ANALYSIS OF THE INFLUENCE OF GRANULAR FRACTIONS ON GEOTECHNICAL CHARACTERISTICS FOR SOILS WITH SIMILAR BEHAVIOR

Cornelia-Florentina DOBRESCU[1], Elena-Andreea CALARASU[2]
[1] Dr. Eng., National Institute for Research and Development in Construction, Urban Planning and Sustainable Spatial Development, URBAN-INCERC, Romania, cornelia.dobrescu@incd.ro, corneliadobrescu@yahoo.com
[2] Dr. Geol., National Institute for Research and Development in Construction, Urban Planning and Sustainable Spatial Development, URBAN-INCERC, Romania, andreea.calarasu@gmail.com

ABSTRACT

The paper presents a series of experimental tests related to the influence of granular fractions on geotechnical characteristics, using different methods of investigation and assessment.
The soil samples selected for the study were collected from two different areas in Romania (Tulcea and Calafat), where similar soil categories were intercepted from the point of view of properties and behavior. Based on laboratory tests, the analysis consisted in establishing the predominant lithological types, the results being processed in order to reveal the variation of specific properties. The research has allowed conducting comparative and correlative analyses, based on the characteristics of soil types (silty and sandy loess), which led to outlined similarities of studied collapsible soils.

Keywords: granular fractions, soil behavior, collapsible soils

REZUMAT

Prezentul articol prezintă o serie de încercări experimentale privind influența fracțiunilor granulare asupra caracteristicilor geotehnice ale pământurilor folosind diferite metode de investigare si evaluare. Probele de pământ selectate pentru studiu au fost recoltate din doua zone diferite din România (Tulcea si Calafat), unde s-au interceptat pământuri similare din punct de vedere al proprietăților si comportamentului. Pe baza încercărilor de laborator, analiza a constat in stabilirea tipurilor litologice predominante, iar rezultatele au fost prelucrate cu scopul de a evidenția domeniile de variație ale parametrilor specifici. Cercetările au permis realizarea unor analize corelative si comparative intre caracteristicile tipurilor de pământuri (loess prăfos si nisipos), care au condus la evidențierea similitudinilor dintre pământurile colapsibile studiate.

Cuvinte cheie: fractiuni granulare, comportarea terenurilor, pământuri colapsibile

1. INTRODUCTION

The solid particles resulting from the formation processes (weathering and alteration, transport and deposition) differ mainly by particle size. The chemical action clearly influenced the small particles, while the coarse ones were preserved almost intact the parent rock properties (Derbyshire et al, 1995). Due to these processes by which sedimentary rocks are formed, different categories of soils (Marschalko et al, 2013) were delimited. The cohesionless category includes all granular soils, formed by mineral particles without internal links, characterized by a high permeability. The cohesive nature of soil results from the existence of very fine particles composed of secondary or clayey minerals. Soil compaction is caused, on one side, by consolidation during the geological evolution, and, on the other side, by physical conditions resulting from the moisture content; these are the elements that have high influence on their strength and deformability (Reznik, 2007), (Calarasu & Dobrescu, 2013).

At a more detailed level, it is well known that the three main fractions of soils are represented by sand, silt and clay. Sandy soil

consists of angular or rounded grains, more or less close to spherical form, with particle sizes in the range between 2 mm and 0.05 mm, which are visible to the naked eye or using a hand-lens. Silty soil is formed by particles ranging between 0.05 mm and 0.005 mm, which can be observed under a microscope. Clay is composed of particles smaller than 0.005 mm, which can be observed under a microscope, with laminar or elongated shape, needle-like or tubular. There is a variety of soil categories between the main grain sizes, with intermediate properties given by the predominant fraction.

2. EXPERIMENTAL LABORATORY TESTS ON COLLAPSIBLE SOIL SAMPLES

For the study, two areas in Romania (Tulcea and Calafat) were selected, where the territorial extent of collapsible soils has a significant proportion. The purpose for which these types of soils were selected consisted of their similarity and their specific behavior (Andrei, 1995), (Dobrescu, 2011), based on which the investigation and evaluation of the influence of granular fractions on geotechnical characteristics was performed. The laboratory plan consisted in experimental laboratory tests using numerous soil samples for establishing the predominant lithological types and the variability of specific properties.

For the site in Calafat area, located on the river Danube, in the southern part of Romania, the laboratory tests were conducted on silty and sandy loess samples, in order to determine the geotechnical parameters. The methods used for testing are conform to the requirements of the Romanian standards. Values for physical properties (water content, plasticity and consistency index, natural density, porosity, void ratio and saturation degree) and mechanical ones (specific settlement, friction angle and cohesion) There were determined. According to the requirements of geotechnical Romanian norms [7], it is mentioned that the determination of the specific settlement index at wetting, under 300 kPa loading step, is required for the identification of collapsible soils and represents one of the fundamental criteria related to their mechanical behavior.

Based on the predominant grain size fraction of the samples collected from different depths up to 13 meters, there were established several lithological types corresponding to the studied sites. From the analysis of soil identification data, it was noticed that the predominant lithological type consists of silty loess.

Based on the statistical processing and interpretation of the results, the variation range of geotechnical characteristics was determined, as seen in Table 1, for physical properties, and in Table 2, for mechanical properties.

The values determined for the geotechnical characteristics of the investigated soils in Calafat area confirm that these belong to the collapsible soils category, susceptible to wetting, with the following specific parameters:

- low natural water content;
- low and medium plasticity in terms of plasticity state and stiff and hard in terms of consistency state;
- low natural density;
- high porosity exceeding 44 % and high void ratio;
- low saturation degree (unsaturated soils).

By analyzing the obtained mechanical properties, it seems that these soils show an activity in relation with water, with values of the specific settlement at wetting under 300 kPa, loading step higher that 2 cm/m and a relatively low cohesion.

The second investigated area is Tulcea, located on the lower Danube River, in the south-eastern part of Romania. Concerning the extent of loess on the country territory, these deposits indicate a significant thickness in Tulcea area.

During the laboratory testing program, there were examined 148 samples collected from 9 boreholes (F1T ÷ F9T) drilled at different sites in Tulcea.

Taking into account the data obtained from grain size analyses, several significant

lithological types have been established: silty clay (type 2), silt (type 5), clayey silt (type 6), sandy silt (type 7), clayey sand (type 9), silty sand (type 10) and sandy clayey silt (type 11).

Table 1. Variation interval of values obtained for physical properties of Calafat soils

Measured values	Water content (%)	Plasticity index (%)	Consistency index (-)	Density (g/cm^3)	Porosity (%)	Void ratio (-)	Saturation degree (-)
Average	11,68	10,69	1,03	1,52	47	0,89	0,35
Minimum	9,5	9	0,75	1,33	44	0,78	0,28
Maximum	16	12	1,14	1,71	49	0,98	0,53

Table 2. Variation interval of values obtained for mechanical properties of Calafat soils

Measured values	Specific settlement (cm/m)		Friction angle (degree)	Cohesion (kPa)
	i_{m300} (*)	i_{m300} (**)		
Average	3,11	3,30	14,73	10,9
Minimum	2,2	2,1	9,5	5
Maximum	4,7	5	22,6	22
(*) im_{300} - specific settlement at wetting for the sample inundated at 300 kPa (**) $i'm_{300}$ – specific settlement at wetting for the initial inundated sample				

It should be noted that loess deposits from Tulcea area are susceptible to wetting and the predominant granular fraction is silt. Graphical representations of specific lithological types with depth variation are illustrated in Figure 1 and 2, being remarked that predominant lithological types are represented by clayey silt and sandy silt.

The experimental work plan consisted of determining the physical and mechanical characteristics of the studied samples. Taking into account that the aim of study is to analyze the influence of granular fraction on geotechnical parameters, their separation in lithological types was considered useful for the approach.

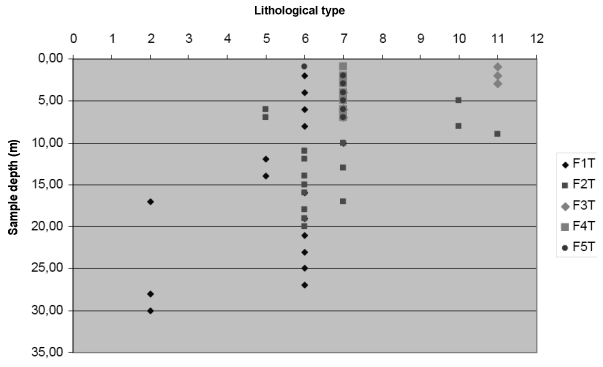

Fig. 1. Variation of lithological types with depths (borehole F1T ÷ F5T)

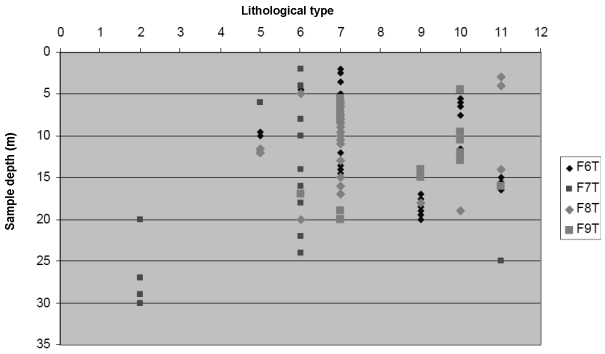

Fig. 2. Variation of lithological types with depths (borehole F6T ÷ F9T)

The results of laboratory testing are presented in Table 3 for silty clay, in Table 4 for sandy silt and sandy clayey silt, in Table 5 and Table 6 for clayey silt lithological type.

Based on an overall analysis of data obtained from laboratory testing, the predominant lithological types from Tulcea sites can be characterized by the following specific parameters:

- for clayey silt type no. 6, the average value for water content is around 17%, porosity exceeding 42 %, medium plasticity and stiff consistency state, oedometric modulus around 9200 kPa, friction angle of 30 degrees and cohesion around 19 kPa;
- for sandy silt type no. 7, the average value for water content is around 15%,

porosity average around 44 %, low to medium plasticity and stiff to hard consistency state, oedometric modulus around 9400 kPa.

Table 3. *Variation interval of values obtained for physical and mechanical properties of lithological types 2, 5, 9, 10*

Measured values	Water content (%)	Plasticity index (%)	Consistency index (-)	Density (g/cm^3)	Porosity (%)	Void ratio (-)	Saturation degree (-)	Oedometric modulus (kPa)
Silty clay - lithological soil type 2								
Average	21,78	17,77	0,82	1,96	39,00	0,64	0,89	7740
Minimum	19,60	15,10	0,72	1,89	36,00	0,56	0,79	6250
Maximum	24,20	19,20	0,95	2,05	41,00	0,69	0,98	10000
Silt - lithological soil type 5								
Average	17,75	12,64	0,72	1,85	41,50	0,71	0,73	10376
Minimum	14,20	9,70	0,57	1,62	38,00	0,61	0,33	7140
Maximum	22,00	15,80	0,85	2,02	45,00	0,82	1,01	14290
Clayey sand - lithological soil type 9								
Average	20,33	11,09	0,70	2,00	39,20	0,64	0,98	12068
Minimum	15,60	9,30	0,54	1,92	37,00	0,59	0,91	10000
Maximum	23,80	13,70	0,78	2,04	42,00	0,72	1,00	16667
Silty sand - lithological soil type 10								
Average	13,67	10,43	0,96	1,94	39,20	0,64	0,84	13475
Minimum	10,70	7,00	0,63	1,59	36,00	0,56	0,39	9090
Maximum	18,10	12,10	1,25	2,07	46,00	0,85	1,03	20000

Table 4. *Variation interval of values obtained for physical and mechanical properties of lithological types 7 and 11*

Measured values	Water content (%)	Plasticity index (%)	Consistency index (-)	Density (g/cm^3)	Porosity (%)	Void ratio (-)	Saturation degree (-)	Oedometric modulus (kPa)
Sandy silt - lithological soil type 7								
Average	14,58	10,50	0,91	1,78	44,50	0,82	0,72	9464
Minimum	10,20	7,20	0,55	1,33	37,00	0,59	0,11	3030
Maximum	19,30	16,00	1,46	2,04	53,00	1,13	1,03	20000
Sandy clayey silt - lithological soil type 11								
Average	16,57	12,52	0,79	1,82	43,36	0,78	0,74	7995
Minimum	11,60	10,10	0,58	1,44	37,00	0,59	0,30	2560
Maximum	21,50	15,10	1,16	2,00	53,00	1,13	0,99	12500

Table 5. *Variation interval of values obtained for physical properties of soil type 6*

Measured values	Water content (%)	Plasticity index (%)	Consistency index (-)	Density (g/cm^3)	Porosity (%)	Void ratio (-)	Saturation degree (-)
Average	16,85	12,22	0,76	1,79	42,42	0,77	0,64
Minimum	12,10	7,80	0,38	1,46	37,00	0,59	0,24
Maximum	23,50	17,00	1,07	2,02	51,00	1,04	0,99

Table 6. *Variation interval of values obtained for mechanical properties of soil type 6*

Measured values	Oedometric modulus (kPa)	Friction angle (degree)	Cohesion (kPa)
Average	9251	30	19
Minimum	2560	10	0
Maximum	16670	59	50

The results obtained for all defined lithological types in Tulcea area, but especially for the silty predominant types, are ranging within the variation limits corresponding to physical and mechanical characteristics for collapsible soils in natural state, values which are indicated briefly in the Romanian norm for building foundations on collapsible soils (NP 126).

3. CONCLUSIONS AND DISCUSSION

The studies were aimed to analyze the influence of the predominant granular fractions on physical and mechanical properties of soil samples collected from Calafat and Tulcea sites. Depending on the predominant granular fraction, several specific lithological types were delimited and a statistical analysis of geotechnical parameters variation was conducted.

Based on the comparative analyzes performed, it was found that the most effective were those that involved a large number of laboratory tests. Also, the correlations were even more conclusive when the soil was uniform in surface and depth, in terms of physical characteristics.

By processing the results obtained from several series of laboratory tests, it can be concluded that the variation limits of geotechnical parameters for Tulcea soil samples are similar to those obtained for the soils located in Calafat. Both types of investigated deposits were included in the category of collapsible soils, by taking into consideration determined values and their variation.

The extensive use of physical properties correlations, which define the soil nature and condition and mechanical properties, involving assessing or predicting the settlement or soil bearing capacity, can contribute to a more realistic characterisation of foundation conditions. The aim of this type of research projects is to ensure that the constructions built on soils with particular behavior have a specified level of safety in exploitation (Bally & Antonescu, 1971).

It should be mentioned that this type of study, based on comparative tests between soils with similar behavior, can be used in geotechnical design, on one side, and in the substantiation of a database required for geotechnical zoning, on the other side.

REFERENCES

1. Andrei S. *Behavior of unsaturated soils*, Roads and Bridges Magazine, no. 30, pp. 22-25, Bucharest, 1995.
2. Bally R. J. & Antonescu I. *Loess soils in constructions*, Technical Publishing House, Bucharest, 1971.
3. Calarasu E. & Dobrescu C. *Studies concerning the influence of relative density and moisture content on the shear resistance of collapsible soils located in the city of Galati, Romania*, 13th SGEM, Vol. 2, 395- 402 pp, 2013.
4. Derbyshire E. & Dijkstra T. & Smalley J. *Genesis and properties of collapsible soils*, Kluwer, Dordrecht, The Netherlands, 1995.
5. Dobrescu C. F. Prognosis of collapsible soils behavior, Bren Publishing House,Bucharest, 2011.
6. Marschalko M. & Yilmaz I. & Fojtova L. & Kubecka K. & Bouchal T. & Bednarik M. *Influence of the soil genesis on soil physical and mechanical properties*, Scientific World Journal, vol. 2013, Article ID 454710, 2013.
7. Reznik Y. M. Influence of physical properties on deformation characteristics of collapsible soils, Engineering Geology, vol. 92, pp. 27-37, 2007.
8. Romanian Norm (NP 126). Constructions with foundations on collapsible soils, Bucharest, 2010.