Engineering soil classification according to EN ISO 14688-2:2018

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Preliminary report

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Engineering soil classification according to EN ISO 14688-2:2018

This paper presents novelties in the identification and description of soil according to European standard EN ISO 14688-1:2018, as well as changes in the principles of soil classification according to European standard EN ISO 14688-2:2018. A new version of the European Soil Classification System (ESCS) for engineering purposes is developed. A detailed comparison with the Unified Soil Classification System (USCS) is performed according to soil group symbols, soil group names, and soil classification procedures. A new version of the KLASIF computer software is also developed. The program provides IT support for implementing both USCS and ESCS classifications, and facilitates their parallel use.

Key words:
soil classification, computer software, standard, particle size distribution, plasticity

Prethodno priopćenje

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Inženjerska klasifikacija tla prema EN ISO 14688-2:2018

U radu se prikazuju novosti u identificiranju i opisu tla prema europskoj normi EN ISO 14688-1:2018 i promjene u načelima za klasifikaciju tla prema europskoj normi EN ISO 14688-2:2018. Razvijena je nova verzija Europske klasifikacije tla za inženjerske potrebe (ESCS). Napravljena je detaljna usporedba s Jedinstvenom klasifikacijom tla (USCS) s obzirom na označavanje grupa tla simbolima, nazive grupa tla i procedure za klasifikaciju. Razvijena je i nova verzija računalnog programa KLASIF. Program predstavlja informatičku podršku za provođenje Jedinstvene (USCS) i Europske (ESCS) klasifikacije tla i olakšava njihovu jednostavnu paralelnu primjenu.

Ključne riječi:
klasifikacija tla, računalni program, norma, granulometrijski sastav tla, plastičnost

Vorherige Mitteilung

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Technische Klassifizierung des Bodens gemäß EN ISO 14688-2:2018

In der Abhandlung werden die Tragfähigkeit bei der Identifizierung und der Beschreibung des Bodens gemäß der europäischen Norm EN ISO 14688-1:2018 sowie die Änderungen in den Grundsätzen für die Bodenklassifizierung gemäß der europäischen Norm EN ISO 14688-2:2018 dargelegt. Entwickelt wurde eine neue Version der Europäischen Bodenklassifizierung für technische Zwecke (ESCS). Durchgeführt wurde ein detaillierter Vergleich mit der Einheitlichen Bodenklassifizierung (USCS) in Bezug auf die Kennzeichnung der Bodengruppen mit Symbolen, Bezeichnung der Bodengruppen sowie der Klassifizierungsprozedur. Entwickelt wurde auch eine neue Version des Computerprogramms KLASIF. Das Programm stellt eine IT-Unterstützung für die Durchführung der Einheitlichen (USCS) und der Europäischen (ESCS) Bodenklassifizierung dar und erleichtert eine einfache parallele Anwendung.

Schlüsselwörter:
Bodenklassifizierung, Computerprogramm, Norm, granulometrische Bodenzusammensetzung, Plastizität

1. Introduction

In civil engineering, the description and classification of soil for engineering purposes is the basis for communication among engineers all over the world, the aim being to ensure better understanding and comparison of in-situ and laboratory test results. The engineering classification of soil enables engineers to generally estimate the type of soil and the range of its mechanical properties. By classification according to principles determined in advance, different types of soil can be classified into groups with similar mechanical properties and behaviour under load. The best known and the most widespread engineering classification of soil is the USCS (Unified Soil Classification System), which is presented in ASTM D 2487-11 [1].

The Technical Committee of the International Organisation for Standardisation ISO/TC 182 "Geotechnics", in collaboration with the Technical Committee of the European Committee for Standardisation CEN/TC 341 "Geotechnical Investigation and Testing" prepared in March 2018 the following standards: Geotechnical investigation and testing - Identification and classification of soil - Part 1: Identification and description (EN ISO 14688-1:2018) [2] and Geotechnical investigation and testing - Identification and classification of soil - Part 2: Principles for a classification (EN ISO 14688-2:2018) [3]. These standards supersede former standards EN ISO 14688-1:2002 [4] and EN ISO 14688-2:2004 [5], as well as the annexes to these standards EN ISO 14688-1:2002/A1:2013 [6] and EN ISO 14688-1:2004/A1:2013 [7].

European countries, i.e. CEN members required to implement new European standards no later than by August 2018, are: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Danmark, Estonia, Finland, France, Greece, Croatia, Ireland, Iceland, Italy, Latvia, Lithuania, Luxembourg, Hungary, Macedonia, Malta, Netherlands, Norway, Germany, Poland, Portugal, Romania, Slovakia, Slovenia, Serbia, Spain, Sweden, Switzerland, Turkey, and Great Britain.

Following proposal of the Technical Committee HZN/TO 182/PO 2 *Geotechnical Structures*, the Croatian Standards Institute adopted in March 2018 European standards EN ISO 14688-1:2018 and EN ISO 14688-2:2018 in their English language originals as Croatian standards bearing the marks HRN EN ISO 14688-1:2018 [8] and HRN EN ISO 14688-2:2018 [9]. The publication of these standards supersedes former standards HRN EN ISO 14688-1:2008 [10] and HRN EN ISO 14688-2:2008 [11], as well as national annexes to these standards HRN EN ISO 14688-1:2008/A1:2013 [12] and HRN EN ISO 14688-2:2008/A1:2013 [13].

Kovačević and Jurić-Kaćunić [14] developed a European soil classification for engineering purposes i.e. the European Soil Classification System (ESCS) according to the description and symbols used in the European standard EN ISO 14688-1:2002 and as per soil classification principles set out in EN ISO 14688-2:2004. The CLASSIF Ver.01 software was developed at the Geotechnical Department of the Faculty of Civil Engineering in Zagreb. This software is an information technology support for the implementation of the Unified Soil Classification System (USCS) and the European Soil Classification System (ESCS), and it also facilitates parallel use of the two systems [15-17].

The New European standards have brought some novelties with regard to the identification and description of soil, as well as some changes in the soil classification principles, which are important for the preparation of an integral classification of soil that is well suited for practical engineering purposes. That is why it is necessary to develop a new version of the European soil classification (ESCS) and a new version of the CLASSIF software, compliant with the EN ISO 14688-1:2018 and EN ISO 14688-2:2018.

2. Novelties in soil identification according to EN ISO 14688-1:2018

The soil fraction that defines its engineering properties is called the primary fraction and is designated by a noun, e.g. SAND or CLAY. Although it is indicated that the primary fraction is usually written in capital letters, it is actually exclusively written in capital letters throughout the entire standard, and in the standard related to soil classification principles. For that reason, it has been accepted that the primary fraction be marked with a noun written in capital letters in the new version of the engineering classification of soil, which is proposed in this paper. Soil fractions that influence or modify engineering properties of soil are called secondary and tertiary fractions, and are marked with one or several adjectives that are written in lower-case letters. They can be placed either in front of or after the primary fraction, e.g. silty SAND or CLAY, gravelly. Although it is left to the choice of the users of the standard to employ any word order in marking the fractions, in the entire standard, and in the standard related to soil classification principles, the primary fraction is used at the end. That is why it has been accepted that the primary fraction is used at the end in the new version of the engineering classification of soil that is proposed in this paper. The secondary fraction that exerts the greatest influence on engineering properties of soil is written in front of the primary fraction. The tertiary fraction that influences engineering properties of soil is written in front of the secondary and primary fractions, e.g. gravelly silty SAND. Due to arbitrary order of words in the marking of fractions, the marking of fractions by symbols has been avoided.

3. Changes in soil classification principles according to EN ISO 14688-2:2018

The primary fraction of the coarse-grained soil is marked with symbols composed of two letters, the first of which is written in capital letter:

- Gr - GRAVEL
- Sa - SAND

The coarse-grained soil is additionally classified according to its grading as follows:

- well graded SAND or GRAVEL
- medium graded SAND or GRAVEL
- poorly graded SAND or GRAVEL
- uniformly graded SAND or GRAVEL
- gap graded SAND or GRAVEL

The classification is conducted through determination of the soil particle size distribution (grading). Typical grain diameters D_{10}, D_{30} and D_{60} are determined as grain diameters at which 10%, 30% and 60% of the sample mass contains grains of smaller diameter. This information is used to determine parameters for the soil grading curve, uniformity coefficient $c_u = D_{60}/D_{10}$, and the coefficient of curvature $c_c = (D_{30})^2/(D_{10}xD_{60})$. The classification of coarse-grained soil according to grading is presented in Table 1:

Table 1. Soil description according to grading [3]

Classification of coarse-grained soil	c_u	c_c
Well graded	> 15	1 to 3
Medium graded	6 to 15	< 1
Poorly graded	3 to 6	< 1
Uniformly graded	< 3	< 1
Gap graded	> 15	< 0.5

The primary fraction of the fine-grained soil is marked with symbols consisting of two letters, the first of which is a capital letter:
- Si - SILT,
- Cl - CLAY.

The fine-grained soil is additionally classified according to plasticity as follows:
- low plasticity CLAY or SILT,
- medium plasticity CLAY or SILT,
- high plasticity CLAY or SILT,
- very high plasticity CLAY or SILT.

The classification is conducted by determining the consistency limits. The liquid limit w_L and plastic limit w_P are determined, and the plasticity index is calculated $I_P = w_L - w_P$. The plasticity diagram is used and the liquid limit w_L is entered on the abscissa, and the plasticity index I_P on the ordinate. The liquid limit w_L is used to classify the fine-grained soil according to plasticity, while the A-line on the plasticity diagram is used for classifying soil into clay and silt (Figure 1).

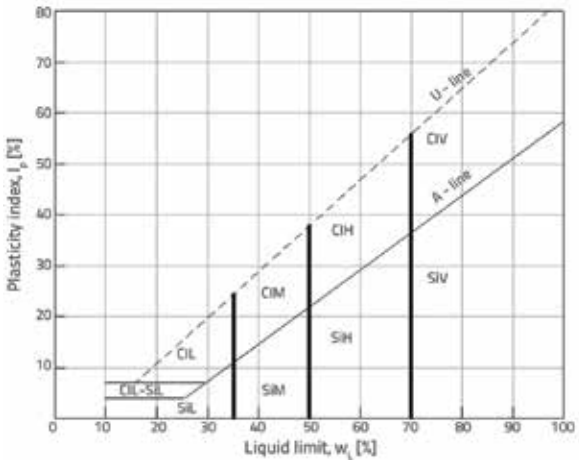

Figure 1 .Plasticity diagram according to EN ISO 14688-2:2018

4. Classification of soil according to EN ISO 14688-2:2018

The new European soil classification for engineering purposes ESCS (European Soil Classification System) based on principles set out in EN ISO 14688-2:2018 is presented in Table 2.

5. Comparison of ESCS and USCS soil classifications

According to both classifications, soil can be divided into: coarse-grained soil and fine-grained soil that may contain organic matter. Particle size distribution (grading) and consistency limits are used as bases for soil classification. According to the ESCS, the soil is classified as coarse-grained if more than 50% of the total quantity of dry sample remains on sieve size 0.063 mm and, according to the USCS, if more than 50% of the total quantity of dry sample remains on sieve size 0.075 mm.

5.1. Use of symbols for soil group marking

The basic idea behind soil classification is to mark soil by symbols that represent the primary, secondary and tertiary fractions out of which soil is composed. The primary fraction of soil determines engineering properties of soil. The secondary and tertiary fractions do not determine engineering properties of soil, but they influence or modify these properties.
According to the ESCS classification, the primary fraction of soil that determines engineering properties of soil is marked by a symbol composed of the first two letters of the English name of the fraction, the first of which is written in capital letter: Gr - GRAVEL, Sa - SAND, Si - SILT and Cl - CLAY.
According to the USCS classification, the primary fraction of soil is marked by symbol consisting of a single capital letter: G - gravel, S - sand, M - silt, and C - clay.
According to the ESCS classification, the secondary fraction of coarse-grained soil that influences the engineering properties of soil the most is the fraction that contains more than 5% of fine particles in the coarse-grained soil sample. If the sample contains 5 to 15% of fine particles, it is marked by symbol consisting of two first letters of the fraction name, which are written in lower-case letters before the primary fraction and, at the end of the mark, a capital letter denoting the primary fraction grading is added: siGrW - silty well graded GRAVEL or clSaU - clayey uniformly graded SAND. The exceptions are fine fractions that are classified as CiL-SiL in the plasticity diagram and that obtain double mark of the secondary fraction, while the grading of the primary fraction is omitted: siclGr - silty clayey GRAVEL or siclSa - silty clayey SAND. If the sample contains more than 15% of fine particles it is marked by symbol consisting of two first letters of the fraction name, which are written in lower-case letters before the primary fraction: siGr - silty GRAVEL, clGr - clayey GRAVEL, siSa - silty SAND, or clSa - clayey SAND.
According to the ESCS classification, in case of fine-grained soil, the secondary fraction is the fraction containing more than 15% of coarse grains. It is marked by symbol consisting of the first two

Table 2. ESCS classification of soil according to EN ISO 14688-2:2018

Criteria for allocating symbols and names to individual soil groups based on laboratory testing[A]				Soil classification	
				Symbol	Group name[B]
COARSE-GRAINED SOIL (more than 50 % remaining on sieve 0.063 mm)	Gravel (more than 50% remaining on 2 mm sieve)	Pure gravel (less than 5% of fine particles[F,G])	$c_u \geq 15$ and $1 \leq c_c \leq 3$[C]	GrW	Well graded GRAVEL[D]
			$6 \leq c_u < 15$ and $c_c < 1$[C]	GrM	Medium graded GRAVEL[D]
			$3 \leq c_u < 6$ and $c_c < 1$[C]	GrP	Poorly graded GRAVEL[D,E]
			$c_u < 3$[C] and $c_c < 1$[C]	GrU	Uniformly graded GRAVEL[D]
			$c_u \geq 15$ and $c_c < 0.5$[C]	GrG	Gap graded GRAVEL[D]
		Gravel with fine particles (more than 15% of fine particles[F,G,H])	Fine particles are classified as siL, sil, siH or siV	siGr	Silty GRAVEL[D]
			Fine particles are classified as clL, cll, clH or clV	clGr	Clayey GRAVEL[D]
	Sand (50 % or more passing through 2 mm sieve)	Pure sand (less than 5% of fine particles[G,J])	$c_u \geq 15$ and $1 \leq c_c \leq 3$[C]	SaW	Well graded SAND[I]
			$6 \leq c_u < 15$ and $c_c < 1$[C]	SaM	Medium graded SAND[I]
			$3 \leq c_u < 6$ and $c_c < 1$[C]	SaP	Poorly graded SAND[E,I]
			$c_u < 3$[C] and $c_c < 1$[C]	SaU	Uniformly graded SAND[I]
			$c_u \geq 15$ and $c_c < 0.5$[C]	SaG	Gap graded SAND[I]
		Sand with fine particles (more than 15% of fine particles[G,H,J])	Fine particles are classified as siL, sil, siH or siV	siSa	Silty SAND[I]
			Fine particles are classified as clL, cll, clH or clV	clSa	Clayey SAND[H]
FINE-GRAINED SOIL (50 % or more passing through 0.063 mm sieve)	Liquid limit less than 35 %	Inorganic[G]	$I_P > 7$ and on or above A-line[K]	ClL	Low plasticity CLAY[L]
			$I_P < 4$ or below A-line[K]	SiL	Low plasticity SILT[L]
	Liquid limit from 35 to 50 %	Inorganic[G]	On or above A-line	ClM	Medium plasticity CLAY[L]
			Below A-line	SiM	Medium plasticity SILT[L]
	Liquid limit from 50 to 70 %	Inorganic[G]	On or above A-line	ClH	High plasticity CLAY[L]
			Below A-line	SiH	High plasticity SILT[L]
	Liquid limit more than 70 %	Inorganic[G]	On or above A-line	ClV	Very high plasticity CLAY[L]
			Below A-line	SiV	Very high plasticity SILT[L]
Organic soil		Primarily organic matter, dark colour and organic odour		Or	Organic soil

[A]Based on materials that passed through the 63 mm sieve.
[B]If an in-situ soil sample contains fragments or blocks or both, then this soil should be described by adding to the soil group name either "with fragments" or "with blocks" or "with fragments and blocks"
[C]$c_u = D_{60}/D_{10}$; $c_c = (D_{30})^2/(D_{10} \times D_{60})$.
[D]If soil contains ≥ 15 % of sand, than the word "sa" written in lower-case letters should be added before the group name symbol, and the word "sandy" should be added before the group name.
[E]If the uniformity coefficient and curvature coefficient do not meet criteria for the good, medium, uniform or gap graded soils, the soil will be classified as poorly graded GRAVEL, GrP, i.e. as poorly graded SAND, SaP.
[F]Depending on their grading and plasticity, gravels with 5 to 15% of fine particles shall be marked as follows: siGrW - silty well graded GRAVEL, siGrM - silty medium graded GRAVEL, siGrP - silty poorly graded GRAVEL, siGrU - silty uniformly graded GRAVEL, siGrG - silty gap graded GRAVEL, clGrW - clayey well graded GRAVEL, clGrM - clayey medium graded GRAVEL, clGrP - clayey poorly graded GRAVEL, clGrU - clayey uniformly graded GRAVEL, clGrG - clayey gap graded GRAVEL.
[G]If fine particles contain organic matter, the mark "or" should be added in lower-case letters in front of the group name symbol, and the word "organic" will be added before the group name.
[H]If fine particles in the plasticity diagram are classified as CiL-SiL, then gravel and sand with 5 to 15% of fine particles will be marked as follows: siclGr - silty clayey GRAVEL and siclSa - silty clayey SAND.
[I]If soil contains ≥ 15% gravel, the mark "gr" should be added in lower-case letters in front of the group name symbol, and the word "gravelly" will be added before the group name.
[J]Depending on its grading and plasticity, the sand with 5 to 15% of fine particles will be marked as follows: siSaW - silty well graded SAND, siSaM - silty medium graded SAND, siSaP - silty poorly graded SAND, siSaU - silty uniformly graded SAND, siSaG - silty gap graded SAND, clSaW - clayey well graded SAND, clSaM - clayey medium graded SAND, clSaP - clayey poorly graded SAND, clSaU - clayey uniformly graded SAND, clSaG - clayey gap graded SAND.
[K]If the pair of values (w_L, I_P) in the plasticity diagram is situated above the line A and if $4 \leq I_P \leq 7$ then the soil will be marked with ClL-SiL, as silty CLAY.
[L]If soil contains ≥ 15% of coarse-grained material, then the mark "sa" or "gr" should be added in lower-case letters in front of the group name symbol, and the word "sandy" or "gravelly" will be added before the group name, depending on which of the two materials is better represented.

letters of the fraction name, and the letters are written in lower-case letters before the primary fraction: grSi - gravelly SILT, saSi - sandy SILT, grCl - gravelly CLAY or saCl - sandy CLAY. The exception is made for the soil called silty CLAY that is classified by mark CiL-SiL in the plasticity diagram.

According to the USCS classification, the secondary fraction of coarse-grained soil that influences the engineering properties of soil the most is the fraction that contains more than 5% of fine particles in the coarse-grained soil sample. If the sample contains 5 to 12% of fine particles, it is marked with a double symbol consisting of four capital letters, first two relating to soil grading, while the link to the fraction is marked by the last capital letter: GW-GM - well graded GRAVEL with silt or SP-SC - poorly graded sand with clay. The exception is made for fine fractions that are classified as CL-ML in the plasticity diagram, and that are marked by double secondary fraction symbols, while the grading of the primary fraction is omitted: GC-GM, silty clayey gravel, or SC-SM - silty clayey sand. If the sample contains more than 12% of fine particles, it is marked with symbol consisting of two letters, depending on whether fine particles are in fact silt or clay: GM - silty gravel, GC - clayey gravel, SM - silty sand, or SC - clayey sand.

According to the USCS classification, in case of fine-grained soil, the secondary fraction is the fraction containing more than 30% of coarse particles. The fraction is not marked with any symbol in this classification, but rather it is described with words "sandy" or "gravelly" that are added in front of the group name.

According to the ESCS classification, the tertiary fraction of coarse-grained soil that influences engineering properties of soil is the fraction that contains more than 15% of the second coarse-grained fraction in the coarse-grained soil sample. It is marked with symbol consisting of the first two letters of the fraction name, which are written in lower-case letters in front of the secondary fraction, or in front of the primary fraction if the secondary fraction does not exist: sasiGr - sandy, silty GRAVEL, grclSa - gravelly, clayey SAND, saGr - sandy gravel or grSa - gravelly sand. According to the ESCS classification, the tertiary fraction does not exist in fine-grained soil.

According to the USCS classification, the tertiary fraction of the coarse-grained soil that influences engineering properties of soil is the fraction that contains more than 15% of the second coarse-grained fraction in the coarse-grained soil sample. The fraction is not marked by any symbol in this classification, but rather the wording "with sand" or "with gravel" is added after the group name. According to the USCS classification, in case of fine-grained soil, the tertiary fraction is the fraction containing between 15 and 30% of coarse grains. The fraction is not marked by any symbol in this classification, but rather the wording "with sand" or "with gravel" is added after the group name.

Coarse-grained soils are additionally marked depending on their grading. According to the ESCS classification, capital letters are added to symbols of coarse-grained soils containing less than 15% of fine particles: W - well graded SAND or GRAVEL, M - medium graded SAND or GRAVEL, P - poorly graded SAND or GRAVEL, U - uniformly graded SAND or GRAVEL and G - gap graded SAND or GRAVEL. According to the USCS classification, capital letters are added to symbols of coarse-grained soils that have less than 12% of fine particles: W - well graded sand or gravel and P - poorly graded sand or gravel.

Fine-grained soils are additionally marked with regard to their plasticity. According to the ESCS classification, capital letters are added to symbols of fine-grained soil: L - low plasticity, M - medium plasticity, H - high plasticity, and V - very high plasticity. According to the USCS classification, capital letters are added to symbols of fine-grained soil: L - low plasticity and H - high plasticity.

According to the ESCS classification, the presence of organic matter in the coarse-grained or fine-grained soil is marked by adding lower-case letters "or" in front of the symbol. According to the USCS classification, the presence of organic matter in the coarse-grained sample is not marked by any symbol, but rather the wording "with organic particles" is added in front of the group name. According to the USCS classification, the presence of organic matter in the fine-grained soil sample is marked by replacing the primary fraction symbol (C or M) with the capital letter "O".

5.2. Soil group names

According to the ESCS classification, the names of soil groups consistently follow soil group symbols, so that every individual symbol represents one soil group. Some examples of symbols and soil group names are: SaP - poorly graded SAND, grSaM - gravelly medium graded SAND or grSiL - gravelly SILT of low plasticity.

According to the USCS, one soil group symbol can represent several soil group names. An example of a symbol representing several soil group names is: CL - lean clay, lean clay with sand, lean clay with gravel, sandy lean clay, sandy lean clay with gravel, gravelly lean clay or gravelly lean clay with sand.

5.3. Soil classification procedure

Procedures used for the ESCS and USCS classifications are quite similar. The procedures are conducted in five steps, differently for coarse-grained and fine-grained soil.

In the first step, it is determined based on sieving test results whether the primary soil fraction is the coarse-grained or fine-grained soil.

In the case of coarse-grained soil, it is determined in the second step, based on percentage, whether the primary fraction is sand or gravel.

In the case of the fine-grained soil it is determined according to the ESCS classification, based on the liquid limit value w_L, whether the primary fraction is the low, medium, high, or very high plasticity soil while, according to the USCS classification, it is determined whether the primary fraction is the low or high plasticity soil.

In the third step, it is determined for the coarse-grained soil, based on percentage, whether there is a secondary fraction made of fine-grained soil. In the case of the fine-grained soil it is determined, according to both classifications, based on the liquid limit w_L and the plasticity index I_P, whether the primary fraction is clay, silt or silty clay.

In the fourth step, the grading of the primary fraction is determined for the coarse-grained soil, except in the case when there is a secondary fine-grained soil fraction whose percentage is greater than 15% according to the ESCS classification, or greater than 12%

according to the USCS classification. If the secondary fine-grained soil fraction does exist, both classifications are used in this step to determine, based on liquid limit w_L and plasticity index I_P, whether the primary fraction is clay, silt, or silty clay. In the case of fine-grained soil, it is determined, based on percentage, whether the secondary coarse-grained soil fraction does exist.
In the fifth step, it is determined for the coarse-grained soil, based on percentage, whether there is a tertiary coarse-grained soil fraction. In the case of the fine-grained soil, and in the case the secondary fraction does exist, it is determined according to the ESCS classification which coarse-grained fraction is dominant. According to the USCS classification, it is determined for the fine-grained soil, in the case the secondary coarse-grained soil fraction does exist, whether there is a tertiary coarse-grained soil fraction.
After these five soil classification steps, an unambiguous decision is made about the soil group symbol and name.

6. CLASSIF - Software support for the ESCS and USCS soil classification

The computer program CLASSIF ver. 01, developed at the Geotechnical Department of the Faculty of Civil Engineering in Zagreb [15, 16, 17], is used for making USCS classifications according to the US standard ASTM D 2487-11, and ESCS classifications according to the European standards EN ISO 14688-1:2002 and EN ISO 14688-2:2004.
A new version 2 of the CLASSIF software (Figure 2) has been subsequently developed to take into account novelties in the identification and description of soil according to the European standard EN ISO 14688-1:2018, as well as changes in soil classification principles as presented in the European standard EN ISO 14688-2:2018.

Figure 2. Computer program CLASSIF Ver.02

CLASSIF Ver.02 was developed in Microsoft Excel using the integrated program language Visual Basic for applications (VBA). This software can be downloaded using the following link: http://www.grad.unizg.hr/zavod_za_geotehniku. The fact that both classifications use the same input data enables simple comparison of soil classification results. The program shows soil classification steps from procedures presented in Section 5.3, using only those input data groups that are relevant for their realisation. The comparison of ESCS and USCS classifications based on CLASSIF Ver. 02 software is presented in figures 3 and 4.

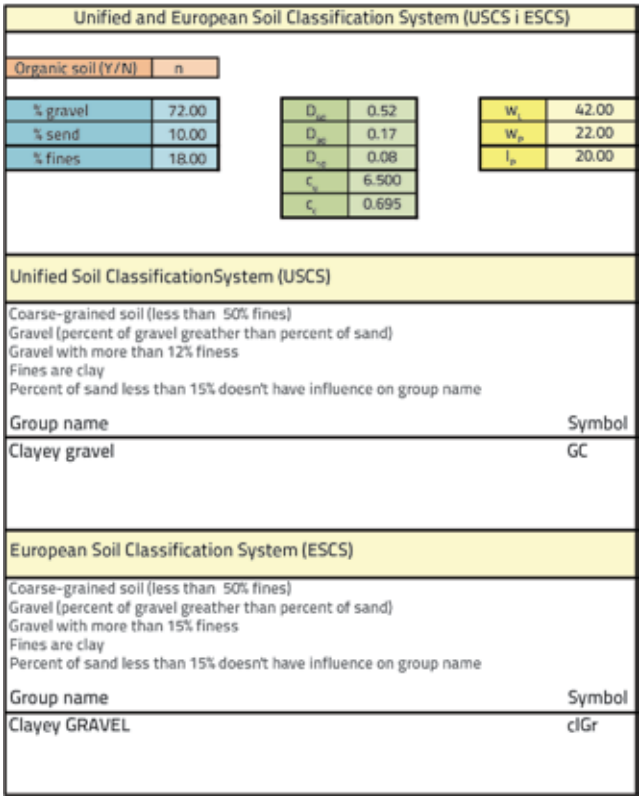

Figure 3. Classification of coarse-grained soil using CLASSIF Ver. 02 software

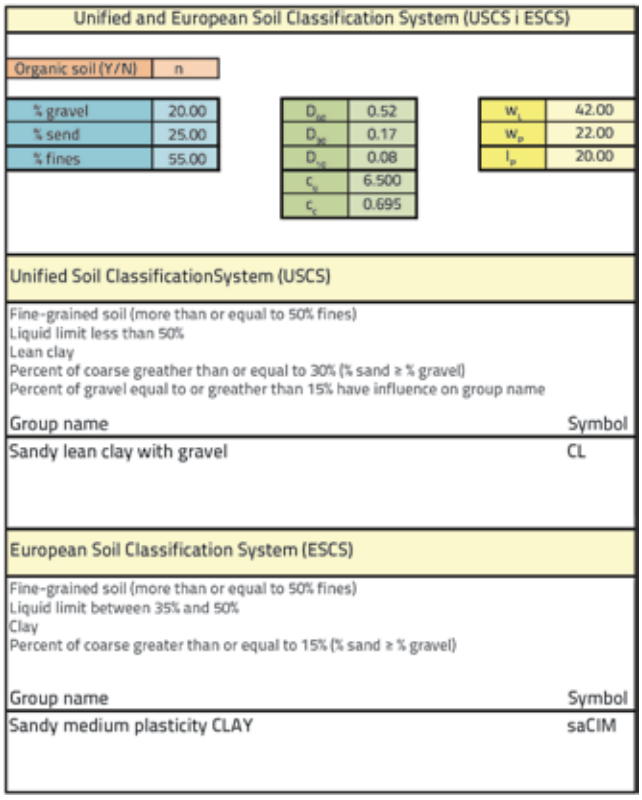

Figure 4. Classification of fine-grained soil using CLASSIF Ver. 02 software

Classification examples for coarse-grained soil (Figure 3) and fine-grained soil (Figure 4) are presented in the above figures. The percentages of gravel and sand in the sample are entered as input data for the coarse-grained soil. The result is not influenced by liquid limit and plasticity limit values. According to the USCS classification, the sample is classified as GC - clayey gravel, and according to the ESCS classification as clGr - clayey GRAVEL, i.e. the same group name is obtained according to both classifications, and the symbols are also quite similar. The following data are entered as input data for the fine-grained soil: gravel and sand percentages in the sample, liquid limit, and plasticity limit. According to the USCS classification, the sample is classified as CL - sandy lean clay with gravel. At that, the soil group symbol does not reveal whether the secondary and tertiary fractions are present. According to the ESCS classification, the soil is classified as saCIM - sandy medium plasticity CLAY. Unlike the USCS classification, the symbol shows the presence of secondary fraction (the ESCS classification does not recognise tertiary fraction of fine-grained soil), and the clay is classified as medium plastic, unlike USCS classification where the term lean clay is used. In this example of fine-grained soil, the soil group name and soil group symbol differ completely in the ESCS and USCS classifications.

7. Conclusion

The Technical Committee ISO/TC 182 "Geotechnics", in collaboration with the Technical Committee CEN/TC 341 "Geotechnical Investigation and Testing" prepared in March 2018 the following new standards: Geotechnical Investigation and testing - Identification and classification of soil - Part 1: Identification and description (EN ISO 14688-1:2018), and Geotechnical investigation and testing - Identification and classification of soil - Part 2: Principles for a classification (EN ISO 14688-2:2018). These new standards supersede former standards EN ISO 14688-1:2002 and EN ISO 14688-2:2004. European countries that are CEN members committed themselves to implement the new European standards no later than by August 2018.

The New European standards have brought some novelties in the identification and description of soil as related to the standard issued in 2002, as well as changes in soil classification principles as related to the standard from 2004. In order to take into account these changes, a new version of the European classification of soil for engineering purposes (ESCS) was developed and compared in detail with the best known and most widely spread Unified Soil Classification System (USCS). Similarities and differences in the way soil groups are marked by symbols, in soil group names, and in soil classification procedures, are also analysed in the paper.

The new version of the CLASSIF software was developed in Microsoft Excel using the integrated programming language Visual Basic for Applications (VBA). The program enables simultaneous use of both classifications based on the same input data, and it fully supports the soil identification, soil description, and soil classification principles as presented in new European standards.

REFERENCES

[1] ASTM D2487-11: Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System). ASTM International, West Conshohocken, PA, 2011.

[2] EN ISO 14688-1:2018: Geotechnical investigation and testing – Identification and classification of soil – Part 1: Identification and description. Comité Européen de Normalisation. Brussels, 2018.

[3] EN ISO 14688-2:2018: Geotechnical investigation and testing – Identification and classification of soil – Part 2: Principles for a classification. Comité Européen de Normalisation.Brussels, 2018.

[4] EN ISO 14688-1:2002: Geotechnical investigation and testing – Identification and classification of soil – Part 1: Identification and description. Comité Européen de Normalisation. Brussels, 2002.

[5] EN ISO 14688-2:2004: Geotechnical investigation and testing – Identification and classification of soil – Part 2: Principles for a classification. Comité Européen de Normalisation.Brussels, 2004.

[6] EN ISO 14688-1:2002/A1:2013: Geotechnical investigation and testing – Identification and classification of soil – Part 1: Identification and description – Amendment 1. Comité Européen de Normalisation.Brussels, 2013.

[7] EN ISO 14688-2:2004/A1:2013: Geotechnical investigation and testing – Identification and classification of soil – Part 2: Principles for a classification – Amednment 1. Comité Européen de Normalisation.Brussels, 2004.

[8] HRN EN ISO 14688-1:2018 en: Geotehničko istraživanje i ispitivanje – Identifikacija i klasifikacija tla – 1. dio: Identifikacija i opis. Zagreb, Hrvatski zavod za norme. 2018.

[9] HRN EN ISO 14688-2:2018 en: Geotehničko istraživanje i ispitivanje – Identifikacija i klasifikacija tla – 2. dio: Načela klasifikacije. Zagreb, Hrvatski zavod za norme. 2018.

[10] HRN EN ISO 14688-1:2008 en: Geotehničko istraživanje i ispitivanje – Identifikacija i klasifikacija tla – 1. dio: Identifikacija i opis. Zagreb, Hrvatski zavod za norme. 2008.

[11] HRN EN ISO 14688-2:2008 en: Geotehničko istraživanje i ispitivanje – Identifikacija i klasifikacija tla – 2. dio: Načela klasifikacije. Zagreb, Hrvatski zavod za norme. 2008.

[12] HRN EN ISO 14688-1:2008/A1:2013 en: Geotehničko istraživanje i ispitivanje – Identifikacija i klasifikacija tla – 1. dio: Identifikacija i opis – Amandman 1. Zagreb, Hrvatski zavod za norme. 2013.

[13] HRN EN ISO 14688-2:2008/A1;2013 en: Geotehničko istraživanje i ispitivanje – Identifikacija i klasifikacija tla – 2. dio: Načela klasifikacije – Amandman 2. Zagreb, Hrvatski zavod za norme. 2013.

[14] Kovačević, M.S., Jurić-Kaćunić, D.: Europska klasifikacija tla za inženjerske potrebe , GRAĐEVINAR, 66 (2014) 9, pp. 801-810

[15] Librić, L., Jurić-Kaćunić, D., Kovačević, M.S.: Primjena rezultata statičkog penetracijskog pokusa za klasifikaciju tla, GRAĐEVINAR, 69 (2017) 1, pp. 11-20, https://doi.org/10.14256/JCE.1574.2016

[16] Kovačević, M.S., Jurić-Kaćunić, D., Librić, L.: Prilagodba hrvatskog graditeljstva europskim smjernicama za opis i klasifikaciju tla, Izazovi u graditeljstvu 3, Lakušić, Stjepan (ur.). Zagreb: Hrvatski savez građevinskih inženjera, pp. 163-193, 2015.

[17] Reale, C., Gavin, K., Librić, L., Jurić-Kaćunić, D.: Automatic classification of fine-grained soils using CPT measurements and Artificial Neural Networks, Advanced Engineering Informatics, 36 (2018), pp. 207-215.