park, Y. S., Kum, D., Jung, Y., Kim, B., Hwang, S. J., Kim, H.B., Kim, Ch., Lim, K. J. (2014). Assessing the effect of watershed slopes on recharge/baseflow and soil erosion. *Paddy and Water Environment*, Vol. 12, Issue 1. P. 169-183.

[13] Khusanov, B., Khaydarova, O. (2019). Stress-strain state of earth dam under harmonic effect. *E3S Web of Conferences,* Vol. 97. Article number 05043.

[14] Shokparova, D.K., Kakimjanov, E.K., Meyer, B.C. (2014). Erosion rates depending on slope and exposition of cropped chestnut soils. In L. Mueller, A. Saparov, & G. Lischeid, *Novel Measurement and Assessment Tools for Monitoring and Management of Land and Water Resources in Agricultural Landscapes of Central Asia.* Cham: Springer International Publishing.

[15] Qiao, X., Li, X., Guo, Y., Ma, S. (2018). In-situ experimental research on water scouring of loess slopes. *Environmental Earth Sciences*. Vol. 77, Issue 11. Article number 417. https://doi.org/10.1007/s12665-018-7593-1

[16] Bendak, A.V., Skubenych, K.V., Pogodin, A.I., Bilanych, V.S., Studenyak, I.P. (2019). Mechanical properties of composites based on (Cu1−xAgx)7GeSe5I mixed crystals. *Scientific Herald of Uzhhorod University. Series "Physics",* Vol. 46. P. 76-83.

[17] Becht, M. (1994). Investigations of slope erosion in the Northern Limestone Alps. In P. Ergenzinger & K.-H. Schmidt (Eds.), *Dynamics and Geomorphology of Mountain Rivers*. P. 171-193. Berlin, Heidelberg: Springer Berlin Heidelberg.

[18] Kerimov, V.Yu., Mustaev, R.N., Osipov, A.V. (2018). Peculiarities of hydrocarbon generation at great depths in the crust. *Doklady Earth Sciences,* Vol. 483, Issue 1. P. 1413-1417.

[19] Guliyev, I.S., Kerimov, V.Yu. Osipov, A.V. Mustaev, R.N. (2017). Generation and accumulation of hydrocarbons at great depths under the earth's crust. *Socar Proceedings,* Vol. 1. P. 4-16.

[20] Skvortsov, A.A., Kalenkov, S.G., Koryachko, M.V. (2014). Phase transformations in metallization systems under conditions of nonstationary thermal action. *Technical Physics Letters,* Vol. 40, Issue 9. P. 787-790.

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Редакторы *Д. С. Аленов, М. С. Ахметова, Р. Ж. Мрзабаева*
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