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ANALYSIS OF THE BONDING STRENGTH OF COHESIVE SOILS IN STREAM SCOUR

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Abstract. The results of experimental studies on the mechanical properties of cohesive soils associated with the use in the study of the erosion process are presented. The influence of cohesion force of cohesive soil to erosion is described. The relationship between the eroding water flow velocities and soil cohesion has been obtained.

Key words

normal stress, angle of internal friction, cohesion force, tensile strength, flow velocity.

In this work, we do not aim to deeply study external factors such as hydromechanical and other influences. Instead, we focus on factors that are less covered in the literature related to this topic. One of these important factors is the resistance of soils to displacement. Clarifying this factor plays a significant role in developing effective and improved methods for determining the scouring velocity of water flow.

Maslov proposed using the following three-term formula, rather than the two-term formula, to determine the resistance to displacement [3]:

$$\tau = \sigma tg\varphi + C_k + C_c , \qquad (1)$$

here σ - normal force; φ - angle of internal friction; C_k - Cohesion of a self-healing or resilient formation; C_c - Structural cohesion due to non-recoverable bonds.

This formula represents two types of bonding: C_k bonding due to coagulation, and C_c bonding strength observed in strong transitions and phase connections. In the washing process of clayey soils, the bonding strength due to coagulation, i.e., $C \approx C_k$, is often determined. Therefore, the magnitude of bonding depends on factors such as the density and moisture content of the material, the dispersion and hydrophilicity of the mineral components, the arrangement of particles during displacement, and other factors. In soils where phase bonding predominates, the structural cohesion is determined by the C_c magnitude, which is primarily dependent on the soil's moisture content and composition. In soils with mixed bonding, the structural cohesion is determined by both components, i.e., $C = C_k + C_c$. In normal loadings, where the structural strength is low in $\sigma < P_c$, C_c, $\sigma > P_c$ plays a significant role, whereas in cases where $\sigma < P_c$ is high, C_k becomes crucial. Thus, in clayey soils, depending on the type of structural bonding, not only the magnitude but also the nature of the structural cohesion changes [6].

It is possible to analyze the relationship between the angle of internal friction and the nature of structural bonding. Under underwater conditions, the formation of structural bonding begins with coagulation and aggregation processes that occur during the settling of fine dispersed minerals. It should be emphasized that both short-range and long-range coagulation interactions can form depending on the particle size and shape, their surface potential, relative hydrophilicity, the solution concentration and composition in the voids, and their mutual arrangement in a dispersed medium [4].

Sections of many channels are located in cohesive soils, such as sandy, sandy-clay, and clayey soils. Depending on their ability to retain moisture, these soils can be in a solid, plastic, or liquid state.

Since cohesive soils possess binding properties, they resist both shear and tensile deformations. The ultimate resistance of soils is classified into σ_c ultimate shear resistance and σ_p ultimate tensile resistance. σ_c ultimate shear resistance and σ_p ultimate tensile resistance are interrelated characteristics and can be determined using the same testing methods. For instance, this can be assessed using the ball penetration method.

The σ_p tensile strength of cohesive soils is significantly lower than their σ_c shear strength, and according to the data provided by S.E.Mirtskhulava [5], this value is $(0{,}15 \div 0{,}18)\sigma_c$ for soils with an aggregated structure and $(0{,}20 \div 0{,}22)\sigma_c$ for soils with a massive structure. In this case, the σ_p dynamic strength in tension can be considered as $\sigma_p = 0{,}18\sigma_c$.

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Thus, for cohesive soils, the key strength characteristic is the σ_c shear strength. To determine the cohesion of water-saturated soils, the following empirical correlation has been established [1]:

$$\sigma_c = 10^7 \frac{W_p^4}{\varepsilon_n^3} \qquad (2)$$

here, W_p – the moisture content of the soil at the rolling (kneading) limit (the ratio of the mass of water in the sample to the dry mass of the soil); ε_n – the porosity coefficient.

According to the experimental data obtained from cohesive soil samples, σ_c – dynamic shear strength and σ_p – dynamic tensile strength were determined (Table 1).

In sandy soil No. 6, due to the high content of fine sand, there is no σ_c dynamic shear strength and σ_p dynamic tensile strength.

At the initial stage of the formation of cohesive soils, the fissures are filled as a result of coagulation, followed by the sinking of the fissures and the continuous consolidation of the deposited sediments. This process leads to the development of a fissured cellular structure in the soils. In such soils, the particle size $d < 10^{-5}$m is very small, and their porosity coefficient $\varepsilon_n > 1 \div 1,5$ and moisture content are 80-85%, and they are referred to as clays.

Table 1

Dynamic strength of σ_c shear and σ_p tensile

	Soil mple	C, $кг/см^2$	υ_p, $м/с$	$\upsilon_{кр}$, $м/с$	d	i	U_*	$\sigma_c = 10^7 \frac{W_p^4}{E_n^3}$	$\sigma_p = 0,18 \cdot \sigma_c$
1	2		4	5	6	7	8	9	10
1	1-soil	0,094	0,67	0,48			0,0108	0,004 *10⁷	0,0007 2*10⁷
2	2- soil	0,088	0,51	0,36			0,0108	0,001 *10⁷	0,0001 8*10⁷
3	3- soil	0,084	0,67	0,48			0,0108	0,000 7*10⁷	0,0001 26*10⁷
4	4- soil	0,068	0,5	0,36			0,0108	0,000 5*10⁷	0,0000 9*10⁷
5	5- soil	0,043	0,45	0,32	0,004	[illegible]	0,0108	0,000 6*10⁷	0,0001 08*10⁷

6	6- soil	0	0,47	0,34			0,0108	-	-

It is known to us that clay soils, strongly saturated with water, create a viscous-plastic environment that does not obey Newton's law of flow.

$$\tau = \tau_b + \mu_{эф} \frac{d\bar{u}}{dz}, \qquad (3)$$

here, τ – shear stress between the moving layers; $\mu_{эф}$ – effective cohesion.

Effective cohesion can be determined using the following formula:

$$\mu_{эф} = \mu\left(1 - ac^n\right)^n, \qquad (4)$$

here a and n -parameters

According to experimental studies [1], $a = 1{,}58$ and $n = 0{,}175$ can be accepted. According to Mirtskhulava's experiments, it is equal to $a = 1{,}3$.

Now, let's consider the effect of cohesion forces on erosion in cohesive soils. The cohesion forces in cohesive soils have very complex characteristics and are determined by the following internal bonds: molecular-contact; colloidal structure; cementation [3, 4, 5, 6, 7].

If cohesive soils are saturated with water, the cohesion forces increase their resistance to erosion by flow, and these forces determine their stability.

To study the erosion of cohesive soils under the influence of flow, we conducted experiments in the laboratory of "UzGASHKLITI" LLC (State Design and Research Institute of Construction, Geoinformatics, and Urban Cadastre).

Based on the experimental data, we will examine the effect of cohesive soils' resistance to shear (Table 2).

According to Table 2, we construct the correlation diagram between τ shear strength and normal stress (Figure 1) and analyze it based on the cohesion. From Table 2, as the frictional force C increases, the value of τ shear strength also increases.

Since the experiments were conducted under slowly consolidated shear conditions, $\varphi = f(\sigma)$ shows a linear relationship, while the value of φ coefficient increases. The increase in the coefficient φ can be attributed to the following reasons:

- The decrease in the hydrated film layer at coagulation contacts and the increase in molecular interactions between particles as water is squeezed out of the system;
- The increase in the number of contacts.

Table 2

The shear resistance of cohesive soils.

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№	Soil example	σ	$tg\varphi$	C	$\tau = \sigma tg\varphi + C$
1	2	3	4	5	6
1	1-soil	1,194	27	0,094	0,703
2	2- soil	1,113	27	0,088	0,656
3	3- soil	1,063	26	0,084	0,579
4	4- soil	1,025	25	0,068	0,545
5	5- soil	0,956	25	0,043	0,488
6	6- soil	0,191	10		0,034

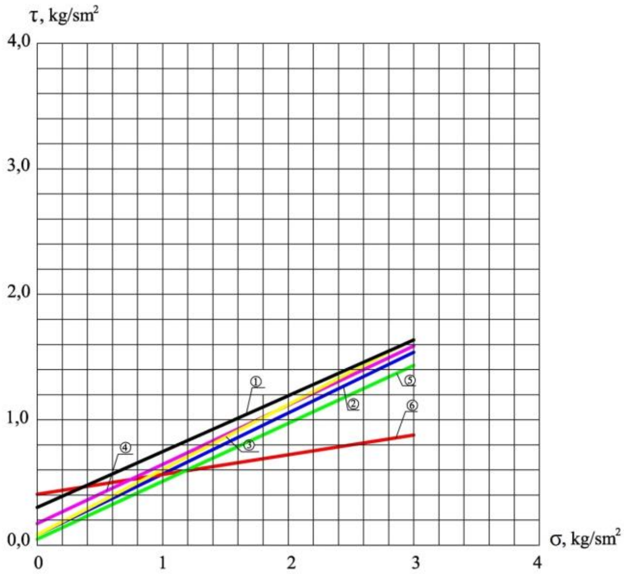

Fig. 1. $\tau = f(\sigma)$ **Cohesion diagram.: soil 1; soil 2; soil 3; soil 4; soil 5; soil 6.**

Thus, in clayey rocks with strong spatial contact, $\tau = f(\sigma)$ cohesion shows a linear relationship, and its intercept on the abscissa axis is almost independent of the experimental conditions. Since these clayey rocks have a high degree of stability, their φ angle is considerably higher.

The erosion of cohesive soils by flow is mainly more dependent on their cohesion strength. The cohesion strength of fully water-saturated cohesive soils often determines the degree of strong bonding and stands out due to its predominance over other physical-mechanical properties that resist erosion.

To demonstrate the predominant nature of this factor, we will analyze the laboratory data (Table 1) obtained for determining the cohesion strength of cohesive soil samples.

In cohesive soils with an aggregate structure (sandy, sandy-clay), erosion results from the disruption of the inter-aggregate bonding. It should be emphasized that the size of the dislodged aggregate particles is determined by the turbulence of the water flow, its structure, and intensity. In nearly flat channel beds, the disintegration of aggregates occurs only within the range of pulsating pressure forces, and this can be determined as follows [2]:

$$p' = 3,5\rho u_*^2 \quad (5)$$

here u_* - dynamic velocity of the flow.

The changing dynamic pressure, which is dependent on pulsating pressure, leads to the disruption of the bonding characteristics between aggregates. As a result, this always creates conditions for the formation of micro-cracks. At this point, the aggregates can only remain in their position due to their own weight. The pressure pulsations that occur cover a large portion of the channel bed surface. In this particular situation, since the pressure standard pulsation value on the surface of the soil aggregate is very small, it can be neglected. If the negative sign pulsating pressure acting on the surface of the aggregate is equal to the gravitational force acting on the aggregate, the erosion of the cohesive soil will occur. This condition can be expressed as follows:

$$p' \cdot d_a^2 = (\rho_s - \rho) g d_a \cdot d_a^2, \quad (6)$$

here d_a - aggregate size.

Taking into account the magnitude (5), we write the equation in the following form (6):

$$3,5\rho u_*^2 d_a^2 = (\rho_s - \rho) g d_a^3 , \quad (7)$$

ρ_s - soil density.

From equation (7), the size of the dislodged aggregates can be found, that is:

$$d_a = \frac{3,5u_*^2}{g\left(\frac{\rho_s}{\rho} - 1\right)} . \quad (4)$$

According to laboratory experiments, at dynamic speeds of $u_* = 10 \div 15$ $см/с$, the size of the dislodged aggregates is approximately $d_a = 3 \div 4$ $мм$. From this, we can see that the process of erosion of cohesive soil related to turbulent flow is always dependent not only on the cohesion strength but also on other factors.

Now, based on the experimental data, we will establish the relationship between the washing rate of the flow and the cohesion strength of cohesive soil (Figure 2).

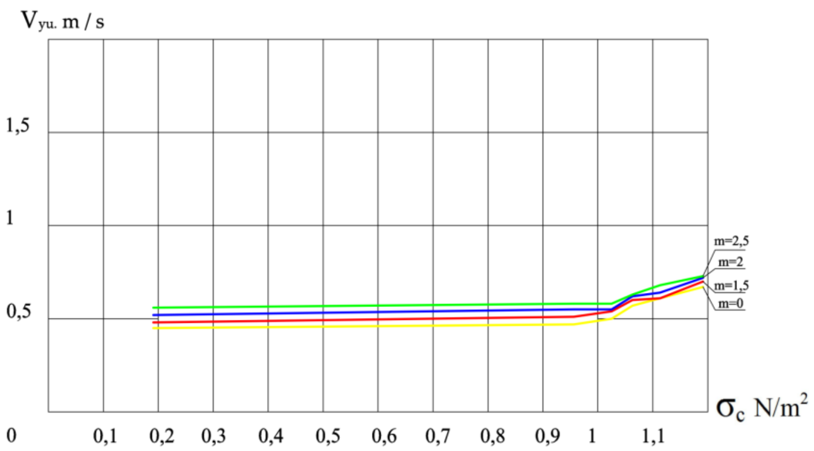

Fig. 2. $\upsilon_p = f(\sigma_c)$ **Cohesion diagram**

In Figure 2, the $\upsilon_p = f(\sigma_c)$ relationship graph shows the condition for determining the flow washing rate in relation to the dynamic shear strength parameter.

Also, based on the experimental data, we will construct the relationship graph $\upsilon_p = f(C_b)$ between the υ_p washing rate of the flow and the C_b cohesion strength of the cohesive soil.

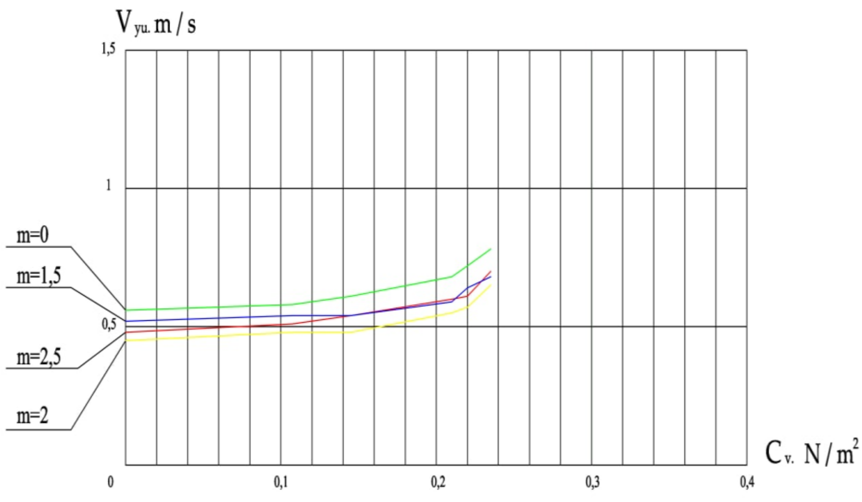

Fig. 3. $\upsilon_p = f(C_b)$ **Cohesion diagram**

In laboratory and field conditions, it was observed that with an increase in the cohesion strength of cohesive soils passing through the channels, their resistance to erosion also increased.

REFERENCES

1. Брянская Ю.В., Маркова И.М., Остякова А.В. Под ред. В.С.Боровкова. Гидравлика водных и взвесенесущих потоков в жестких и деформируемых границах. – М.: Издательство АСВ, 2009, - 264с.

2. Лятхер В.М. Турбулентность в гидросооружениях. М.: Энергия, 1968, - 408 с.

3. Маслов Н.Н. основы механики грунтов и инженерной геологии. М.: Высщая школа, 1968. -285 с.

4. Месчян С.Р. Экспериментальная реология глинистых грунтов. М.: Недра, 1985. -342.

5. Мирцхулава Ц.Е. Размыв русел и методика оценка их устойчивости. М.: Колос, 1967. - 179 с.

6. Осипов В.И. Природа прочностных и деформационных свойств глинистых пород. -Изд. Московского университета. 1989, - 235 с.

7. Цытович Н.А. Механика грунтов. – М.: Высшая школа, 1983, -288 с.

8. Sobir, E., Furkat, B., Alisher, I., & Nurbek, M. (2022). EVALUATION OF THE INFLUENCE OF THE PHYSICAL PROPERTIES OF BOUND SOILS ON THE WASHING PROCESS. Universum: технические науки, (9-5 (102)), 18-22.

9. Эшев, С. С., Авлакулов, М., & Бобомуродов, Ф. Ф. (2022). Боғланган грунтларнинг физик хусусиятларини ўзан ювилиш жараёнига таъсирини баҳолаш. Инновацион технологиялар, 3(3 (47)), 48-54.

10. Хазратов, А. Н., Раҳимов, А. Р., & Бобомуродов, Ф. Ф. (2022). Моделирования смешанных течений земляных каналов. In Актуальные проблемы науки и образования в условиях современных вызовов (pp. 160-167).

11. Эшев, С. С., Каримов, Э. К., Бобомуродов, Ф. Ф., & Маматов, Н. З. (2022). БОҒЛАНГАН ГРУНТЛАРДАГИ БИРИКИШ КУЧИНИНГ ЎЗАН ЮВИЛИШИГА ТАЪСИРИНИ БАҲОЛАШ. Инновацион технологиялар, 3(3 (47)), 76-82.

12. Eshev, S. S., Avlakulov, M., & Bobomurodov, F. F. (2022). Assessment of the effect of the physical properties of bonded grunts on the process of self-washing. Innovation of technology, 3, 47.

13. Eshev, S. S., Bobomurodov, F. F., Isakov, A. N., & Mamatov, N. Z. (2022). Evaluating the effect of cohesive strength on self-leaching in bonded soils. International Journal of Advanced Research in Science, Engineering and Technology, 9(8), 19636-19641.

14. Khazratov, A. N., Bazarov, O. S., Jumayev, A. R., Bobomurodov, F. F., & Mamatov, N. Z. (2023). Influence of cohesion strength in cohesive soils onchannel bed erosion. In E3S Web of Conferences (Vol. 410, p. 05018). EDP Sciences.

15. Sobir, E., Israil, G., Ashraf, R., Furqat, B., & Dilovar, A. (2023). Calculation of parameters of subsurface ridges in a steady flow of groundwater channels. In E3S Web of Conferences (Vol. 410, p. 05022). EDP Sciences.

16. Eshev, S., Mamatov, N., Bobomurodov, F., Usmonov, R., & Makhmudov, U. (2023). SHO ‘RLANGAN BOG ‘LANGAN GRUNT NAMLIGINING YUVILISHGA QARSHILIK QILISH TA’SIRINI BAHOLASH. Innovatsion texnologiyalar, 51(03), 70-76.

17. Farxod o‘g‘li, B. F. BOG ‘LANGAN GRUNTLI KANAL KESIMI BO ‘YICHA TEZLIKLARNING TAQSIMLANISHI.

18. Рахимов, А. Р., Назаров, О. О., Исаков, А. Н., & Бобомуродов, Ф. Ф. (2021). ДИНАМИЧЕСКИ УСТОЙЧИВЫЕ СЕЧЕНИЯ КРУПНЫХ КАНАЛОВ С УЧЕТОМ ВЕТРОВОГО ВОЛНЕНИЯ. Инновацион технологиялар, (Спецвыпуск 1), 82-89.

19. Bobomurodov, F. F., & Erkinov, S. (2023). EVALUATION OF THE PHYSICAL PROPERTIES OF GROUND AND BOUND IN O'ZAN WASH. Intent Research Scientific Journal, 2(6), 10-17.

20. Abdurakhmanovich, A. S., & Shokirovich, T. J. (2024). CALCULATION OF TOTAL CHANNEL EROSION IN COHESIVE SOILS. *AMERICAN JOURNAL OF EDUCATION AND LEARNING*, *2*(5), 965-975.

21. Gaimnazarov, I., Rakhmatov, M., Otakulov, U., Jumayev, A., & Khazratov, A. (2023). KANALLARNING NOSTATSIONAR OQIM SHAROITLARIDA OQIZIQLAR SARFINI ANIQLASH BO‘YICHA DALA TADQIQOTLARI. *Innovatsion texnologiyalar*, *52*(3).