3-бөлім **Раздел 3** **Section 3**

Информатика **Информатика** **Computer Science**

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DETERMINATION OF THE SLIDING STATE OF THE SOILS OF THE SHYMBULAK SLOPE WITH THE DEVELOPMENT OF THE CRITERION OF FAILURE

On the basis of the known criterion for the destruction of Coulomb Mor applied to soils of isotropic structure, developed the general criteria for the destruction of stratified, anisotropic, inclined layer of soils. New expressions were obtained to determine the parameters of the mechanics of disruption allowing not only the direction of disruption, but also the possible distribution of dislocations along the layers of soil and perpendicular. Applying the proposed criterion, the problem of determining the stressful condition of the soils of the dangerous rock slope of the slope, and on the joints of soils of different geological structure, such as eluvium and delta. The results of the analysis are presented in the form of tables, diagrams and graphs. Deductions are made on the reliability of the proposed approach to the solution of the problem on the determination of the precondition of the soil of mountain slopes. The first part of the work describes the different categories of communication conditions. The second section gives various examples of the construction of individual elastic curved joints and their connections, supplemented by certain connection conditions of the limit problem. The result is a numerical calculation of the natural frequency of free oscillations of the joints of elastic bent joints.
Key words: slope, soil, layers, stress, anisotropy, landslide.

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ШЫМБҰЛАҚ БӨКТЕРІ ТОПЫРАҚТАРЫНЫҢ КӨШКІН ЖАҒДАЙЫНДА БҰЗЫЛУ КРИТЕРИЙІН ӘЗІРЛЕУ АРҚЫЛЫ АНЫҚТАУ

Изотропты топырақтарда қолданылатын белгілі Кулон Мордың бұзылу критерийі негізінде құрылымы қатпарлы, анизотропты, көлбеу қабатты топырақтар үшін жалпыланған бұзылу критериі жасалды. Бұзылу механикасының параметрлерін анықтайтын жаңа өрнектер алынды, бұл тек бұузылудың таралу бағытын ғана емес, сонымен қатар бұзылу сызығының топырақ қабаттары бойымен және оған перпендикуляр бойынша таралуын да анықтауға мүмкіндік береді.ұсынылған критерийді қолдана отырып,көлбеу төсеніштердің көшкінге бейімді тау беткейіндегі және элювий мен делювий сияқты әртүрлі геологиялық құрылымдардың топырақтарының түйіскен жерлеріндегі топырақтардың стресс жағдайын анықтау мәселесі шешілді. Талдау нәтижелері кестелер, сызбалар және графиктер түрінде өсынылған. Тау беткейлері топырақтарының көшкін алдындағы жағдайын анықтау мәселесін шешуге ұсынылған тәсілдің сенімділігі туралы қорытынды жасалады.

Жұмыстың бірінші бөлімі байланыс шарттарының әртүрлі категорияларын сипаттайды. Екінші бөлімде шектік есептің белгілі бір байланыс шарттарымен толықтырылғандағы жұқа серпімді иілген өзектер мен олардың байланыстарының контрукцияларының әртүрлі мысалдары келтірілген. Қорытындыда серпімді жұқа иілген өзектердің түйіспелерінің бос тербелістерінің табиғи жиілігін сандық есептеуі келтірілген.

Түйін сөздер: көлбеу, топырақ, қабаттар, стресс, анизотропия, көшкін.

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ОПРЕДЕЛЕНИЕ ОПОЛЗНЕВОГО СОСТОЯНИЯ ГРУНТОВ СКЛОНА ШЫМБУЛАК С РАЗРАБОТКОЙ КРИТЕРИЯ РАЗРУШЕНИЯ

На базе известного критерия разрушения Кулона Мора применяемого для грунтов изотропного строения, разработан обобщенный критерий разрушения для грунтов слоистого, анизотропного, наклонно слоистого строения. Получены новые выражения для определения параметров механики разрушения позволяющих определить не только направление распространения разрушений, но и возможного распространения линии разрушения вдоль слоев грунта и перпендикулярно к нему. Применением предложенного критерия решена задача об определений напряженного состояния грунтов оползнеопасного горного склона наклонной слоистости, и на стыках грунтов различного геологического строения, типа элювия и делювия. Приводятся результаты анализа в виде таблиц, эпюр и графика. Делаются выводы о надежности предложенного подхода решения задачи по определению предоползневого состояния грунтов горных склонов. В первой части работы описаны разные категории условий сообщения. Во втором разделе приведены различные примеры построения отдельных упругих криволинейных соединений и их соединений, дополненные некоторыми условиями соединения предельной задачи. Результатом является численный расчет собственной частоты свободных колебаний соединений упругих гнутых соединений.

Key words: склон, грунт, слои, напряжение, анизотропия, оползень.

1 Introduction

Due to the lack of a reliable criterion for the destruction of soils on slopes of complex structure, it is still not possible to predict the landslide hazard of mountain slopes, at the immediate foot of which there are buildings, houses, objects of the national economy and densely populated areas. It is assumed that soil failure occurs when the value of stress concentration near the heterogeneity of the soil structure reaches the maximum possible breaking stress. Despite the large number of works on fracture mechanics, research in this area cannot be considered complete, all the more complete, especially in the field of fracture mechanics on mountain slopes, under the foundations of civil and engineering structures for various purposes. The rapid development of computer technologies and methods of computer-mathematical modeling makes it possible to solve specific practical problems with a high degree of reliability in the application of the results. Among these methods of mathematical modeling, the most widespread is the finite element method (FEM). Instantaneous, unexpected landslide masses on the slopes represent a great danger and cause significant human and material damage. To apply the results of the development of a new criterion, one of the specific mountain slopes of the Northern Tien Shan, the Shym Bulak mountain slope, is considered. Landslides of various types have often occurred here over the past decades. These include landslides, avalanches, embankments, and mixed-type landslides. This slope is located on a mountain gorge on a mountain road between the Medeu dam and the Shym Bulak sports complex. The landslides listed above occurred here in 2009, 2011, and in 2015, which are shown in figures1. The types

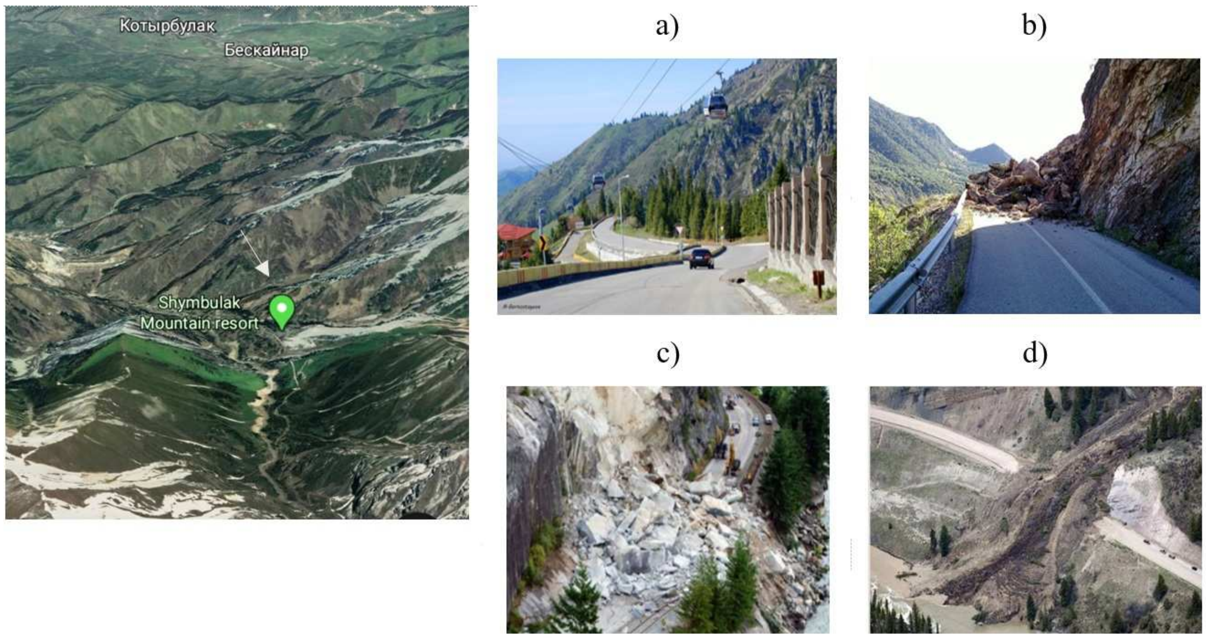

Figure 1: View from space of the Shym Bulak mountain gorges together with the Kishi Almaty River and the road from the Medeu dam to the sports complex

and characters of landslides are as follows: a -2009, species before the landslide; b - and c - landslides and collapses of boulder soils in 2011; d - landslide deluvial soil masses 2015.

2 Materials and Methods

After finding the FEM values of the stress components in the elements σ_x, σ_z and τ_{xz}, the values of the principal stresses and the directions of the main areas $alpha$ are calculated using the following well-known expressions of the theory of elasticity [6].

$$\sigma_{max} = \frac{\sigma_{\text{ya}} + \sigma_{\text{ch}}}{2} + \frac{1}{2}\sqrt{(\sigma_z - \sigma_x)^2 + 4\tau_{zx}^2},$$

$$\sigma_{min} = \frac{\sigma_z + \sigma_x}{2} - \frac{1}{2}\sqrt{(\sigma_z - \sigma_x)^2 + 4\tau_{zx}^2}, \tag{1}$$

$$\tan 2\alpha = \frac{2\tau_{zx}}{\sigma_z - \sigma_x}, \tau_{max} = \frac{\sigma_{max} + \sigma_{min}}{2}.$$

Values of normal stress components $\sigma_{n,\overline{\varphi}}, \sigma_{t,\overline{varphi}}, \tau_{nt,\overline{\varphi}}$ across and along layers of isotropy planes of transtropic array $\overline{\varphi}$, calculated using the following relations, after applying transformation formulas /7/

$$\sigma_{n,\overline{\varphi}} = \frac{1}{2}(\sigma_x + \sigma_y) + \frac{1}{2}(\sigma_x - \sigma_y)\cos 2\overline{\varphi} + \tau_{xy}\sin 2\overline{\varphi}, \tag{2}$$

$$\sigma_{t,\overline{\varphi}} = \frac{1}{2}(\sigma_x + \sigma_y) - \frac{1}{2}(\sigma_x - \sigma_y)\cos 2\overline{\varphi} - \tau_{xy}\sin 2\overline{\varphi}, \tag{3}$$

$$\tau_{nt,\overline{\varphi}} = -\frac{1}{2}(\sigma_x - \sigma_y)\sin 2\overline{\varphi} + \tau_{xy}\cos 2\overline{\varphi} \tag{4}$$

The values of the normal stress components σ_n, σ_t, τ_{nt} at the main sites are similarly calculated for the angle $alpha$ using the following formulas

$$\sigma_n = \frac{1}{2}(\sigma_x + \sigma_y) + \frac{1}{2}(\sigma_x - \sigma_y)\cos 2\alpha + \tau_{xy}\sin 2\alpha,$$

$$\sigma_t = \frac{1}{2}(\sigma_x + \sigma_y) - \frac{1}{2}(\sigma_x - \sigma_y)\cos 2\alpha - \tau_{xy}\sin 2\alpha,$$

$$\tau_{nt} = -\frac{1}{2}(\sigma_x - \sigma_y)\sin 2\alpha + \tau_{xy}\cos 2\alpha.$$

For any angle $0 \leq \overline{\alpha}\, le 90^0$, which defines an arbitrary direction measured from the isotropy plane $\overline{\varphi}$ to the perpendicular to them, for breaking shear stresses, we determine using the Casagrande Carrillo condition in the form [6].

$$\tau_{\overline{\alpha}} = \tau_{max,\perp} + (\tau_{max,\coprod} - \tau_{max,\perp})cos^2\overline{\alpha} \tag{5}$$

or

$$\tau_{\overline{\alpha}} = \tau_{max,90^0} + (\tau_{max,0} - \tau_{max,90^0})cos^2\overline{\alpha} \tag{6}$$

where $\tau_{max,\coprod}$, $tau_{max,\perp}$ are the experimentally determined critical values of layered rocks for the cases $overline\alpha = 0$ and $overline\alpha = 90^0$. Comparing the calculated values of the maximum tangential stresses τ_{max} according to (1) with their critical values according to (4), we determine the zones of destruction of soils and rocks.

If $\tau_{max} < \tau_{\overline{\alpha}}$, then the state of the array is stable.

If $\tau_{max} > \tau_{\overline{\alpha}}$, then the array is destroyed in the direction of the $\overline{\alpha}$ corner.

3 Simulation of the Shymbulak slope using FEM

For the transition to mathematical modeling of the Shym Bulak mountain slope, the following calculation scheme was developed with a West - East view shown in Figures 2 below. Here, the red dotted line shows the slope surface before the landslide, the blue dotted line after the landslide, that is, the current state of the slope. Pebbles and other lines show the movements of the landslide mass and their accumulation on the road. Figure 3 shows the design scheme of the slope consisting of the joints of eluvium, diluvium and proluvium. It also shows the

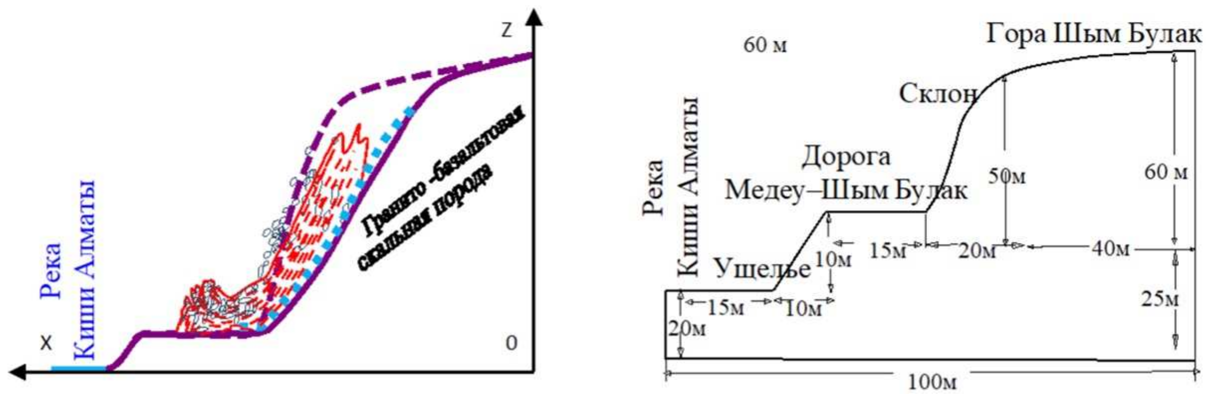

Figure 2: Cross-sectional diagram of the "Shym Bulak"landslide, which consists of granite-basalt rock, soil deposits on a steep slope, a road and the Kishi Almaty river

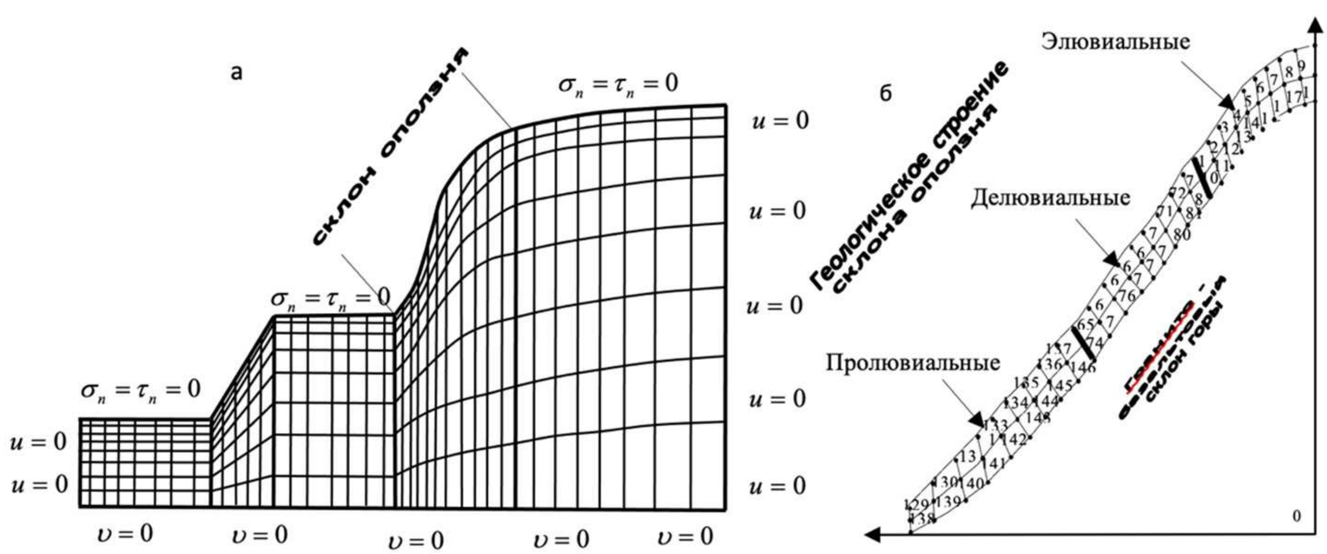

Figure 3: Design scheme of the "Shym Bulak"landslide, prepared for finite element modeling

geometrical dimensions prepared for mathematical modeling. It covers all real natural objects with exact dimensions that are located near landslides and avalanches, shown in Figures 1.

Boundary conditions of the problem. To solve this problem, mixed boundary conditions in stresses and displacements are set. On the two lateral boundaries there are no horizontal displacement components ($U = 0$), based on the computational domain, there are no vertical displacement components ($V = 0$), everywhere at the upper boundaries, there are no normal stress components on the free day surface ($\alpha_n = \tan_n = 0$).

The area shown in Figure 3 is divided into 1260 isoparametric quadrangular elements with a total number of subdivisions of 1334. Slope soils consist of varieties of loam obtained with mixtures of eluvial, deluvial deposits. Therefore, it has an anisotropic structure. The strength properties of the soils of the slope are given in Table 1. Calculations for determining the stress-strain state of soils on the ShymBulak slope were carried out by FEM algorithms and work programs [6] - [9].

Soils	Young's Modules, MPa		Poisson's Ratios		Shift modules, MPa	Volume weight	Forces adhesion, MPa		Angles internal friction, degree	
	E_1	E_2	ν_1	ν_2	G_1	γ	C_1	C_2	φ_1	φ_2
Loam	30.0	15.0	0.36	0.24	7.60	2.00	0.03	0.06	19	23
Loam	12.0	8.0	0.39	0.35	3.40	0.94	0.010	0.014	20	24

4 Results and Discussion

Results of calculated stress values σ_x, σ_z τ_{xz} and σ_{max}, σ_{min}, τ_{max} [6] for different zones and slope layers are shown in Table 2.

The northern slope of the Shym Bulak landslide												
zone	layer	elem №	Stress components in elements, MPa			zone	layer	elem №	Components stresses at the main sites, MPa			Main sites, degree
			σ_x	σ_z	τ_{xz}				σ_{max}	σ_{min}	τ_{max}	α
№ I	№ B 1	8 9	-1.18	-1.05	0.45 -0.42	№ I	№ B 1	8 9	-0.62	-1.53	0.59	31 -69
	2	16 17 18	-1.67	-2.23	-0.44		2	16 18	-1.47	-2.16	0.85	46 -82
II	1	69 73	0.95	-0.49	-0.90	II	1	69 73	1.57			-51
	2	77 81 82	0.41	-1.24	-1.08		2	82		-0.55	1.01	-70
III	1	131 132	-2.57	-2.49	2.29	III	1	131 132 133	2.59	-3.86 -3.48	3.18	52 48 44
	2	139 140	-2.0	-2.61	1.82		2	139 140		-3.48	2.65	56 43

5 Conclusion

By generalizing the critical criteria of fracture mechanics known for an isotropic medium, analytical expressions are obtained that make it possible to determine the type of fracture and opening of cracks propagating along and across the layers of the isotropic plane in a transtropic massif. Thus, the proposed model, research methodology, calculations performed, results obtained for one of the real slopes of the Northern Tien Shan show its reliability.

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