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## SELECTION OF DESIGN VALUES FOR PHYSICAL-MECHANICAL PROPERTIES IN THE CONSTRUCTIONS ON COLLAPSIBLE SOILS

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**Abstract.** The article substantiated the necessity of detailed geological-engineering surveys during the design and construction on collapsible soils. A landslide incident on the Cahul-Giurgiulești railway line at 74<sup>th</sup> km was highlighted. Among the main causes there were the soaking of collapsible soils and the development of suffusion processes. A brief historical overview of the study of collapsible soils in Republic of Moldova was provided. The results of theoretical and laboratory studies aimed at further revealing the nature of collapsible soils were presented. The impact of additional soil moisture on the values of physical-mechanical property characteristics was studied. Based on the moisture-density theory, the dependencies of strength on consistency were constructed. It was established that the decrease in the strength of collapsible loams over time might have been caused by the disruption of rigid cementation bonds of structural cohesion ( $C_c$ ) and the reduction of hydrocolloid cohesion ( $\Sigma_w$ ) under conditions of changes in the existing natural moisture regime (consistency) due to additional moisture from engineering activities and the rise of the groundwater level. Recommended design values for physical-mechanical characteristic parameters for construction projects were provided.

**Keywords:** *foundation, loess, landslide, strenght, soaking, reology.*

**Rezumat.** În articol a fost subliniată necesitatea efectuării unor investigații geologico-inginerești aprofundate pentru proiectarea și construcția pe pământuri sensibile la umezire. A fost menționat cazul de apariție a alunecării de teren pe un segment al drumului de cale ferată Cahul-Giurgiulești, km-ul 74. Printre principalele cauze au fost menționate anume umezirea pământurilor sensibile la umezire și dezvoltarea proceselor de sufoziune. A fost oferită o scurtă prezentare istorică a studiilor efectuate asupra pământurilor sensibile la umezire din Republica Moldova. Au fost prezentate rezultatele cercetărilor teoretice și celor de laborator, menite să aprofundeze înțelegerea naturii pământurilor sensibile la umezire. A fost studiată influența umezirii suplimentare a pământurilor asupra valorilor caracteristicilor fizico-mecanice ale acestora. Pe baza teoriei densității-umidității au fost construite dependențele rezistenței în funcție de consistență. S-a stabilit că scăderea rezistenței

argilelor sensibile la umezire în timp poate fi cauzată de distrugere legăturilor rigide ale coeziunii structurale ( $C_c$ ) și de reducerea coeziunii de natură hidrocoloidală ( $\Sigma_w$ ) în condițiile schimbării regimului natural de umiditate (consistență) din cauza umezirii suplimentare ca urmare a activităților ingineresti și a creșterii nivelului apelor subterane. Au fost recomandate valori de calcul ale parametrilor caracteristicilor fizico-mecanice pentru proiectare.

**Cuvinte cheie:** fundație, loess, alunecare de teren, rezistență, înmuiere, reologie.

## 1. Introduction

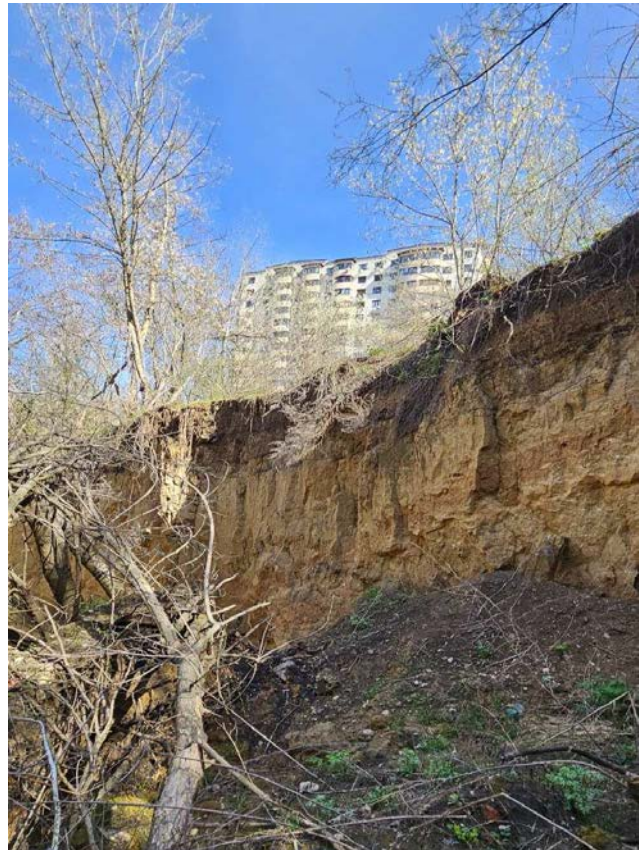
The analysis of literary sources and expert studies has shown that construction on loess soils in the Republic of Moldova is generally carried out successfully. However, newly identified cases of deformation in several areas during field surveys have necessitated revisiting the peculiarities of design and construction on collapsible soils.

Figures 1 and 2 show photographic material reflecting the development of gully-landslide deformations in Chisinau, near the residential complex on Tudor Strisca Street 6. The deformations are occurring within the layer of collapsible loess. The gully extends up to 150m in length, with a width varying from 1.5 to 12m and a depth ranging from 1.0 to 5.7m.



**Figure 1.** The damaged drainage ditch, which became the cause of the gully formation.

*Photo by A. Cirlan, March 31, 2024.*



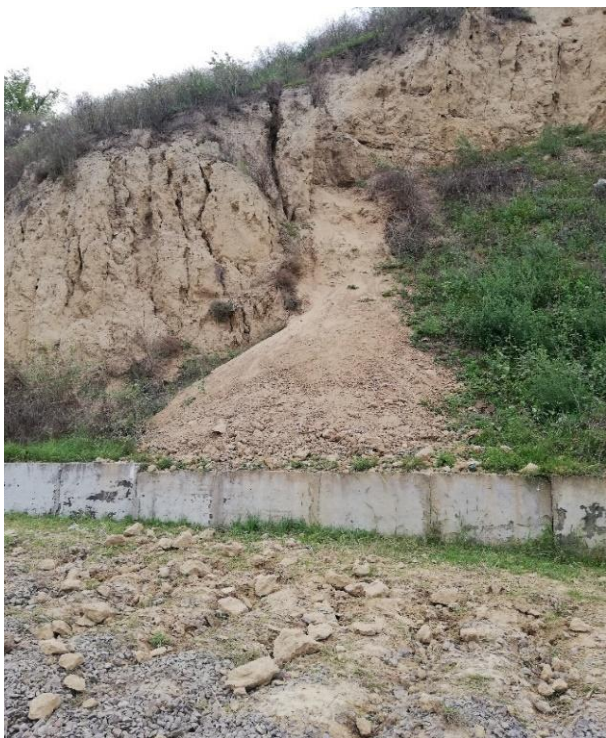
**Figure 2.** Gully-landslide deformations developing 150 m from the residential complex.

*Photo by A. Cirlan, March 31, 2024.*

The following case must unfortunately be classified as catastrophic. In the summer of 2022, a landslide occurred on the Cahul-Giurgiulesti railway line at 74<sup>th</sup> km near the Valeni village. The landslide extended approximately 300m along the railway line, with a width of 90-95m (see Figures 3 and 4).

The thickness of the landslide soils exceeds 30m. The slope and the floodplain area are composed of sandy loam soils. In the deformation zone, the soil profile includes collapsible sandy loams, loams, and water-saturated sand.

Significant difficulties arose during the construction of silos on the area adjacent to the port in Giurgiulesti. The foundation soils here consist of a substantial thickness (over 20m) of collapsible sandy loams and light loams. Undoubtedly, such cases cannot be overlooked.



**Figure 3.** Landslide deformations on a slope composed of collapsible soils.

*Photo by C. Sherepera, 2022.*



**Figure 4.** Displacement of the retaining wall due to the landslide process.

*Photo by C. Sherepera, 2022.*

### **1.1. Brief Historical Overview**

Detailed study of loess soils in Moldova began in the late 1950s. Among the earliest works was that of V.F. Kraev, which investigated the collapsible properties of the loess in the coastal area of the lower part of Transnistria (Administrative-Territorial Units of the Left Bank of the Dniester) [1].

In the early 1960s, the Institute of Geology and Geophysics of the Academy of Sciences of Moldova included a topic on the regional and comprehensive study of loess soils in its research plan. One of the sections was worked on by V.S. Goncharov during the period from 1963 to 1970 [2].

Based on the conducted research, a schematic map of the distribution and thickness of loess soils was created. It is important to note that the thickness of collapsible soils can vary from 1.0 to 25m. The loess cover of the lower part of Transnistria is found on all topographic elements: terraces, valley slopes, ravines, watersheds, and interfluves [2, pp. 19]. This fact is highly valuable as it allows for the differentiation of areas into Type I and II based on collapsibility, which forms the basis for the design of foundations for buildings and structures.

Based on research conducted from 1965 to 1975, G.E. Kostik completed a PhD thesis [3]. The work focused on predicting loess collapse using the method of engineering-geological analogies. G.E. Kostik posits that the extent of collapse should be considered as the sum of random variables, extrapolated within specific intervals of the soil layer or massive, and should also be treated as a random variable.

Based on the research conducted by G.E. Kostik, a methodology was developed that allows for determining the relative collapsibility of soils by evaluating just three indicators: moisture content, bulk density, and particle density.

According to the authors of the present work, the proposed methodology should be tested on a larger number of sites.

In the mid of 1970s, G.E. Kostik identified patterns of distribution, occurrence, and thickness of loess soils in Moldova [4]. This led to the development and implementation of modern methods for elimination of soil collapsibility, which significantly enhanced the safety of constructing buildings and structures on structurally unstable soils.

A significant event in the study of loess soils in Republic of Moldova was the publication of the monograph by Yu.I. Olyanskiy in 1992 [5]. The results of Yu.I. Olyanskiy extensive research are essentially the first attempt to generalize existing data on loess soils in Moldova.

For designers, builders, and professionals in the agricultural sector, the most important fact is that “loess soils cover about 60% of the northern zone of the republic and over 90% of the southern zone, and are located in areas of intensive industrial and civil construction” [5, pp. 3]. Further research by Yu.I. Olyanskiy and his students focused on the patterns of subsidence development, forecasting loess area flooding, and post-collapse compaction issues [6-9].

In recent decades, the number of publications on the study of collapsible soils in Republic of Moldova and construction on these soils has decreased. It is surprising that research is now being conducted outside of Republic of Moldova [10-13].

Recent contributions include the works of A.D. Rascovoi [13, 14] and E.V. Shchekochikhina [15]. In particular, A.D. Rascovoi identified that for a long period, the study of collapsible soil properties was primarily conducted within the confines of major urban areas. Currently, new undeveloped territories are being explored, and construction is actively expanding in the southern regions of the republic. This situation underscores the need not only for theoretical research on loess soils within urbanized areas but also (which is most crucial) for obtaining calculated values of the physical-mechanical characteristics of soils for use in the design and construction on collapsible soils.

E.V. Shchekochikhina emphasizes the need to pay increased attention to factors that can impact the stability of structures during design and construction. One such factor is the co-occurrence of collapsible loess soils and the underlying Sarmatian clays. The impermeable properties of the clays contribute to the development of active groundwater conditions, resulting in the formation of a technogenic aquifer, the filtration of which leads to not only collapsible but also post-collapse deformations in the loess soils [15].

This has defined the main objective of the present study: to obtain new data characterizing the strength and deformation properties of loess soils for reliable design and safe construction on collapsible soils.

## 1.2. Research objectives

The chosen topic and the defined primary objective of this research required addressing the following tasks:

- to analyze previously published research on the study of the characteristics of collapsible soil properties occurring on the Republic of Moldova territory;
- to examine the physical-mechanical and rheological properties of loess soils in Republic of Moldova and their impact on the performance of the base of constructions;
- to determine the causes of potential strength reduction in collapsible soils;
- to determine the values of design strength indicators under varying conditions affecting the bases composed of collapsible soils.

## 2. Materials and Methods

This research is based on the following results:

- the analysis of numerous literature sources revealing the properties of collapsible soils in Republic of Moldova.
- field investigations, sampling of the necessary quantity of soil monoliths, and their subsequent study under laboratory conditions.
- determination of physical characteristics (according to standard methodologies);
- determination of strength and rheological characteristics of collapsible soils.

The experiments were carried out on direct shear devices. Samples with natural moisture content and those subjected to pre-soaking were tested. The results were processed using the moisture-density theory and the Maslov physico-technical creep theory [16].

Rheological characteristics such as structural cohesion ( $C_c$ ), hydrocolloid cohesion ( $\Sigma_w$ ), and creep threshold ( $\tau_{lim}$ ) were determined based on the results of shear tests on prepared surfaces. Long-term strength was determined through tests on prepared wetted surfaces. The results were processed according to the Coulomb-Mohr relationship.

In the overall scope of these studies, primary attention was given to the accurate determination of the physico-mechanical characteristics of soils with undisturbed structure and natural moisture content, as these indicators significantly influence further conclusions about soil properties.

Even slight disturbances in structure and moisture content lead to fundamental changes in strength and deformation characteristics. Therefore, in addition to soil monolith sampling during exploratory drilling, trenching was also conducted, with control samples taken in the form of monolith cubes, which were carefully sealed and tested in the geotechnical laboratory within a short time frame.

Additionally, supplementary control was carried out, based on field tests of soil samples using Litvinov's laboratory for accelerated testing of soil construction properties directly in natural conditions [17].

## 3. Results of the research

For reliable and efficient construction of buildings and structures in areas where structurally unstable soils are prevalent, the necessity of conducting fundamental research on their construction properties is beyond doubt. This is evidenced by the works of most scientists and researchers studying loess soils. The specific characteristics of such soils are determined by their structure, which depends on the conditions of the origin of the

formations, the subsequent process of compaction and transformation of accumulated sediments.

The key features of loess formations primarily include: the presence of vertically oriented macroporous channels, the ability to maintain a vertical slope of significant height, rapid solubility in water, and more. According to the widely recognized expert Yu.M. Abelev, it is precisely the macroporous structure that defines the deformation, strength, and filtration properties of loess formations [18].

When fully saturated with water, and even with minor moisture, the properties of loess formations change significantly. This implies that the safe performance of the base of structures could be compromised. This is clearly demonstrated by the aforementioned case of the loss of stability of the railway embankment on a section located on the western outskirts of the Văleni village in the Cahul district.

Field surveys and analysis of investigation materials conducted by the company "Intexnauca" revealed that the examined section of the railway track passes through a narrow floodplain of the Prut River. The Prut terrace rises 35m above the floodplain. The slopes are nearly vertical (see Fig. 3). The width of the floodplain over a distance of 300-320m is 10-14m. As a result of the landslide, the integrity of the railway track was completely disrupted. The topographic survey analysis showed that the displacement of the railway bed reached 4.5m. The lower retaining wall was displaced and overturned over a length of 25-30m. In the area of maximum deformations, the reinforcing slabs at the bottom of the slope were deformed (see Figure 4). One of the possible causes of the landslide process is attributed to the periodic changes in the water level of the Prut River and seasonal anomalies in precipitation, which contribute to the development of suffusion processes.

Within the framework of the ongoing scientific research, it was important to emphasize the following:

- the presence in the structure of the explored thickness of the slope (among other soils) of loess-like subsidence loams and sandy loams of solid consistency;
- the presence of a thin layer of soft to fluid-plastic loams and sandy loams;
- presence of interlayers of Sarmatian clay.

To quantitatively assess the physical and mechanical properties of loess soils in their natural deposition conditions on undeveloped areas and sites selected for construction in densely built-up areas, an analysis of geological maps and typical geological cross-sections was initially conducted, as well as a review of relevant literature sources. This analysis was based on the most significant works of V.S. Goncharov, G.E. Kostik, Yu.I. Olyanskiy, and other researchers.

The research work by E.V. Shchekochikhina [15] should be included among the latter. The author provided a detailed characterization of the composition and properties of the loess cover of the territory of Moldova. For general conclusions, E.V. Shchekochikhina used the results from over a thousand experiments conducted personally, as well as data previously obtained by various scientists and researchers.

When designing and constructing on collapsible soils, it is essential to first have the following data:

- thickness of the collapsible soil layer;
- soil density;
- values of collapsibility characteristics: initial collapsible moisture, relative collapsibility, initial collapsible pressure;

- values of strength characteristics: angle of internal friction and cohesion;
- values of deformation characteristics: compressibility coefficient, deformation modulus;
- values of the coefficient of filtration.

Undoubtedly, depending on the tasks to be solved, additional data may be required. According to the authors of this work, the least studied aspects are the strength and deformability characteristics of soils, which largely determine the stability of slopes, foundation sizes, dimensions of retaining structures, etc. Therefore, this work focuses primarily on the strength of collapsible soils and its potential change with additional moisture.

It should be noted that since shear resistance significantly depends on the granulometric composition, natural moisture content, and structural features of the soils, there is considerable variability in the results obtained for different types of loess soils.

For example, according to V.S. Goncharov, the angle of internal friction ( $\varphi$ ) varies from 14° to 20°, and cohesion (C) ranges from 12 to 85kPa. For heavy loams, the most common values are:  $\varphi=17-20^\circ$ ,  $C=50-60\text{kPa}$ . For medium and light loams, respectively,  $\varphi=20-23^\circ$ ,  $C=20-40\text{kPa}$ .

Therefore, in studying strength issues, it was taken into account that disturbances in the natural equilibrium of the geological environment, including those caused by the saturation of the foundation and additional loads arising within construction sites, create new qualities and properties of the soils, consequently altering the bearing capacity of the foundations.

The experimental part of this work was conducted at the geotechnical laboratory "Ingeotehgrup."

The results are summarized in Tables 1-4. Graphical interpretation is presented in Figures 5-8.

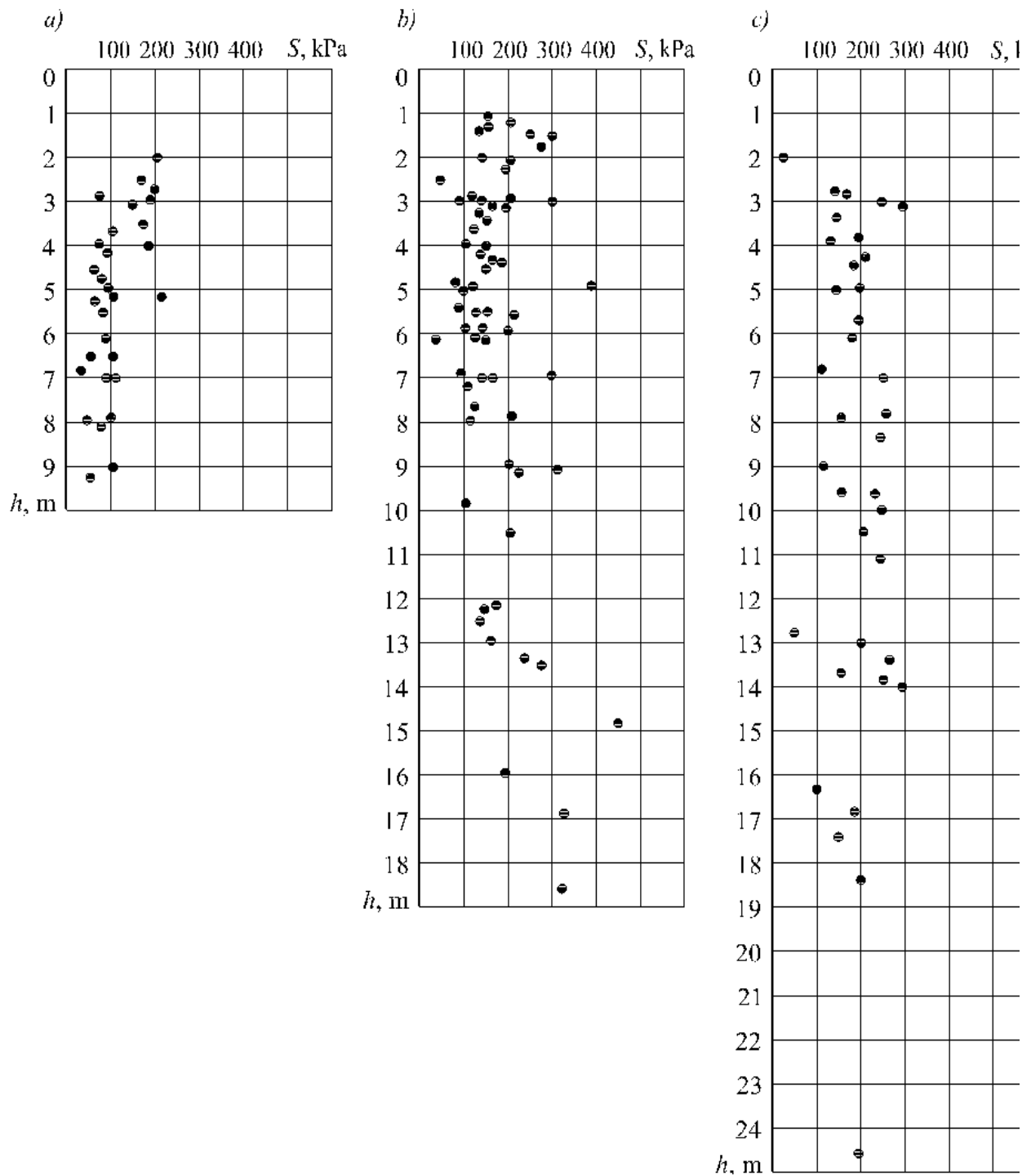
Table 1

<b>Strength property indicators of loams</b>					
<b>Region of the Republic of Moldova</b>	<b>Range of strength variation <math>\tau_f</math> (kPa), at pressure <math>\sigma = 200\text{kPa}</math></b>	<b>Angle of internal friction <math>\varphi</math> (degrees)</b>	<b>Total cohesion <math>C_w</math> (kPa)</b>	<b>Structural cohesion <math>C_c</math> (kPa)</b>	<b>Hydro-colloidal cohesion <math>\Sigma_w</math> (kPa)</b>
Northern	39 ÷ 222	11	60	40	20
Central	50 ÷ 375	14	120	60	60
Southern	20 ÷ 280	17	120	70	50

Based on the results presented in Table 1 and Fig. 5 the results show that in the investigated samples from the northern and central districts the values of structural and hydrocolloid cohesion are of practically the same proportions (50%). For the southern districts, structural cohesion bonds predominate in the total cohesion.

The maximum strength is characterized by the rocks of central and southern Moldova.

Processing of the experimental data showed that there is no systematic change of strength properties of the soils with depth. A significant scatter in the experimental determinations of strength properties was noted (Table 1, Fig. 5).



**Figure 5.** Scatter plots of strength ( $S$ ) versus depth ( $h$ ), for loams. Pressure  $P=200\text{kPa}$ :  
*a)* northern region; *b)* central region; *c)* southern region.

To identify the nature of the strength of the investigated soils, results from more than 750 shear tests of samples with natural and prepared shear surfaces were processed.

The equations characterizing the loams strength for different regions of Republic of Moldova, are expressed by the corresponding equations:

$$S_1 = 0,19\sigma + 60\text{kPa} \quad \text{– for northern region;} \quad (1)$$

$$S_2 = 0,25\sigma + 120\text{kPa} \quad \text{– for central region;} \quad (2)$$

$$S_3=0,30\sigma+120\text{kPa} \text{ – for southern region;} \quad (3)$$

where  $\sigma$  – the normal pressure to the shear plane.

Based on the results of shear tests on prepared surfaces, the total cohesion ( $C_w$ ) was divided into two components: rigid structural cohesion ( $C_c$ ) and hydrocolloid cohesion ( $\Sigma_w$ ). This allowed for the derivation of equations characterizing the strength of the investigated soils at complete disruption of structural cohesion, based on the concept of prof. N.N. Maslov [17].

$$S_{rez1}=0,19\sigma+20\text{kPa} \text{ – for northern region;} \quad (4)$$

$$S_{rez2}=0,25\sigma+60\text{kPa} \text{ – for central region;} \quad (5)$$

$$S_{rez3}=0,30\sigma+50\text{kPa} \text{ – for southern region;} \quad (6)$$

To further investigate the potential reduction in strength with changes in consistency, shear tests on water-saturated soils were carried out, with special preparation of the samples and subsequent processing using the “density-moisture” method (Table 2, Figures 6-8).

Table 2

Indication of physical properties of the studied samples					
Region of the Republic of Moldova	Particle density $\rho_s$ (g/cm <sup>3</sup> )	Density $\rho$ (g/cm <sup>3</sup> )	Moisture $w$ (%)	Plasticity index $I_p$ (fract. unit)	Consistency $I_L$ (fract. unit)
Northern	2.69	$\frac{1.95}{1.65 \div 2.10}$	$\frac{25}{15 \div 40}$	$\frac{14}{7 \div 17}$	$\frac{0,2}{-0.5 \div 0.7}$
Central	2.72	$\frac{1.95}{1.5 \div 2.2}$	$\frac{15}{5 \div 25}$	$\frac{14}{10 \div 17}$	$\frac{0}{-0.5 \div 0.4}$
Southern	2.70	$\frac{2.00}{1.7 \div 2.2}$	$\frac{15}{5 \div 20}$	$\frac{10}{8 \div 17}$	$\frac{-0.1}{-0.6 \div 0.3}$

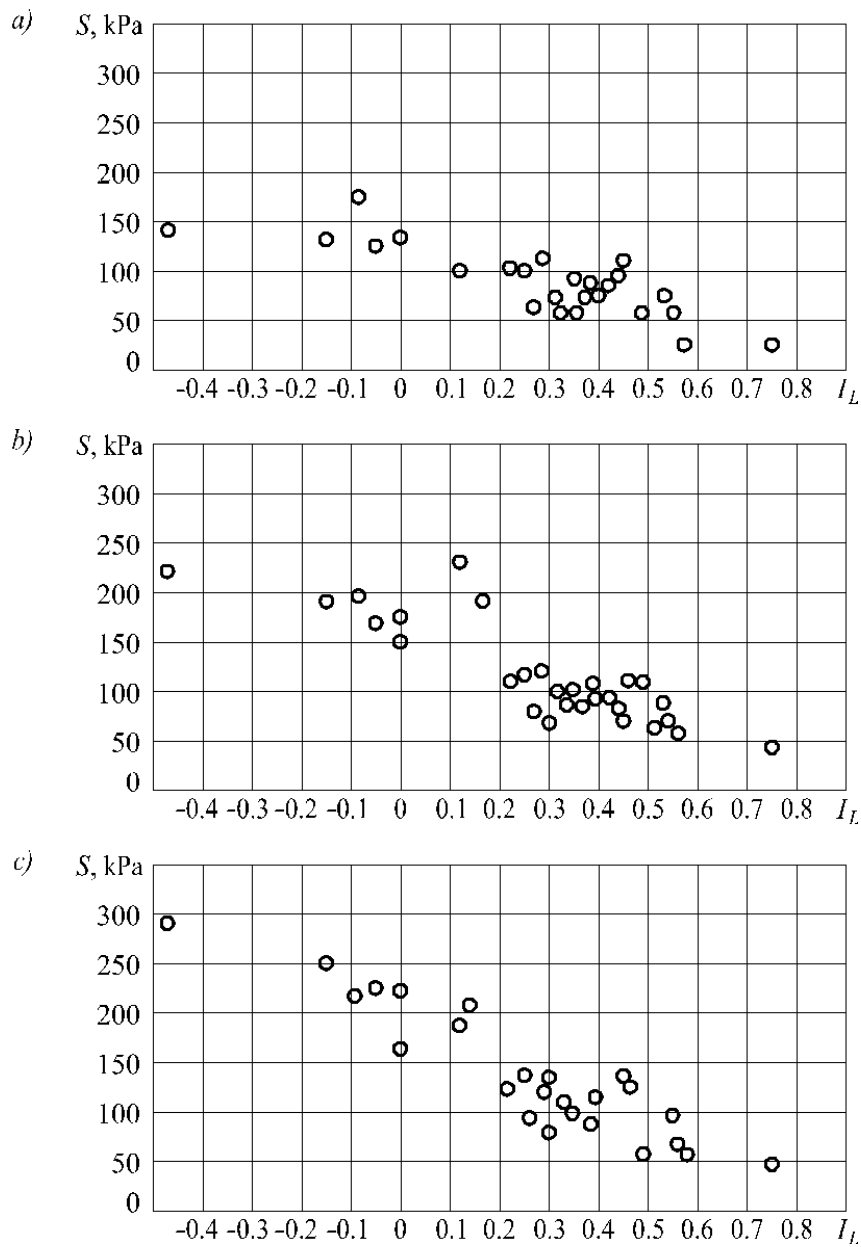
Additional moistening allowed to extend to a great extent the range of fluidity values, especially for samples taken in the northern districts of the republic: from  $I_L=-0.5$  to  $I_L=+0.75$  (Table 2). It was found that the influence of moistening is more pronounced in the consistency interval exceeding solid consistency (Figure 7). A detailed analysis of the physical properties of samples taken from the northern and central regions allowed for the processing of the overall sample.

As a result, dependencies of strength parameters on consistency were obtained (Figures 7-8), which can be used in the preliminary assessment stage when solving engineering problems.

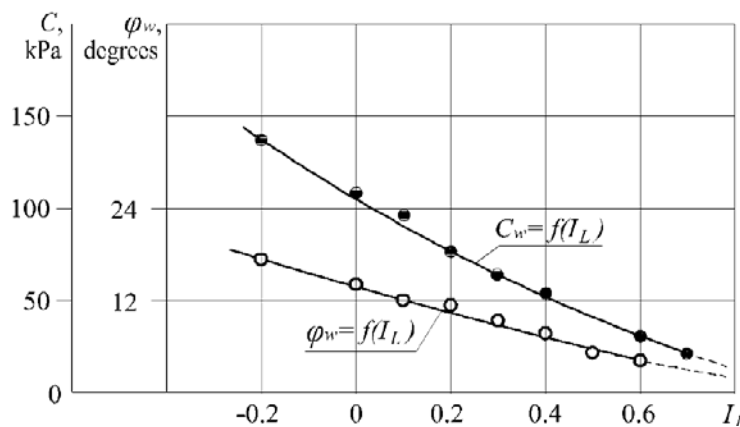
Dependences presented in Figures 7-8 show that strength parameters: hydrocolloid cohesion ( $\Sigma_w$ ) and angle of internal friction ( $\varphi_w$ ) sharply decrease when subsidence soils are moistened.

The following averaged values can be used for design at the stage of preliminary calculations:

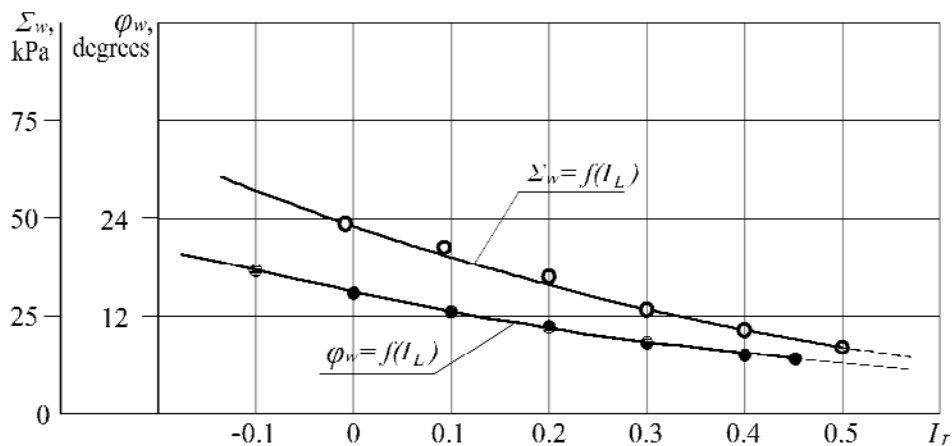
- for solid consistency:  $C_w=105\text{kPa}$ ,  $\Sigma_w=48\text{kPa}$ ,  $\varphi_w=15^\circ$ ;
- for tight plastic consistency:  $C_w=55\text{kPa}$ ,  $\Sigma_w=23\text{kPa}$ ,  $\varphi_w=8^\circ$ .



**Figure 6.** Scatter plots of strength ( $S$ ) versus consistency ( $I_L$ ), for loams at natural moisture and after additional moistening, Northern Region:  
 a) for  $P=100$  kPa; b)  $P=200$  kPa; c)  $P=300$  kPa.



**Figure 7.** Dependence of total cohesion ( $C$ ) and angle of internal friction ( $\varphi_w$ ) on consistency ( $I_L$ ), obtained using the „density-moisture” method for loams from North-Central region.



**Figure 8.** Dependence of hydrocolloidal cohesion ( $\Sigma_w$ ) and angle of internal friction ( $\phi_w$ ) on consistency ( $I_L$ ), for loams (overall sample).

According to the Maslov physico-technical creep theory [16], the main rheological characteristic of soil is the creep threshold  $\tau_{lim}$ , which can be determined analytically using the formula:

$$\tau_{lim} = \sigma_n \cdot tg\phi_w + C_c, \tag{7}$$

where:  $\sigma_n$  – normal stress, kPa;  $tg\phi_w$  – tangent of the true angle of internal friction;  $C_c$  – structural cohesion, kPa.

It should be noted that the results of experimental determination of creep threshold of loams from Republic of Moldova are practically absent. Some individual samples were tested in laboratories of Republic of Moldova, Dnipro and Odesa. However, these studies addressed specific isolated tasks, and there was no consensus on the methodology of tests.

In the context of this study, the value of structural cohesion ( $C_c$ ) was determined based on the results of tests on soil samples with a prepared surface.

Based on the obtained dependencies, applied to the calculated consistency for the selected regions, the expressions for the creep threshold are as follows:

$$\tau_{lim1} = 0.19\sigma + 40 \text{ kPa} \text{ – for northern region;} \tag{8}$$

$$\tau_{lim2} = 0.25\sigma + 60 \text{ kPa} \text{ – for central region;} \tag{9}$$

$$\tau_{lim3} = 0.30\sigma + 70 \text{ kPa} \text{ – for southern region;} \tag{10}$$

In the present research, reddish-brown loams were identified as a separate engineering-geological unit.

The laboratory studies focused on soil samples collected from the construction site of a residential complex on Testemitanu Street, Chisinau Municipality, and the slope of the M21 Brest-Chisinau-Poltava road excavation.

The results of these studies were summarized in Tables 3 and 4.

From Table 3, it is evident that at a depth of 6.0m, a weakened strength zone is clearly identified: the values of total cohesion are 2.6 times lower than at a depth of 1-3m. After moisture, cohesion may decrease by more than 6 times.

At the site along Testemitanu Street, a significant change in strength due to moisture is also observed: cohesion decreased by almost 3 times, and the internal friction angle by 1.3 times.

Table 3

**Results of the research on the strength properties of reddish-brown loams  
Central region, section of the M21 Brest-Chisinau-Poltava road**

Test ing con diti ons	Depth of monoli th sampli ng $h$ (m)	Consistency $I_L$ (fract. unit)		Strength parameters of samples tested for shear			
		natural	after moistening	at natural moisture content		after additional moistening	
				$\varphi$ , degrees	$C$ , kPa	$\varphi$ , degrees	$C$ , kPa
1*	1-3	-0.50	0.38	13	130	13	20
	6	-0.30	0.17	13	50	16	44
	7-15	-0.08	-	16	100	-	-
2*	1-3	-0.50	0.38	15	80	13	10
	6	-0.30	0.17	14	50	16	10
	7-15	-0.08	-	15	50	-	-
3*	1-3	not determined		13	30	9	10
	7-15	not determined		10	20	12	9

**Note:** 1\* – shear of samples with natural structure, 2\* – shear of samples with prepared surface, 3\* – shear of samples with prepared moistened surface.

Table 4

**Results of the research on the strength properties of reddish-brown loams  
Central region, section No. 2, Testemitanu Street, Chisinau Municipality**

Test ing con diti ons	Depth of monoli th sampli ng $h$ (m)	Consistency $I_L$ (fract. unit)		Strength parameters of samples tested for shear			
		natural	after moistening	at natural moisture content		after additional moistening	
				$\varphi$ , degrees	$C$ , kPa	$\varphi$ , degrees	$C$ , kPa
1*	10.0	0.0	0.30	18	70	14	28
2*	10.0	0.0	0.30	16	30	12	20
3*	10.0	not determined		11	22	10	8

**Note:** 1\* – shear of samples with natural structure, 2\* – shear of samples with prepared surface, 3\* – shear of samples with prepared moistened surface.

It is quite clear that the change in strength over time depends not only on the moisture regime (consistency) but also on the working conditions of the soil. In the absence of significant shear (tangential) stresses, in the conditions of soil consolidation under foundations, an improvement in strength characteristics can be expected. On slopes that have not yet reached limit of consolidation, tangential stresses may contribute to the development of creep processes. In the slopes of excavations and artificial structures, the processes of repeated soaking and drying will play a determining role.

Formation of loess soils took place in dry climate conditions with the predominance of physical weathering processes. As a result, these soils are highly sensitive to changes in physical-geographical conditions and geological environments. According to the figurative expression of M.P. Lysenko, loess soils are able to “adapt” to changes in the surrounding natural environment [19, p. 153].

This implies the necessity to take into account the influence on collapsible soils of some aspects of human engineering activities, first of all, the rise of groundwater level, which causes the change of the existing natural moisture regime.

#### **4. Conclusions and Recommendations**

Studies have shown that soils with collapsible properties cannot be considered reliable foundation for buildings and structures without the anthropogenic alteration of their primary structure.

The main cause of the change in the stress-strain state of the slope and the development of a landslide on the studied section of the Cahul-Giurgiulesti railway at 74<sup>th</sup> km was the additional wetting of the foundation soils, which manifested 15 years after construction due to post-collapse compaction associated with prolonged water filtration through the loess layer.

The results of the quantitative assessment of the physical-mechanical and collapsible characteristics of loess soils of Republic of Moldova, obtained by V.S. Goncharov, G.E. Kostik, and Y.I. Olyansky in the period from 1970 to 2000, need to be adjusted, as they do not take into account the changes in the natural-historical environment that have occurred over the past decades, caused by urbanization and construction in densely built-up areas.

The results of the study of loess soils in the area between the Prut and Dniester rivers, conducted by E.V. Shchekochikhina from 2011 to 2021, can be particularly valuable for design purposes. The collected factual material has shown that the issues related to studying the strength of loess soils are insufficiently covered. This fact limited the possibility of obtaining a representative sample based on previous investigations and has necessitated new research into the physical, strength, and rheological characteristics of these soils.

Based on Maslov “density-moisture” theory, the influence of moisture on the values of soil strength characteristics has been established, and dependencies of strength on consistency have been constructed. These derived dependencies can be used for the preliminary selection of design parameters that characterize the strength of collapsible loams.

From the conducted shear tests on samples with prepared surfaces and the established correlation dependencies, equations have been obtained that characterize the creep threshold of collapsible soils for the northern, central, and southern parts of the republic, respectively, as follows:  $\tau_{lim1} = 0,19\sigma + 40\text{kPa}$ ;  $\tau_{lim2} = 0,25\sigma + 60\text{kPa}$ ;  $\tau_{lim3} = 0,30\sigma + 70\text{kPa}$ .

It has been established that the reduction in the strength of collapsible loams over time can be attributed to the following reasons:

- the disruption of rigid cementitious bonds of structural cohesion ( $C_c$ ) under conditions where the shear stresses arising in the soil exceed the creep threshold ( $\tau > \tau_{lim}$ ).
- the decrease in hydrocolloidal cohesion ( $\Sigma_w$ ) due to changes in the existing natural moisture regime (consistency) as a result of additional moisture infiltration caused by engineering activities, including the rise of the groundwater level.

New data have been obtained regarding the physical and strength properties of soils under natural deposition conditions and in densely built-up areas.

The results of these studies can be used for modelling the stress-strain state of foundations and building bases, as well as for assessing the stability of slopes and embankments of artificial structures.

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