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SIMILARITY TOPICS OF SOILS WITH SENSITIVITY TO WETTING BASED UPON DATA GATHERED FROM LABORATORY TESTS

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Abstract: *Special problems are occurred in several areas of Romanian territory, where intensive urbanization process involves the building foundations on soils with high sensitivity to wetting. The paper includes the data gathered from geotechnical laboratory tests carried out on samples collected from different sites located along Danube river shore. The aspects regarding similarity of geotechnical properties for identification and behavior were analyzed. The results have allowed establishing the variation intervals of certain parameters depending on depth and soil class, which have led to a statistical processing of data of data input. The research direction in which is part the present paper consists in creating a comprehensive database required for difficult soil zoning at national level and providing basic information for urban planning. Also, in the present context of sustainable development, it is imposes for an estimation of real foundation conditions and therefore the widespread use of correlations between physical indices, which define the soil nature and state, and mechanical ones, involved in assessment of foundation settlement or in estimation of bearing capacity of soil foundation.*

Key words: *behavior, wetting, sensitivity, correlation*

1. Introduction and objective

The soils with sensitivity to wetting also called "collapsible soils" can manifests additional settlements under a given load or weight, but in same cases, at intensive wetting, those settlements are suddenly increasing and gaining a collapse character [1]. It is widely know that the most important feature of these soil types is very high sensitivity at water action, manifested by strong erosion and large settlements [2].

The soils with sensitivity to wetting cover large areas on approximately 40.000 km^2, which represents 17% of the Romanian territory. It is generally admitted

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that the soil origin is to be sought in the alternation of glacial and inter-glacial periods in Quaternary geologic age [3], characterized by a high percentage of silt grains, ranging from 50% up to 80%, with clay and sand fractions in approximately equal proportions. Due to their unstable structure, to high porosity and high permeability, under the influence of high moisture content, collapsible or loess soils passes from a very loose state to a dense one. As a result of the high suction of water from unsaturated loess pores, the wetting process and the air expulsion can produce linkage breaks in the existing structure, by producing collapse [4]. The building executions on soils with sensitivity to wetting represents an obvious problem at nationally and internationally level, due to the fact that sometimes are required complex constructions on soils which can influence their stability [5].

Taking into consideration the actual interest of building foundation on wetting sensitive soils, the present work is focused on the analysis of these types of soils from the point of view of similarity aspects regarding the their geotechnical parameters and behavior [6], [7].

2. Methods and results of laboratory tests on soil with sensitivity to wetting

For the study, there were selected two areas from Romania (Calafat and Tulcea), where the territorial spread of soils with sensitivity to wetting has a significant proportion. The working plan is based on experimental laboratory tests using a numerous soil samples in order to obtain the variability of specific geotechnical properties.

Regarding the site from Calafat area, located on Danube river shore, on the southern part of Romania, the laboratory tests were conducted on silty and sandy samples collected from soils with sensitivity to wetting. Following the available methods, the values for physical properties (moisture content, plasticity and consistency index, natural density, porosity, void ratio and saturation degree) and mechanical ones (specific settlement, friction angle and cohesion) were achieved. According to the requirements of geotechnical Romanian norms [8], it is mentioned that the determination of specific settlement index at wetting under 300 kPa loading step is required and represents one of the fundamental criteria related to the mechanical behavior.

Taking into consideration the predominant grain size fraction of samples collected from different depths up to 13 meters, there were established several soil categories. From the analysis of soil identification data, it is noticed that the predominant soil category for this site is represented by silty loess.

Based on statistical processing and interpretation of the results gathered from laboratory tests, there were established the limits intervals of geotechnical characteristics for Calafat area, as see in Table 1 for physical properties and Table 2 for mechanical ones.

The measured values can confirm that the soil samples belong to the category of soils with sensitivity to wetting, with the following specific parameters: low natural moisture 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.

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

Limits intervals of physical characteristics values for Calafat soils Table 1

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

Limits intervals of mechanical characteristics values for Calafat soils Table 2

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

The second investigated area is Tulcea, located at the end of the Danube River in Europe, in the south-eastern part of Romania. Concerning the spread of soils with sensitivity to wetting on the Romanian territory, these deposits indicate a significant thickness in Tulcea area.

During the laboratory testing program, there were examined 148 samples collected from 9 boreholes carried out on different sites in Tulcea. Taking into account the data obtained from grain size analyses, several significant soil categories 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). It should be noted that loess samples from Tulcea area are susceptible to wetting and the predominant granular fraction is silt. The soil categories are represented by clayey silt and sandy silt.

The experimental working plan consisted of determining the physical and mechanical characteristics of the samples studied. In the study it was considered useful the delimitation of samples in different soil categories, illustrated in fig. 1 and fig. 2.

The results of laboratory determinations are presented as follows: 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 category.

As an overall analysis of data obtained from laboratory testing, the predominant soil categories from Tulcea sites can be characterized by the following specific parameters:

- for clayey silt (soil category no. 6), the average value for moisture 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 (soil category no. 7), the average value for moisture content is around 15%, porosity average around 44 %, low to medium plasticity and stiff to hard consistency state, oedometric modulus around 9400 kPa.

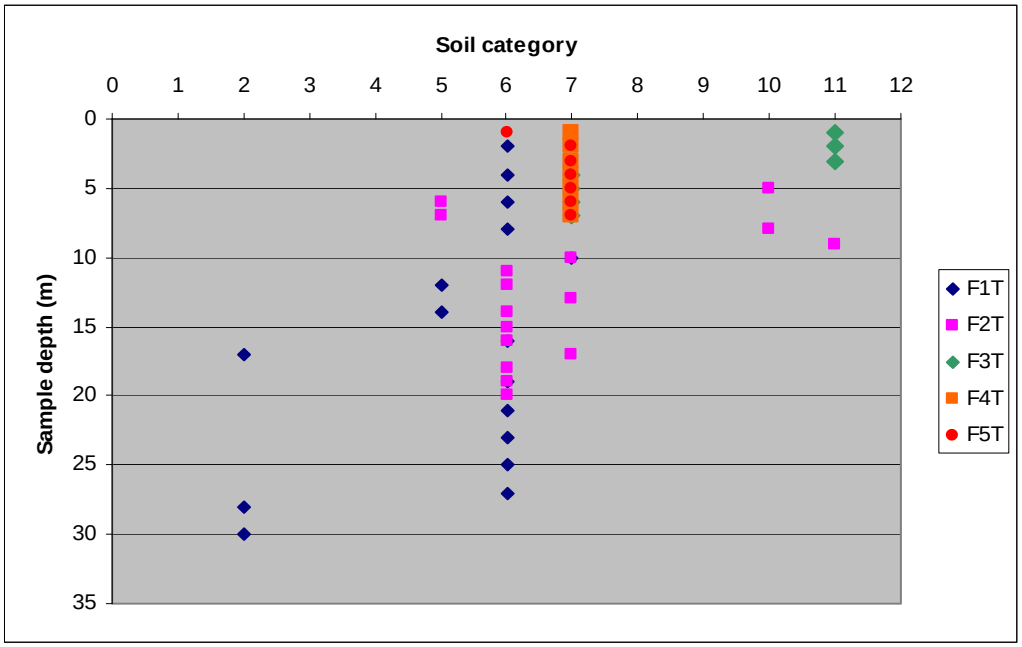

Fig.1 *Variation of soil category with sample depths in Tulcea area (borehole F1T ÷ F5T)*

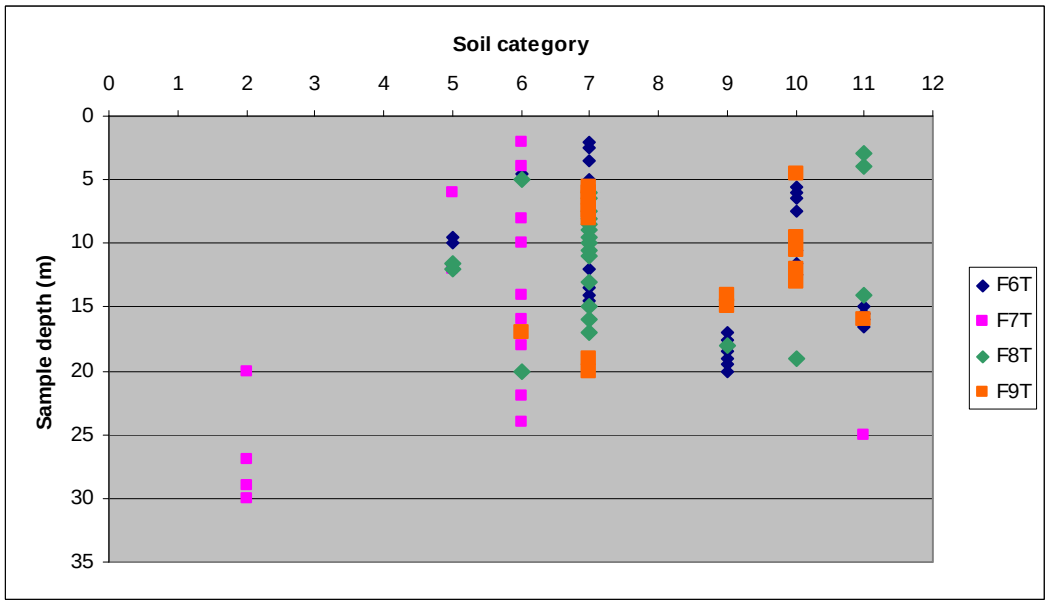

Fig.2 *Variation of soil category with sample depths in Tulcea area (borehole F6T ÷ F9T)*

The results gathered for all defined soil categories in Tulcea area, but especially for the silty predominant types, are ranging within the variation limits corresponding to physical and mechanical characteristics for soils with sensitivity to wetting or collapsible in natural state [8].

Limits intervals of properties values for soil category 2, 5, 9 and 10 Table 3

Measured values	Water content (%)	Plasticity index (%)	Consistency index (-)	Density (g/cm^3)	Porosity (%)	Void ratio (-)	Saturation degree (-)	Oedometric modulus (kPa)
Silty clay - soil category 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- soil category 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 - soil category 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- soil category 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

Limits intervals of properties values for soil category 7 and 11 Table 4

Measured values	Water content (%)	Plasticity index (%)	Consistency index (-)	Density (g/cm^3)	Porosity (%)	Void ratio (-)	Saturation degree (-)	Oedometric modulus (kPa)
Sandy silt - soil category 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- soil category 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

Limits intervals of physical properties values for soil types 6 (clayey silt) Table 5

Measured values	Water content (%)	Plasticity index (%)	Consistency index (-)	Density (g/cm^3)	Porosity (%)	Void ratio (-)	Saturation degree (-)
Clayey silt - soil category 6							
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

Limits intervals of mechanical properties values for soil types 6 (clayey silt) Table 6

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

3. Conclusion and discussions

The studies were aimed to analyze the similarity aspects of soils with sensitivity to wetting based upon gathered from laboratory tests on soil samples collected from Calafat and Tulcea sites. For each site there were delimited several specific soil categories and a statistical analysis of geotechnical parameters variation was conducted.

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

The aim of this kind of research subject is to ensure that the construction built on soils with particular behavior presents a certain level of safety in exploitation. Also, in the present context of sustainable development, it is imposes for an estimation of real foundation conditions and therefore the widespread use of correlations between physical indices, which define the soil nature and state, and mechanical ones, involved in assessment of foundation settlement or in estimation of bearing capacity of soil foundation.

It should be mentioned that this type of study, based on comparative tests between soils with similar behavior, can be used in geotechnical design and in creating a comprehensive database required for soil zoning at national level and providing basic information for urban planning, on the other side.

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