

Features of Assessment of Subsidence Properties of Loess Rocks in the Design of Bases and Foundations in Central Moldova

Yu I Olyansky¹, E V Shekochihina², S A Kalinovsky³

¹Professor of chair „Hydraulic engineering and earthworks”, Volgograd state technical university, Akademicheskaya street 1, Volgograd 400074, Russia

²Associate professor of chair „Hydraulic engineering and earthworks”, Volgograd state technical university, Akademicheskaya street 1, Volgograd 400074, Russia

³Associate professor of chair „Hydraulic engineering and earthworks”, Volgograd state technical university, Akademicheskaya street 1, Volgograd 400074, Russia

E-mail: sk0522@yandex.com

Abstract. The paper presents the results of studying the subsidence of subaerial cover clay deposits distributed in the peripheral part of the Central Moldavian upland in the Northern black sea region. The convergence of data on the magnitude of relative subsidence and initial subsidence pressure obtained by various laboratory and field research methods was analyzed. Regression equations and correction coefficients of interrelation of results of laboratory and field methods of estimation of subsidence are offered.

1. Introduction

Loess soils are one of the most common continental Quaternary deposits. Meet on the territory of Ukraine, Belarus, Moldova, Central Asian States and abroad. In the territory of the Russian Federation they occupy vast areas of Siberia (Loess subsidence soils of Western Siberia occupy up to 20% of the territory. They are such big industrial cities as Barnaul, Novosibirsk, Biysk, Omsk, Kemerovo, etc.), non-Chernozem zone of the European part of Russia, for example, in the Lower Volga Region and the North Caucasus. [1, 2] the Construction of buildings on loess subsidence soils occupies a special place in the theory and practice of construction due to the high sensitivity of these soils to external influences, the expansion of the spectrum of objects under construction and the shortage of land for construction with favorable conditions. In this work the analysis of practical experience of research of behavior of Loess soils in the territory of the Republic of Moldova is resulted. Loess collapsible soils are widely distributed in Central Moldova, where there are such large cities like Chishinau, Tiraspol, Bender and other Buildings and structures here are built very often on loess grounds. In General, the construction of small capacity on such soils is no longer a serious problem. However, for large capacity collapsible soil thicknesses and possible subsidence from own weight of soil above 10.0 – 20.0 cm buildings frequently undergo deformation, which requires additional material costs for their reconstruction. In this regard, the purpose of this work is to analyze various methods of assessment of subsidence of loess rocks, carried out at the stage of engineering-geological surveys and development of recommendations for designers and researchers. Scientific material laid out in this article represents



the results of the geotechnical survey performed on construction sites and special studies concerning scientific subjects, carried out under the guidance of Yu. I. Olyansky in various industrial and scientific organizations of Chisinau in different years.

Geomorphology the Central area of Moldavia represents an erosional upland with a height of about 420 m above sea level, has experienced positive neotectonic movements throughout the Quaternary period. As a result, Neogene Sarmatian rocks represented by clays with fine and dusty sand layers are exposed on the surface. As a result of erosion processes throughout the Quaternary period occurred denudation and demolition of fine-grained deposits in the peripheral parts of the hill, where as a result of the subaerial process occurred accumulation of sediment and its transformation into clay rocks. The peculiarity of these deposits is low content of dusty fraction (17.0 – 30.0% - granulometric composition and 22.0 – 37.0% - microaggregate composition) and high content of clay (10.0 – 20.0%) and sand (14.0 – 50.0%) particles. These soils in accordance with GOST 25100-95 is usually called "loess". They are represented by sandy loam, light and medium loam. The mineral composition of the dispersed fraction is represented mainly from hydro climatological minerals with a predominance of the latter. [3]

Peculiarities of Genesis and mechanical composition appeared in physical properties of deposits: low total porosity (about 0.43% on average) and high density of "dry" soil (about 1.50 – 1.60 g/cm³ on average). Humidity of rocks at the same time remains quite small and rarely exceeds the value of 0.16 – 0.17, which is a consequence of the good natural drain ability of loess thickness and the timing of the region to the area of insufficient moisture with a coefficient of moisture $K_{uv} = 0.80$. [4].

2. Methods execution of works

The study was performed in the territory of the city of Chisinau-VA is characterized by the almost universal spread of the implementation of loess rocks. Was selected 2 plots: plot 1 K. m. R-n Buiucani and plot 2 M. to r-n Budeshti. The power of loess rocks on the first site reaches 16.0 – 18.0 m, on the second – up to 30.0 – 35.0 m. on each of the sites, a complex of field works, consisting of drilling wells and pipes, in which samples of loess rocks of undisturbed addition are selected. Studies were carried out to study the subsidence at the base of the standard stamp. The experimental pits were soaked according to standard and accelerated methods.

Laboratory studies of soil subsidence. Compression tests were performed in accordance with GOST 23161-78 [5]. At the same time, 2 regions were tested-natural moisture and water-saturated. Upon reaching load 0.3 MPa dry branch soaked and recorded the deformation of the drawdown. This test method allows us to obtain the characteristics of the Pro-forma (relative subsidence) according to the scheme of "two" curves and "one" curve.

The field plate-bearing test. Tests of subsidence of rocks by static loads with a soak in field conditions was carried out by standard round stamp with an area of 5000 cm², which was installed in a pipe with a diameter of 900 mm, depth 4,0 -6,0 M. Rocks soaking at the base of the stamp was carried out through the bottom pipes and drainage wells, passed around the stamp-PA at a distance of 0.5 m from the latter. The depth of drainage wells was 1.5 m higher than the depth of the die installation.

The tests were carried out by a simplified method and by a method of "two" curves. The first was the compression of rocks the natural moisture levels of the load of 0.025 MPa to loads up to 0.25 MPa. After conventional stabilization was carried out soaking the rocks and the far-neck of their compression to load 0,30 – 0,40 MPa.

Tests on a method of " two " curves were carried out in parallel in two pipes at distance of 4,0 – 5,0 m one from another. The stamps were set at the same depth. One tested soil of natural humidity, another-water-saturated. For the initial subsidence pressure was taken to be the conditional load limit of portionality, if not the explicit limit load, at which subsidence deformation at the base of the stamp exceeded a value of 0.005 hg, where hg is the magnitude of the active zone stamp. [6]

Soaking experienced pits. Determination of loess thickness planting from the soil weight is the most important task of engineering-geological research for construction [7, 8]. This problem can be solved and in most cases solved using the results of compression tests. However, the most reliable

method for determining the possible drawdown of the thickness is the method of experimental soaking in the field. Done soaking two boiler-Vanir by the method described in SNIP 2.02.01 – 83 [9]. To assess the subsidence of the surface of the bottom of the pit were installed, surface marks, and to assess Prasad key strata in deep – deep reper – 2 for each lithological variation of loess thickness.

In parallel with the soaking of experimental pits according to the standard method, soaking of two experimental pits with an area of 5M2 was performed using the accelerated method [10, 11].

3. The results of the study and their analysis

We evaluated the convergence of the results of determination of the subsidence of loess rocks specimens in the compression device according to the scheme "two" and "one" of the curve. To do this, a correction factor equal to the ratio K is used:

$$K = \frac{\epsilon_{sl}^2}{\epsilon_{sl}^1} \quad (1)$$

where:

- the value of the relative subsidence of the sample at a load of 0.3 MPa, determined by the scheme of "two" curves;

- too, defined by the scheme of "one" curve.

In table.1 the distribution of the correction coefficient K depending on the type of loess rocks and the intervals of its values is given.

Table 1. The lognormal distribution of values of the coefficient K (%).

Types of loess rocks	The number of definitions	The intervals of values of the coefficient K					
		1,0	1,0-1,5	1,5-2,0	2,0-2,5	2,5-3,0	more than 3,0
Sandy loam and light loam	143	17,2	52,5	16,5	4,3	2,8	6,7
Medium loams	92	20,1	53,2	11,2	4,7	3,6	7,1

Table 2. Characteristics of the coefficient K .

Types of loess rocks	Statistical characteristic			
	average value	The limits of fluctuations	Standard deviation	The number of definitions
Sandy loam and light loam	1,11	0,71-2,33	0,54	143
Medium loams	1,20	0,58-2,02	0,63	92

Analysis of the data table. 1 and 2 show that for the sub-air sediments of Central Moldova the overestimation of the values of the relative quantity obtained by the test in compression devices according to the scheme of "two" curves over the values of the same value determined by the scheme of "one" curve on average by 10-20% is characteristic. As evidenced by the studies of a number of authors [12,13, 14], etc., these test methods almost never yield the same results "...Sometimes these differences...depend on the inhomogeneity of soils in the monolith...in other cases, it is possible to suggest the influence of preliminary swelling of clay minerals when soaking samples without loading, the presence of longer moistening the soil or other reasons..." [14, p. 20]. The results of soaking loess rocks at the base of the stamp are shown in the table. 3.

Table 3. The results of stamping tests of loess rocks.

Types of loess rocks	Stamp residue before soaking, mm	Sludge stamp in the process of soaking, mm	Initial drawdown pressure, MPa	The number of experiments
Sandy loam	7,2	14,2	0,08	7
Light loam	7,0	12,2	0,16	4
Medium loam	4,9	2,9	0,16	4
Heavy loam	9,3	4,7	0,29	6

Table 4 shows the values of initial subsidence pressure, calculated from the compression tests and static load on the stamp.

Table 4. Values of initial drawdown pressure of loess rocks determined by different methods.

Types of loess rocks	Physical characteristic			Initial drawdown pressure, MPa		The adjustment factor $K = \frac{P_{sl}^a}{P_{sl}^u}$
	W	J _p	n%	P_{sl}^a	P_{sl}^u	
Sandy loam and light loam	0,11	0,08	45,6	$\frac{0.08}{77;0,06}$	$\frac{0.09}{10;0,008}$	0,87
Medium and heavy loams	0,15	0,12	46,5	$\frac{0.14}{75;0,005}$	$\frac{0.19}{22;0,13}$	0,73

Note: a) P_{sl}^l , P_{sl}^s - according to the results of compression and stamping tests, respectively; b) the numerator – the average denominator – the number of definitions and standard deviation.

Analysis of the data table. 3 and 4 allows us to draw the following conclusions. The initial drawdown pressure of the studied loess rocks increases with an increase in their clay content from sandy loam to heavy loam for example-but 3 times. Initial drawdown pressure on stamp tests for all lithological types of loess rocks in the region exceeds the values obtained from compression tests by an average of 12-27%.

The ratio between the values of relative subsidence of rocks determined by static stress on the stamp and obtained in laboratory conditions at a load of 0.25 MPa was studied for two types of waste.

Sandy loam and light loam:

$$\varepsilon_{sl\ s}^{0.25} = 0,3472\varepsilon_{sl\ l}^{0.25} - 0,0034; \quad r = 0.85;$$

Medium loam:

$$\varepsilon_{sl\ s}^{0.25} = 0,9778\varepsilon_{sl\ l}^{0.25} - 0,0186; \quad r = 0.91;$$

In table 5 a comparative assessment of the value of the relative subsidence determined by various field and laboratory methods is given.

The analysis of this table 5 allows to draw a conclusion that for the ground conditions of Chisinau city the convergence of field methods for determining the value of relative subsidence is better with the results of compressive tests by the method of "one" curve, which does not meet the conclusions of other researchers for analogous loess rocks [15, 16, 17, 18, 19].

Table 5. The comparative characteristic value $\varepsilon_{sl}^{0,25}$ according to various research methods.

Method of determining the indicator	Site 1 microdistrict Boucan	Site 2 microdistrict Budesti
	Sandy loam and light loam	Medium and heavy loams
Compression tests on the scheme of "two" curves	0,015	0,011
Compression tests on a "one" curve	0,012	0,005
The load on a standard stamp with an area of 5000 cm ²	0,007	0,004
Soaking pit according to the standard method	0,002	0
Soaking the pit by an accelerated method	0,003	0,004

4. Conclusions

Subaerial cover deposits, common in the peripheral part of the Central Moldavian upland, have signs of loess: yellow, pale yellow colors and macro porosity. However, their mechanical composition is significantly different from the "true-but" dusty loess. The content of pulverized particles in them is extremely small and rarely reaches a value of 50%. The content of sand and clay particles are also very characteristic of "true" to the loess. The high content (up to 60%) in the dispersed fraction of strongly swelling montmorillonite, also does not testify in favor of "is-Tina" lessovidnosti, and is a consequence of subaerial Genesis (deluvial, proluvial, etc.).

However, these rocks in accordance with GOST 25100-95 [20] may be referred to as "loess" because they obla give collapsible properties by moisture in the track performance of artificial soaking. Knowledge of the peculiarities of the manifestation of the subsidence of these sediments are described Suwannee in this article will be useful to researchers and de-signers involved in the design and construction of similar rocks in engineering-geological conditions of the Northern black sea and in other regions of the South of the Russian platform.

5. References

- [1] Pantushina E V 2011 *Loess soils and engineering ap-proaches to eliminate them sagging properties* (polzunovskii vestnik) № 1 pp 127-130
- [2] Shvetsov G I and Noskov I V 2000 *Loess subsidence soils of Western Siberia, their engineering-geological, geoecological properties and their change under the influence of man-made influences* (Polzunovskii almanac Barnaul: publishing house of ASTU) № 3 pp 176-187
- [3] Olyansky Y I 1992 *Loess soils of South-Western black sea area (within the Republic of Moldova)* (Stiintsa: Chisinau) pp 130
- [4] Olyansky Y I, Bogdevich O P and Vovk V M 1994 *Engineering-geological features of the loess rocks of Moldova Geo-ecology. Engineering geology. Hydrogeology. Geocryology* (Moscow: Nauka) № 1 pp 65-75
- [5] 1978 *Soils. Laboratory method for determining the charac-teristics of the subsidence GOST 23161-76* (Moskow)
- [6] 1979 *Soils. Field test method static loads GOST 12374-77* (Moskow)
- [7] Olenski I, Makhova S I, Tikhon-VA T M and Kiseleva O V 2011 *Tasks of engineering-geological surveys for designing bases and foundations on prosodic-tion in soils* (Volgograd: the Reliability and durability of building materials, structures and grounds funda-ments) VI international scientific-technical confer-ence pp 245-248
- [8] 1983 *Foundations of buildings and structures SNIIP 2.02.01.-83* (Moskow: Stroyizdat)

- [9] 1986 *Manual on the design of the bases of buildings and structures* SNiP 2.02.01 - 83 (Moscow: Stroyizdat) p 416
- [10] Krutov V I and Popchenko N To 1981 *A rapid method for the determination of the subsidence of loess soils sumacheva-tion pits a small area. Engineering Geology* № 3 pp 108-116
- [11] Bogomolov A N, Skibin G M, Olyansky Y I, Makhova S I, Alekseev A F and Galai B F 2015 *Evaluation of the subsidence of loess field grounds-ment and laboratory methods* Vestnik (Rostov-on-don: VolgGASU Ser. Page and arch, Volgo-grad: publishing house of Volgas) Vol.40 (59) pp 98-115
- [12] Anan'ev V P 1964 *Mineralogical composition and proper-ties of loess rocks* (Rostov-on-don: RGU) p 143
- [13] Sagitova E M 1970 *Comparison of methods for the evalua-tion of subsidence of loess soils* (Rostov-on-don: Ed. Rostov state University, research Questions loess soils, bases and foundations) vol 2 pp 90-98
- [14] Krieger N 1972 *The state of the question of the as-sessment of subsidence properties of loess soils (a review)* (Moscow: PNIIS) p 60
- [15] Bogomolov A N, Olyansky Y I 2016 *Geotechnical aspects of the interaction of clay with water (on the example of Sar-matian clays and loess rocks)* (Volgograd: VolgGASU) p 351
- [16] Bogomolov A N, Olyansky Yu I, Shiyani S I, Tikhonova T M and Kiselev O V 2011 *Engineering-geological characteristics of less-on of the rocks between the rivers Prut-Nistru* (Vestnik VolgGASU.Ser.: Page and arch, Volgograd: publishing house of VolgGASU) vol 24 (43) pp 33-45
- [17] Bogomolov A N, the Brinesky Yu I, Schekochikhin E V, Tikhonova T M and Kuzmenko I Yu 2015 *Changes in the composition and properties of loess rocks in the man-made watering* (Volgograd: Publishing house of Vol-gGASU) p 204
- [18] Bogomolov A N, Olensky Yu I, Schekochikhin E V, Kuzmenko I Yu, Moz-guna M. D and Tcharykov D A 2017 *Features of construction of buildings and structures on loess grounds in Moldova* (Perm: Bulletin of Perm national research Polytechnic University. Construction and architecture) vol 8 No 1 pp 53-59
- [19] Brine-sky Y I, Stepanova E A, Kargin S V, Sabitova T A 2017 *Features of engineering-geological surveys for design and construction of road infrastructure on collapsible soils* (Volgograd: transport and road economy: problems of regions and ways for their solution: materials of vseros. science prakt Conf Volgograd 8 Dec) pp 233-237
- [20] 1995 (2011) *GOST 25100-95 Soils Classification* (Moscow)