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Prethodno saopštenje

THE USE OF COMPUTERS IN DETERMINING THE PARAMETERS OF THE FUNCTIONS FOR LOESS SOIL

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ABSTRACT
The paper presents the possibilities of determing functions of some characteristic parameters of loess soil. The loess soil is of Eolian origin, its formation is related to the Ice Age, it is classified as dusty-sandy-clayey soil, and very large extent of results are possible depending on humidity, location, porosity, anisotropy, etc. The problem of loess soilis is very complex and this is an attempt to restore partially neglected research by Milović, Stevanović and others with the classification of characteristics, which can only be used with a certain probability.

KEY WORDS: Loess soil, porosity, anisotropy, loess sampling, dry weight, curve edometric curve, specific coefficient of settlement.

UPOTREBA RAČUNARA U ODREĐIVANJU PARAMETARA FUNKCIJA ZA LESNO TLO

REZIME
U radu su prikazane mogućnosti određivanja funkcija nekih karakterističnih parametara lesnog tla. Lesno tlo je eolskog porekla, njegov nastanak vezan je za ledena doba, klasifikovano je kao prašinasto-peskovito-glinovito tlo i moguća su veoma velika rasipanja rezultata u zavisnosti od vlažnosti, lokacije, poroznosti, anizotropije i sl. Problematika lesnog tla je veoma složena i ovo je pokušaj obnavljanja delimično zapostavljanih istraživanja Milovica, Stevanovica i dr. uz klasifikaciju karakteristika, koje se mogu koristiti samo sa određenom verovatnoćom.

KLJUČNE REČI: lesno tlo, poroznost, anizotropija, uzorkovanje lesa, težina u suvom stanju, edometarska kriva, specifični koeficijent sleganja

INTRODUCTION ABOUT LOESS

In the north part of Serbia, there is often problem with funding on loess soil. The loess is a dusty-sandy clay of eolian origin, formed by onfall of dust during the ice age, it is often of different characteristics. In the north of Serbia, it is usually yellow and practically not bedding, except with thin black layers of over-scratch soil as marks of disintegration of organic layers during interglacial periods. One of the most important characteristics of loess behavior is the bulk density in the dry state, the degree of natural humidity and the anisotropy coefficient. Characteristic for loess are vertical pores formed by water leaching, that results an anisotropic behavior. There are also terrestrial and matrix coal loess, which can have more or less different characteristics .

This paper will show the way of data preparation and processing, with the help of computers, so that they can be further numerically processed on the computer or displayed graphically.

SOME PROPERTIES OF LOESS

In works by Milovic, Milovic and Djogo, Stevanovic, Bogdanovic. The bulk density of the loess in the dry state is within a very wide range γ_d=11,5−18 kN/m3. Mechanical characteristics of loess, such as one-axial strength and modulus of elasticity, are in direct correlation with bulk density, and in large part with humidity.

Chemical composition of loess soil: SiO_2 about 50%; CaO from 5 to 10%; Al_2O_3 from 5 to 10%, carbonate and less iron, sodium, potassium and magnesium oxide (Fe_2O_3, MgO, Na_2O, K_2O). It may also contain calcium carbonate concretions, created by water circulation and dissolving of carbonates from the upper layers and re-depositted in the lower layers of the same.

In Milović () are given characteristic parameters of loess:

- edometric curve, edometric modulus of compressibility,
- edometric curve with saturation,
- specific coefficient of settlement,
- water permeability coefficient
- angle of internal friction, cohesion
- anisotropy coefficient, etc.

Loess which in dry condition weighs from γ_d=16 kN/m^3 can be treated as solid clay.

METHOD OF TAKING SAMPLES. TYPES OF SAMPLES

Loes parameters largely depends on the method of sampling and testing. Method of sampling:

- Undisturbed samples taken by cutting cubes from the boreholes.
- Samples obtained by extraction from the cylinder.

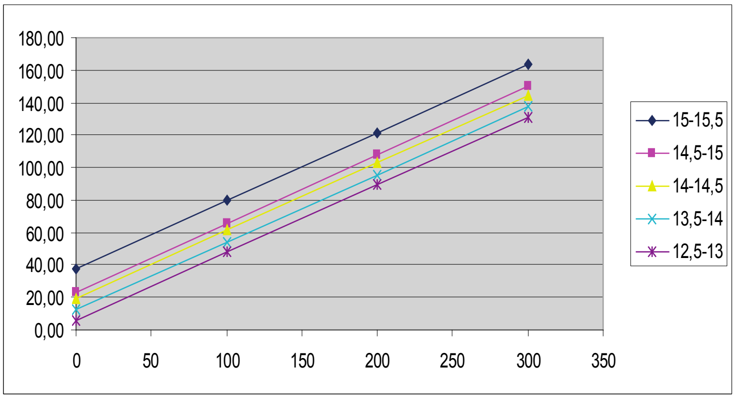
In undisturbed soil samples there is a stress disorder, which occurs when the sample is released from the pressure of the surrounding soil. Tests have shown that the samples taken with the cylinder give even lesser and higher results than the undisturbed samples.

Table 1. Influence of obtained method of loess samples on bearing parameters of loess soil.
Tabela 1. Uticaj načina uzimanja uzorka na parametre nostivosti lesa.

	undisturbed Block 1	disturbed Cylinder 2	undisturbed Block 1	disturbed Cylinder 2
γ_d [kN/m3]	12.9	15.1	17.3	16.5
w_0 [%]	12.2	12.8	20.6	23.1
q_u [kPa]	27	74	150	86
E_S [MPa]	2.5	4.1	13.3	2.3

COULOMB'S SHEAR LINES

Based on Coulomb's shear lines, for natural humidity, the angle of internal friction moves in a very narrow interval, while cohesion changes significantly depending on the bulk density. Figure 1. Coulomb's shear lines: $\tau = c + \sigma \tan(\varphi)$



c (kPa)	ϕ (deg)
37,81	22,75
23,39	22,84
19,63	22,57
12,51	22,57
6,09	22,57

$\tau = c+\sigma \tan(\varphi)$
σ - hor. axis
τ- vert. axis

Figure 1. Coulomb's shear lines, for natural humidity of loess. γ_d=12,5−15,5 kN/m^3.
Slika 1. Kolumbove prave smicanja, za prirodne vlažnosati lesa. γ_d=12,5−15,5 kN/m^3.

SOME TYPICAL PROPERTIES OF LOESS

Undisturbed samples were taken from the probing wells on over 13 locations, here are selected 3 locations in Table 2. Undisturbed samples were also cut and examined in the vertical and horizontal direction, for the purpose of determined anisotropy. Samples were grouped at intervals of their own weight in dry state: γ_d. Table 2.

There is an approximate relation between one-axial strength and modulus of elasticity:

$$E \approx 100 q_u$$

The degree of anisotropy $n=E_v/E_h$ is expressed as the ratio of the Young's modulus in the vertical and horizontal direction. For example. the degree of anisotropy for samples taken at several different locations in the north of Serbia range from 1.3 to 1.6.

Table 2. Some caracteristic properties of loose.
Tabela 2. Neka karakteristična svojstava lesa.

	γ_d (kN/m^3)	w_v (%)	w_h (%)	n	E_v (MPa)	q_{uV} (kPa)	E_h (MPa)	q_{uh} (kPa)
GZ	12,0-14,0	19,0±3,0	18,2±3,7	1,5	7,9±4	46±16	5,1±2,5	41±20
	14,0-15,0	16,5±2,5	-	-	12,0±4,5	190±60	-	-
Bc	12,0-14,3	16,5±3,5	16,5±3,5	1,4-1,5	5±2	60±30	4±2,5	40±20
BT	10,9-12,7	-	-	-	8±2	80±20	-	-
	14,5-15,5	18,5±4,1	21,4±1,2	1,6	13,9±6	100±30	8,8±2,5	80±30

GZ - Gornji Zemun 1,5-5,5m; Bc- Banovci 8,5m ; BT- Bačka Topola ~7m

w_v, w_h –humidity of the sample for testing in the vertical and horizontal direction.
q_{uV}, q_{uh} - One-axial strenght of the soil sample in the vertical and horizontal direction
E_v, E_h - Young's modulus of elasticity in vertical and horizontal direction.

SETTLEMENT POTENTIAL OF LOESS SOIL

To determine the settlement potential of loess soil is used specific settlement coefficient and oedometric curve of compressibility module. A change in porosity with a stress change was investigated in the oedometer for a naturally wet sample, up to a certain stress σ_n. With a constant vertical stress σ_n, the sample is satturated with water, and porosity coefficient is measured, in addition with testings of stress change and porosity on sample. More samples with the same characteristics were tested for different stress values σ_n.

The series of tests were repeated for groups of samples of different characteristics.

Oedometric modulus of compressibility

$$E_{oe} = \frac{\Delta\sigma}{\Delta e}(1+e_o)$$

$\Delta\sigma$- increase the vertical stress
Δe - change of the porosity coefficient for the investigated interval
eo - initial value of the porosity coefficient

The settlement potential of loess soil is determined by the specific settlement coefficient i_m:

$$i_m = \frac{e_n - e_n'}{1+e_n} = \frac{\Delta e_n}{1+e_n}$$

e_n - porosity coefficient of the tested soil layer (sample thickness) in the state of natural humidity for vertical stress σ_n

e'_n - porosity coefficient in saturation state (watering) and for the same load with vertical stress the porosity coefficient in saturation state (watering) and for the same load with vertical stress σ_n

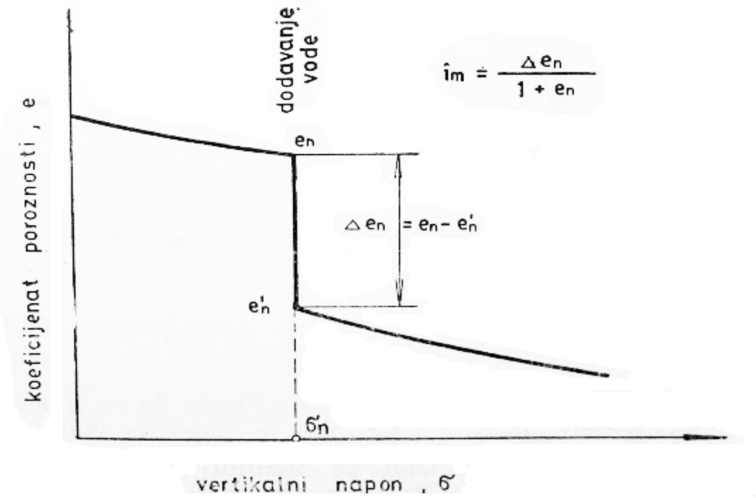


Figure 2. Specific settlement coefficient and oedometric curve of saturation at the stress σ_n.
Slika 2. Specifični koeficijent sleganja i edometarska kriva zasićenja pri naponu σ_n.

SPECIFIC SETTLEMENT COEFFICIENT

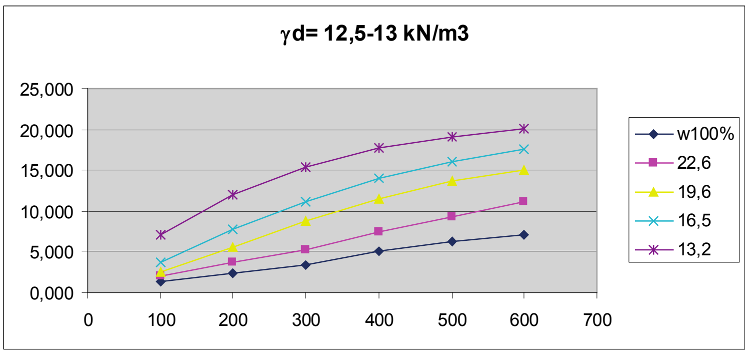


Figure 3. Specific settlement coefficient for the weight of loess for 12,5 to 13 kN/m3
Slika 3. Specifični koeficijent sleganja za težine lesa od 12,5 до 13 kN/m3

It is necessary to split the settlement coefficients with 100. For numerical reasons (reduction of error), the results in Graph 3 for the specific settlement coefficient are multiplied by 100.

Table 3.Functions for determining a specific settlement coefficient for weight from 12,5 to 13 kN/m^3.
Tabela 3. Funlcije za određivanje specifičnog koeficijenta sleganja za težine od 12,5 do 13 kN/m^3.

w(%)	
100	y = 5E-17x6 - 9E-14x5 + 6E-11x4 - 2E-08x3 + 2E-06x2 + 5E-05x + 8E-11
22,6	y = 7E-17x6 - 1E-13x5 + 8E-11x4 - 2E-08x3 + 3E-06x2 + 1E-04x + 1E-10
19,6	y = 1E-15x5 - 1E-12x4 - 6E-10x3 + 6E-07x2 + 0,0002x + 2E-05
16,5	y = 5E-16x5 + 1E-13x4 - 9E-10x3 + 3E-07x2 + 0,0004x - 2E-05
13,2	y = 7E-16x5 - 1E-12x4 + 2E-09x3 - 2E-06x2 + 0,0008x - 3E-05

OEDOMETER COMPRESSIBILITY MODULE FOR SATURATED SAMPLE.

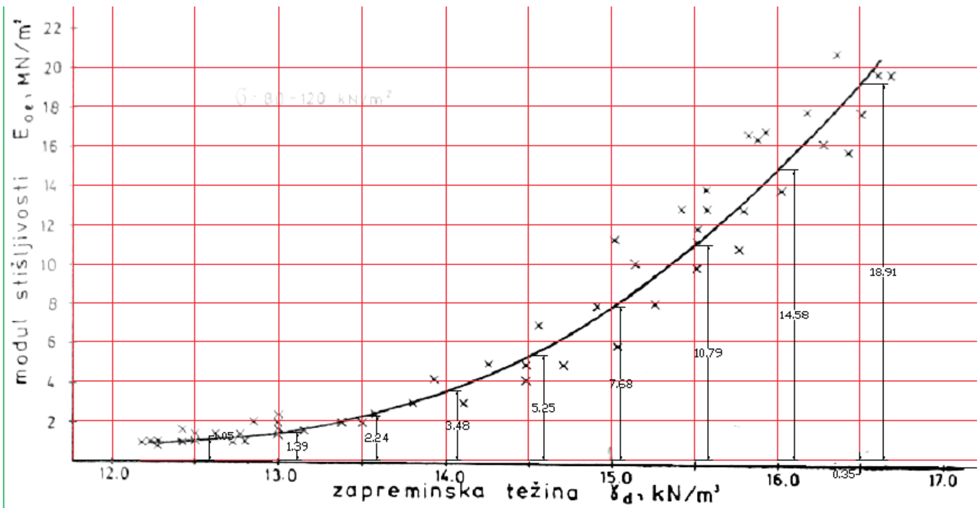


Figure 4 Modulus of compressibility for saturated loess samples. Stress Interval 80-120 kPa.
Slika 4. Modul stišljivost za potopljene uzorke lesa. Interval napona 80-120 kPa.

Table 4 Eqation for compressibility modulus for saturated loess.
Tabela 4. Jednačine za modul kompresije za potopljen les.

R^2= 0,9997	y = 1,1762x2 - 29,7x + 188,66
R^2= 0,9999	y = 0,059x3 - 1,3898x2 + 7,3334x + 11,341
R^2= 1	y = -0,0201x4 + 1,2271x3 - 26,714x2 + 250,53x - 861,59

Table 5.Results for the modulus of compressibility, for different degrees of polynomials.
Tabela 5. Rezultati za modul kompresije, za različite stepene polinoma.

Миловић*	1,05	1,39	2,24	3,48	5,25	7,68	10,79	14,58	18,91
R^2= 0,9997	1,19	1,34	2,07	3,40	5,31	7,80	10,89	14,57	18,83

R^2= 0,9999	1,09	1,42	2,21	3,50	5,34	7,76	10,82	14,55	19,00
R^2= 1	1,93	2,50	3,44	4,89	6,92	9,61	12,98	17,03	21,74
γ_d (kN/m^3)	12,5	13	13,5	14	14,5	15	15,5	16	16,5

Table 4 and 5 show the results for the modulus of compressibility for saturated loess samples using different degrees of polynomials. One should pay attention to the picture, it looks like the original graph was scanned with a certain deviation that gives errors up to 2% in the area of larger specific weights of loess, but so the module is lower by 2% (which is on the security side). It is important here to specify modules in the area of lower specific weights, i.e. from 12 to 14 kN/m^3, and for further research it is necessary to check the quality of the solution with the division of curves into two or more segments, to fit functions, or to use an exponential function.

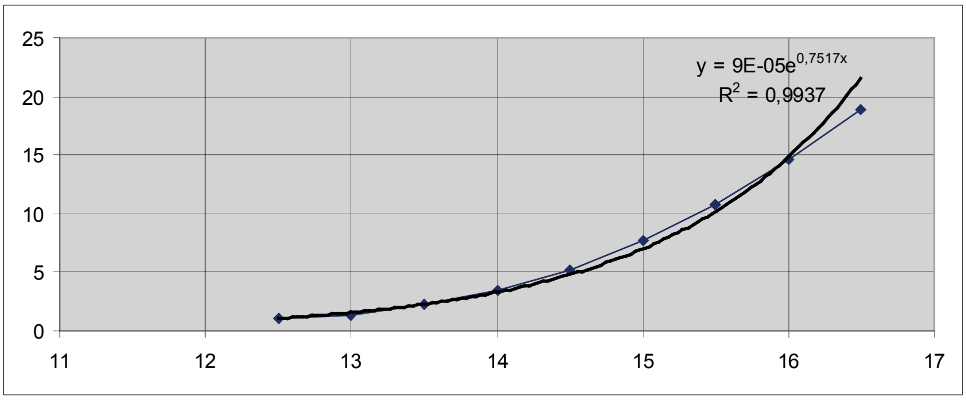


Figure 5 Modulus of compressibility for saturated loess samples. Exponential curve.
Slika 5. Modul stišljivost za potopljene uzorke lesa. Eksponencijalna kriva.

Exponential function, Figure 5, has good matching in the interval γ_d од 12 до 14 (kN/m^3), and then from 14 to 16 is below the experimental curve, and from 16 is rapidly increases and has no good match.

Therefore, in determining the replacement functions and the intervals of validity, it is not always the main criterion of the degree of correlation (correlation) R2, but the impact on the safety coefficients.

RELATION OF COHESION OF DRY DENSITY AND HUMIDITY OF LOESS

Of significance for assessing the change in the properties of loess is to determine the relation between the bulk density cohesion and the humidity of the samples.

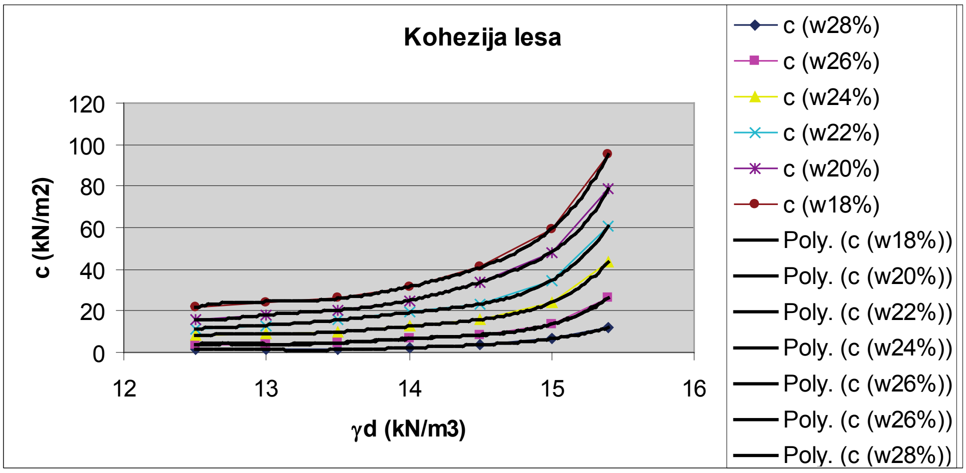


Figure 6. Dependence of size cohesion of dry density, for different degrees of humidity.
Slika 6. Zavisnost veličine kohezije od težine u suvom stanju, za različite stepene vlažnosti.

Table 6. Functions dependence of size cohesion of dry density, for different degrees of humidity, and polynomials 5 and 6 degrees.
Tabela 6. Funkcija zavisnosti veličine kohezije od težine u suvom stanju, za različite stepene vlažnosti i polinome 5 i 6 stepena.

%	Functions dependence of size of bulk density cohesion, for different degrees of humidity	R^2
w18	y = 3,1741x5 - 218,22x4 + 5998,4x3 - 82398x2 + 565600x - 2E+06	1
w20	y = 2,304x6 - 190,24x5 + 6539,5x4 - 119790x3 + 1E+06x2 - 7E+06x + 2E+07	1
w22	y = 1,7023x5 - 114,97x4 + 3103,7x3 - 41863x2 + 282110x - 759865	1
w24	y = 1,7452x5 - 119,01x4 + 3243,8x3 - 44174x2 + 300535x - 817163	1
w26	y = -0,7106x6 + 60,813x5 - 2163,3x4 + 40948x3 - 435036x2 + 2E+06x - 6E+06	1
w28	y = -0,3532x6 + 30,181x5 - 1072,4x4 + 20285x3 - 215430x2 + 1E+06x - 3E+06	1

Functions dependence of size of bulk density cohesion for % of humidity 18, 22 and 24 are the fifth degree, while the other polynomials are of the sixth degree. For % of humidity 22 and 24, better matching results shows polynomials of the fifth degree, or R^2 is =1. The curves were originally fitted for the fifth-degree polynomail, but at half of the number of curves the better matching is for sixth degree polynomials If choose all polynomials of sixth degree, the biggest "error" R^2 for this data set is only 2 tens of thousands.

Milović gives a three-dimensional shape diagram of the dependence of size of bulk density cohesion on which the third axis is humidity of loess samples, Figure 7. This is a very important graphic, but it should be divided into series of new graphs for different rate of loess anisotropy 1.3 to 1.6).

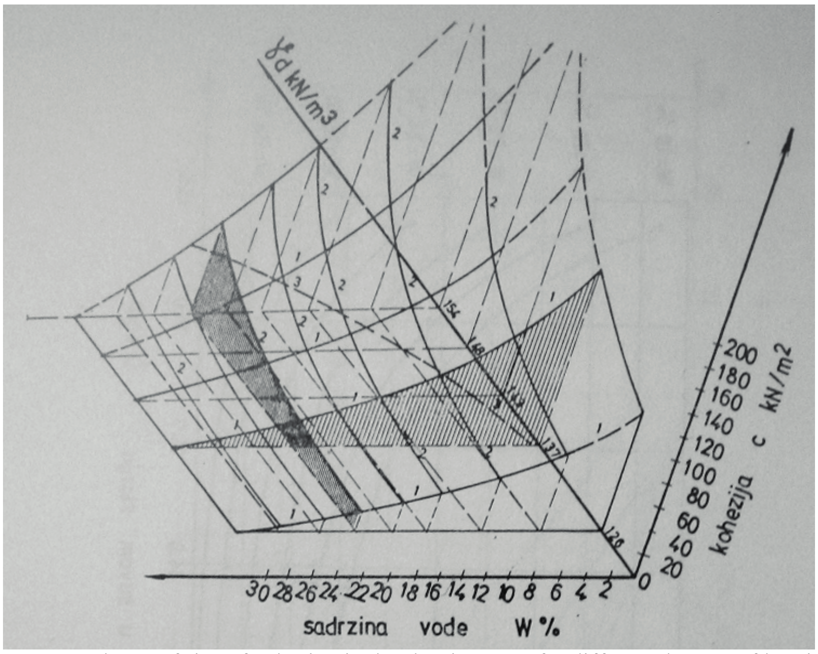


Figure 7. Dependence of size of cohesion in dry density state, for different degrees of humidity of loess. 3D graphics

Slika 7. Zavisnost veličine kohezije od težine u suvom stanju, za različite stepene vlažnosti lesa. 3D grafik.

DIRECTIONS FOR FURTHER RESEARCH

Recent research on loess, carried out by colleagues from the Faculty of Mining and Geology (Ćorić et al.), and the Faculty of Forestry (the influence of plant cover), etc., can not be shown here, but they are certainly necessary in the development of the expert package for the loess soil of Serbia. The characteristics of individual locations can be applied or used as initial research, for other similar locations in the territories of neighboring countries.

CONCLUSION

The paper presents methods of data processing of numerous tests of different loess samples at numerous locations, which are mostly located in the north of Serbia. The results presented by Milović from the survey during the 1970s and early 1980s, have been insufficiently used in recent research, and thanks to the development of computer techniques and software packages, they can be used and integrated into recent research. This paper shows the way how to prepare and process data in the excel table, which significantly simplifies the selection of the replacement functions of the set of geomechanical properties of loess. When selecting functions, it is necessary to critically evaluate the application interval in certain characteristics in relation to the safety coefficients.

In the future, this would enable the creation of a complete loess soil database in the territory of Serbia, while respecting the specificity of certain locations.

When data is processed, it is necessary to have information on the method of sampling, that is, priority should be given to tests of undisturbed samples obtained through probing pit (exploration wells). It is also necessary to perform new selection of grouping samples, not only by more precise selection and location description, but also by the depth at which the same is taken and by the degree of anisotropy.

If the samples are taken on loess cuts, this should be noted separately.

Acknowledgments
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