

PROBLEMS OF USAGE OF SOIL CLASSIFICATION SYSTEMS FOR SAND SOILS OF LITHUANIA

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Abstract. Sand soils cover approximately 30 % of the territory of Lithuania. They are frequently used as foundation for different buildings. Lately, in geotechnical investigations, classification of sand soils according to their grain size distribution has been based on different classification schemes: Lithuanian (LST 1445:1996, LST 1331:2002), German (DIN 18196), United Kingdom (BS 5930:1990), USA (ASTM D2487-06e1), European (EN ISO 14688-2:2004), and Russian (GOST 25100-82). In Lithuania, in different classifications, principles for sand division are various. The purpose of this article is to assess similarities and differences of classification of sand soils according to their grain size distribution based on investigations of sand soil grain size distribution and of mechanical properties using different classification systems.

Keywords: grain size distribution, sand soils, classification systems, cone resistance, Lithuania.

1. Introduction

Sand soils cover approximately 30 % of the territory of Lithuania. They are widely used in sites of mass construction. Thus, these soils are often used as bases, as a medium and as a construction material for different buildings. Lately, in geotechnical investigations, classification of a wide range of sand soils according to their grain size distribution has been based on different classification schemes (LST 1445:1996, LST 1331:2002, DIN 18196, EN ISO 14688-2:2004, BS 5930:1990, ASTM D2487-06e1). Furthermore, for many decades investigations were carried out in compliance with requirements of the Former Soviet Union national standard GOST 25100-82. Thus, the name of sand soil with identical grain size distribution belongs on a kind of classification scheme used for investigations of grain size distribution (Dundulis and Gadeikis 2002; Jaros *et al.* 2007; Jaros *et al.* 2004; Jaros and Majer 2006).

In Ignalina AE industrial site, while conducting geotechnical surveys, more than 148 samples of sand soil were picked and identified. It must be noted that since 2000, in geological, engineering geological, geotechnical

and hydrogeological investigations, DIN standards of German Standardization Institute have been followed. The purpose of this article is to assess similarities and differences of classification of sand soils according to their granular composition based on our parallel investigations using different classification systems.

2. Similarities and Differences between Classification Systems of Sand Soils

Firstly, it must be noted, that in the Former Soviet Union and Western countries, while conducting analysis of grain size distribution of sands and classifying them accordingly, different sets of sieves were used. This determined the differences between classification limits of particles of sand soils (Fig 1). In the Former Soviet Union, to determine granular composition of sand during geotechnical investigations according to GOST 25100-82, a so called “2” system was employed. Standard set of sieves was composed of sieves with meshes of 10, 5, 2, 1, 0.5, 0.25 and 0.1 mm (Ломтадзе 1984; Трофимов *et al.* 2005). Type of sand soil was determined using a so called method of totalizing (Table 1).

Countries	Grain size, mm															
	0.001	0.002	0.005	0.01	0.02	0.05	0.075	0.1	0.2	1	2	4.75	10	20	40	60
EN ISO	Clay		Silt					Sand				Gravel			Cobble	Boulder
Russia	Глина		Пыль					Песок				Гравий		Галька		Валун
Germany	Ton		Schluff					Sand				Kies			Stein	

Fig 1. Geotechnical divisions and limits of fractions in different countries (Dundulis 1997)

Table 1. Types of sand soil according to their granular composition (GOST 25100-82)

Sand type	Requirements for granular composition
Gravelly sand	Mass of particles of >2 mm is >25 %
Coarse sand	Mass of particles of >0.5 mm is >50 %
Medium coarse sand	Mass of particles of >0.25 mm is >50 %
Fine sand	Mass of particles of >0.1 mm is 75 per cent and more
Silty sand	Mass of particles of >0.1 mm is <75 %

Additionally, according to this standard, soils were divided according to uniformity coefficient C_u to well graded ($C_u < 3$) and poorly graded ($C_u \geq 3$).

In European Union countries, sieve analysis system “2–6” is used. According to this system, the following main fractions are distinguished: gravel – 63–2 mm, coarse – 2–0.63 mm, medium coarse – 0.63–0.2 mm, fine – 0.2–0.063 mm, and silty <0.063 mm.

This data demonstrates that limit of fine particles in the Former Soviet Union and European Union countries is already different. For Soviet Union it is 0.1 mm, and for European Union – 0.063 mm (Dundulis *et al.* 2000; Dumbleton 1981).

To assess particularities of Western classification of sand soils according to their granular composition, two different classifications used in the territory of Lithuania are discussed: DIN 18196 and EN ISO 14688-2:2004.

In German classification system of soils – DIN 18196 – sands are divided into two main groups – coarse soils and mixed soils. To the first group, sands where particles smaller than 0.063 mm equal to <5 % of total mass and particles <2 mm compose >60 %, are assigned. Within this group, sand is further classified according to the character of granular curve into poorly graded, well graded and gap graded (Fig 2). Division of sands according to prevailing fraction is not necessary. To the second group of mixed soils, sand soils where particles <0.063 mm compose from 5 to 40 %, and particles <2 mm compose more than 60 % of total mass are assigned (DIN 18196:1988-10; Karlsson and Hansbo 1989).

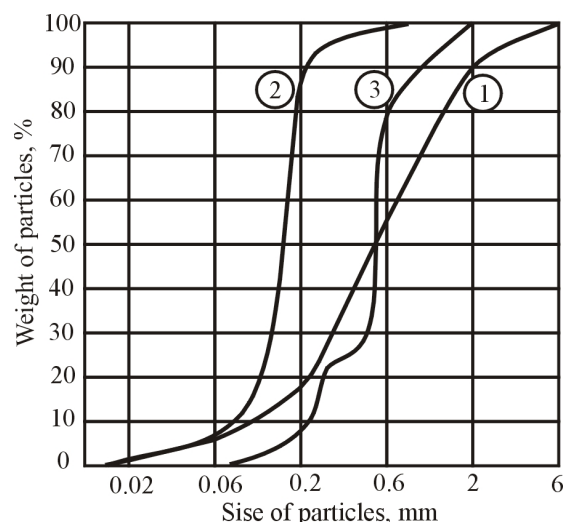


Fig 2. Curves of grain size distribution of sands: 1 – well graded, 2 – poorly graded, 3 – gap graded

According to the requirements of the latest European standard EN ISO 14688-2:2004, sand soils are assigned to groups of coarse and mixed soils, where most of the particles are larger than 0.063 mm. Four subgroups of sand are distinguished. These are: gravelly sand, when larger than 2 mm particles compose 20 to 50 % of total mass, and smaller than 0.063 mm particles compose only up to 15 % of total mass, gravelly silty or clay sand, when larger than 2 mm particles compose 20 to 50 % of total mass, and smaller than 0.063 mm particles comprise 15 % to 40 % of total mass. Subgroup of pure sands includes sands, where larger than 2 mm particles compose up to 20 % of total mass, and smaller than 0.063 mm particles compose up to 15 % of total mass. Subgroup of silty and clay sands includes sands, where larger than 2 mm particles compose less than 20 % of total mass, and smaller than 0.063 mm particles compose 15 % to 40 % of total mass. Additionally, EN ISO 14688-2:2004 recommends to further divide pure sands according to prevailing fraction into fine, medium coarse and coarse sands.

Summarizing presented particularities of classifications, it may be stated that in different classifications, principles of sand division are very different.

In geotechnical design, one must be aware of mechanical behavior of soils. Therefore, particularities of

sand soils division in Lithuania according to above mentioned classifications while also assessing distribution of mean values of cone resistance q_c and of coefficient of variation.

3. Research Results

The results of parallel investigations with 148 samples classifying sands according to the requirements of DIN 18196, EN ISO 14688-2:2004, GOST 25100-82, have demonstrated that in many cases, quite different results are achieved. Sample sand soils according to sieve analysis were first divided according to GOST into gravelly, medium coarse, fine and silty sands. Their further classification using standard sieves according to ISO 3310-1 and ISO 3310-2 using DIN 18196 has demonstrated (Fig 3) that previously mentioned gravelly sands consist of poorly graded sands (39 %) and of gap graded sands (17 %). Other part of gravelly sands becomes silty sands (38 %) and very silty sands (6 %). In medium coarse sands, poorly graded sands prevail (61 %). Silty sands amount to 35 % of total mass. Mass of very silty sands equals to 3 %, and mass of clean well graded sands is only one percent. Fine sands are divided into three types: poorly graded sands (51 %), silty sands (38 %) and very silty sands (11 %). Accordingly, division of so called silty sands of GOST according to DIN is the closest – 49 % of silty sands, 32 % of very silty sands and only 16 % of clean poorly graded and 3 % of well graded sands.

Division of sands classifying them according to GOST and naming them according to prevailing fraction based on requirements of EN ISO 14688-2:2004 is shown in Fig 4. In gravelly sands, medium coarse sands (44 %) and coarse sands (28 %) prevail. Accordingly, gravelly sands constitute 24 %, and silty sands constitute only 6 % of all investigated samples. Medium coarse sands as according to EN ISO are close to classification according to GOST. Naming conformity includes 86 % of samples. A small part of samples were called coarse (4 %), fine (3 %), silty (6 %) and gravelly (1 %) sands. Naming conformity of fine sands encompasses 51 % of samples. 36 % of sands are renamed to medium coarse, coarse (2 %) and silty (11 %) sands. The clearest division according to GOST is that of silty sands. In this case, naming conformity is only 33 %. As medium coarse sands 32 % of sands were renamed, as coarse – 4 %, as fine – 32 %.

4. Evaluation of Mechanical Behavior of Sand Soils

Investigation results provided above demonstrate that with different classifications used in European countries it is possible to achieve a much more detailed division of geological cross-section according to granular composition. This is very important in evaluation of soil water permeability, effect of permafrost on soil, etc. However, in geotechnical design, one of the most important tasks is to assess mechanical behavior of soil, that is, to determine its strength and.

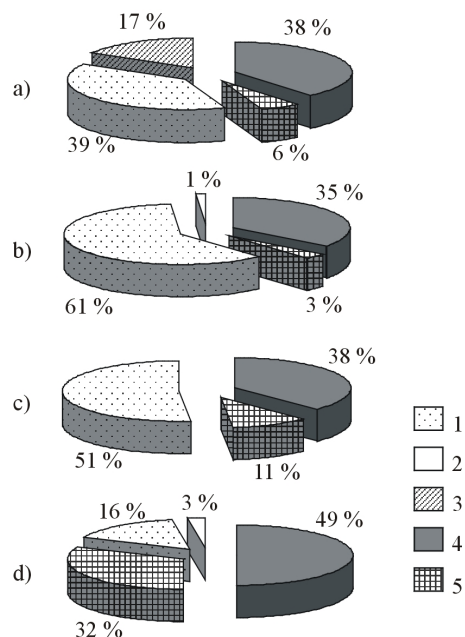


Fig 3. Division of sand types according to GOST 25100-82 based on DIN classification 18196: According to GOST 25100-82: a) gravelly sand, b) medium coarse sand, c) fine sand, d) silty sand. According to DIN 18196: 1 – poorly graded sand (SE), 2 – well graded sand (SW), 3 – gap graded sand (SI), 4 – silty sands (SU), 5 – very silty sands (SU_o)

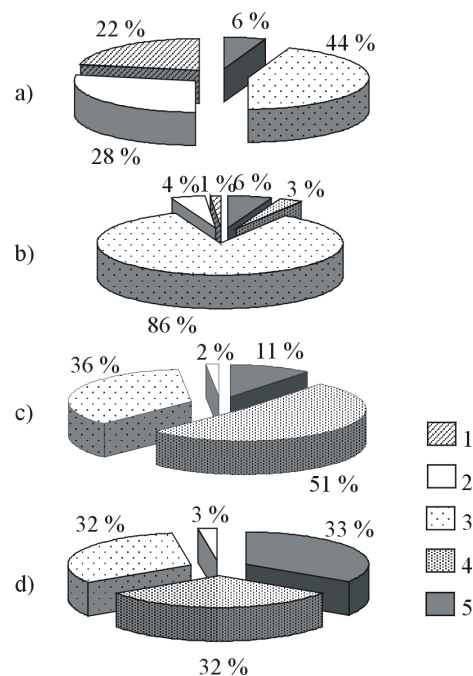


Fig 4. Types of sand by GOST 25100-82 division according to classification of EN ISO 14688-2:2004: According to GOST 25100-82: a) gravelly sand, b) medium coarse sand, c) fine sand, d) silty sand. According to EN ISO 14688-2:2004: 1 – gravelly sand, 2 – coarse sand, 3 – medium coarse sand, 4 – fine sand, 5 – silty sand

Table 2. Mean values of cone resistance (\bar{q}_c) and coefficients of variation (V) for types of sand soils according to different classifications

Soil type according to GOST 25100-82	Cone resistance values		Type of soil according to DIN 18196	Cone resistance values		Type of soil according to LST EN ISO 14688-2	Cone resistance values	
	\bar{q}_c , MPa	V, %		\bar{q}_c , MPa	V, %		\bar{q}_c , MPa	V, %
Gravelly sand	18.5	35	Well graded sand (SW)	12	-	Gravelly sand	17	-
Medium coarse sand	17.5	34	Poorly graded sand (SE)	18	26	Coarse sand	18.5	34
Fine sand	16.1	37	Gap graded sand (SI)	22	35	Medium coarse sand	16.7	30
Silty sand	20.1	32	Silty sand (SU)	18	23	Fine sand	20	29
			Very silty sand (SU _o)	17	21	Silty sand	15.3	30

Compressibility. Currently, together with direct investigations of soil mechanical properties to assess mechanical behavior, indirect methods of penetration are used frequently – cone penetration test and others (Amšiejus *et al.* 2009).

Authors consider it a must to compare types of sand soils, determined according to their granular composition based on different classifications with the results of cone penetration test, performed in sample picking sites. In Table 2, data of soils division according to their granular composition based on different classifications is provided. Also, by each determined soil type, mean values of cone resistance (q_c) and coefficients of variation are provided.

According to mean values of cone resistance, significant tendencies and peculiarities of distribution were not observed. In all cases, mean values of cone resistance vary within a rather small interval – 15 to 20 MPa. Only according to classification DIN 18196, well graded sands have smaller q_c values ($q_c = 12$ MPa). Assessing according to values of coefficient of variation, it has been noted that soil types determined according to GOST 25100-82 are more heterogeneous. Sand types according to DIN 18196 and according to LST EN ISO 14688-2:2004 are more homogenous. Based on this data, it might be stated that classifications LST EN ISO 14688-2:2004 or DIN 18196 are more suitable in geotechnical investigations to assess mechanical behavior sand soils.

Conclusions

In different countries, soil classifications according to their granular compositions vary significantly according to sieve sets, classification diameter sizes of fine (silty) particles and according to their percentage of total mass.

Using standard EN ISO 14688-2:2004 and German standard DIN 18196, sand soil lugs are better divided into different types according to their grain size distribution.

A more detailed division of sand soils enables us to distinguish sand layers that are more homogenous in regard to mechanical behavior.

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