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Comparison of Unified and European Soil Classification Systems

M.S. Kovacevic, D. Juric-Kacunic, L. Libric
Faculty of Civil Engineering, University of Zagreb, Zagreb, Croatia

ABSTRACT: Soil classification for engineering purposes is a set of procedures which enables engineers all over the world to separate different soil types into groups of similar mechanical properties. It also enables them to compare results obtained in different laboratories, communicate with one another, and understand soil test results more easily. This paper presents a comparison of two soil classification systems using computer program Classif, developed by the authors. CLASSIF is a spreadsheet solution based on Microsoft Excel and VBA. It enables performing both the USCS and ESCS using the same input data. The examples presented in the paper show that the symbols are completely different, soil group names are relatively different, while the soil classification procedures are pretty similar.

1 INTRODUCTION

For engineers around the globe, soil description and classification for engineering purposes is a basis for ensuring mutual communication as well as studying and understanding soil test results. Soil description and classification enable rough identification of the type of material at hand and definition of the range within which its mechanical properties are expected to vary. What is more, types of soil with the same description and classified into the same category share similar mechanical characteristics and behave similarly under the influence of load.

Traditionally, soil belongs to one of the 4 major groups: gravel, sand, silt or clay. Initial efforts to classify soil were strictly related to the classification according to the size of grains, i.e. particle size distribution of soil (Child 1986). Such divisions were based on soil texture, i.e. relative proportions of sand, silt and clay in the total mass of soil tested. The best known texture-based classification is the classification by the US Department of Agriculture (USDA). Developed in 1938, this classification has been modified on several occasions since its initial appearance (Soil Survey Staff 1951). It is based on the use of a triangular classification chart proposed by Davis & Bennet 1927. This classification is nowadays used mostly in agriculture and hardly ever in geotechnical engineering.

Textural classifications were first researched in detail by Atterberg, at the beginning of the 20th century (Atterberg 1905, Atterberg 1912). In his work, he pointed to the fact that textural classifications of soil can successfully be used in agriculture, but that clay and silt parameters also have to be considered when this classification is used for geotechnical applications. In line with his conclusions, in 1929, the AASHTO (American Association of State Highway and Transportation Officials) classification was developed, which, apart from the particle size distribution, considered also the consistency limits of coherent soil particles (AASHTO, 1978). For the most part it is used for designing roads.

In 1942, Arthur Casagrande developed the Airfield Classification System (ACS) for the design of the US airfields during the Second World War, which considered particle size distribution and consistency limits of coherent soil particles, as did the AASHTO (Casagrande 1947, Casagrande 1948). A modification of the ACS in 1952 resulted in the creation of the Unified Soil Classification System (USCS), which is an integral part of the US standard (ASTM D 2487-11). Adjustment of the ACS to the mechanical properties of soil prevailing in the UK gave rise in 1981 to the British Soil Classification System (BSCS) (Dumbleton 1968, Dumbleton 1981), which makes an integral part of the British standard (BS 5930:1999). The DIN (*Deutsches Institut für Normun*) soil classification was developed in a similar way in 1988, and makes an integral part of German standards (DIN 18196:2011-05).

In order to improve the quality, safety, reliability, efficiency, compatibility, and communication among experts in the field of geotechnics, the ISO (International Standards Organisation) and CEN (Comité Européen de Normalisation) developed the standards

for the identification and description of soil and defined the principles of soil classification, with their soil marking methods differing greatly from the formerly used national classification systems. In 2002, the ISO/TC 182 "Geotechnics" Technical Committee, in cooperation with the CEN/TC 341 "Geotechnical Investigation and Testing" Technical Committee, prepared the soil description standard entitled: Geotechnical investigation and testing – Identification and classification of soil – Part 1: Identification and description (EN ISO 14688-1:2002). In 2004, the relevant committee prepared the standard on soil classification principles entitled: Geotechnical investigation and testing – Identification and classification of soil – Part 2: Principles for a classification (EN ISO 14688-2:2004).

European countries that have undertaken, as CEN members, to adopt and implement European standards through their national standardisation bodies are: Austria, Belgium, Bulgaria, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Greece, Croatia, Ireland, Iceland, Italy, Latvia, Lithuania, Luxembourg, Hungary, Macedonia, Malta, the Netherlands, Norway, Germany, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, and the UK.

The acceptance of European standards did not result in transition to the new way of describing, identifying, and classifying soil in most European countries. Objective reasons for this lie in the fact that European standards merely describe classification principles. There is room to develop a more comprehensive classification using the relevant principles on a national or project level. Kovacevic and Juric-Kacunic (2014) developed the European Soil Classification System (ESCS), which makes use of soil descriptions and symbols in line with the European standard EN ISO 14688-1 and is based on soil classification principles prescribed in EN ISO 14688-2.

2 CLASSIF PROGRAM - IT SUPPORT FOR USCS AND ESCS SOIL CLASSIFICATIONS

CLASSIF computer program was developed at the Department of Geotechnical Engineering, Faculty of Civil Engineering in Zagreb to facilitate the adaptation to the new manner of marking and classifying soils further to European guidelines. The program provides IT support for implementing the bothUSCS and ESCS classifications and facilitates their parallel use (Fig. 1).

CLASSIF was developed using the Microsoft Excel program and Visual Basic for Applications (VBA) integrated programming language, which enables programming of special functions, not included in Microsoft Excel by default. The program is available for free download from the link: http://www.grad.unizg.hr/download/repositorij/classif.

Figure 1. Initial user interface in CLASSIF

Input data for both classifications are the same, which enables simple comparison of the results.

The total number of input parameters that can be set or changed is 8. Not every change in every parameter will affect the final results. For example, changing the liquid limit will not affect the result of both soil classifications if the percentage of fine grains in the soil is below 5%.

The first parameter is textural one-letter information which answers the question whether the sample of the soil being tested contains organic matter. The second and third parameters are numeric data on the percentage of gravel and sand in the total mass of soil tested. The program automatically calculates the percentage of fine grains (silt + clay) so that the total sum equals 100%. The fourth, fifth and sixth parameters are numeric data on characteristic diameters of grains D_{60}, D_{30} and D_{10}, expressed in mm. The program automatically calculates the coefficient of uniformity (c_u) and the coefficient of curvature (c_c). The seventh and eighth parameters are numeric data on liquid limit w_L and plasticity w_P. The program automatically calculates the index of plasticity I_P.

CLASSIF continuously controls data input so as not to allow the input of unrealistic values of parameters (Fig. 2).

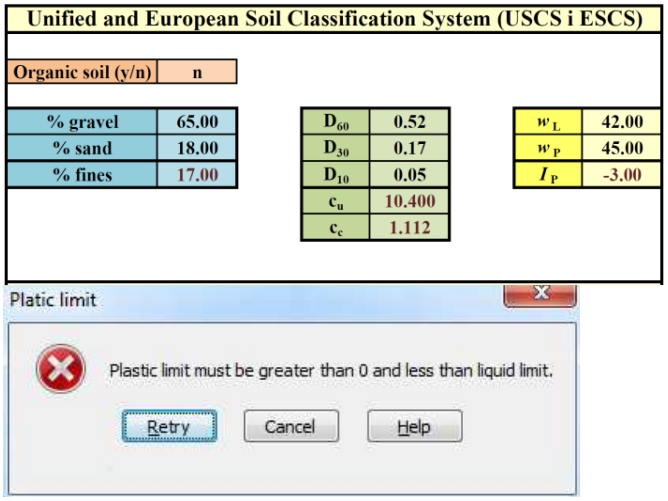

Figure 2. The value entered for plastic limit is not valid

3 SOIL GROUP SYMBOLS

According to both classifications, soils are divided into coarse-grained and fine-grained soils, whereas the latter may contain organic matter. Both classifications also identify highly organic soils (peat), for which no classification procedures are carried out. Soil grading and consistency limits are both used when classifying soils. According to the ESCS, a soil is classified as coarse-grained if more than 50% of the total quantity of a dry sample is retained on a 0.063 mm sieve, and according to the USCS, if more than 50% of the total quantity of a dry sample is retained on a 0.075 mm sieve.

The main idea behind soil classification is to mark the soils using symbols that represent the principal and secondary fractions which make up the soil. The principal fraction of the soil determines engineering properties of the soil. Secondary fractions do not determine, but rather influence, the engineering properties of the soil.

According to the ESCS, the principal fraction of the soil, that which determines its engineering properties, is marked with a symbol consisting of the first two letters of the name of the fraction, the first of which is written in capital letters:

Gr – gravel, Sa – sand,
Si – silt, Cl – clay.

According to the USCS, the principal fraction of the soil is marked with a symbol consisting of a single capital letter:

G – gravel, S – sand,
M – silt, C – clay.

According to the ESCS, the first secondary fraction, which has the most influence on the engineering properties of the soil, is that which, in a coarse-grained soil sample, contains more than 5% of fine grains. It is marked with a symbol consisting of the first two letters of the fraction name, which are written in lowercase in front of the principal fraction:

siGr – silty gravel, clGr – clayey gravel,
siSa – silty sand, clSa – clayey sand.

With fine-grained soils, the ESCS defines the first secondary fraction as the one which contains more than 15% of coarse grains. It is marked with a symbol which consists of the first two letters of the fraction name, written in lowercase in front of the principal fraction:

grSi – gravelly silt, saSi – sandy silt,
grCl – gravelly clay, saCl – sandy clay,

According to the USCS, the first secondary fraction, which has the most influence on the engineering properties of the soil, is that which, in a course-grained soil sample, contains between 5% and 12% of fine grains. It is marked using a two-part symbol comprising of 4 capital letters, the first two of which refer to the grading level of the soil, and the fraction is marked with the last capital letter:

GW-GM – well graded gravel with silt,
GW-GC – well graded gravel with clay,
GP-GM – poorly graded gravel with silt,
GP-GC – poorly graded gravel with clay,
SW-SM – well graded sand with silt,
SW-SC – well graded sand with clay,
SP-SM – poorly graded sand with silt,
SP-SC – poorly graded sand with clay.

According to the USCS, the first secondary fraction is the one that, in a course-grained soil sample, contains more than 12% of fine grains. It is marked using a symbol that consists of 2 or 4 capital letters, depending on whether the fine grains are silt, clay, silty clay:

GM – silty gravel, GC – clayey gravel,
SM – silty sand, SC – clayey sand,
GC-GM – silty, clayey gravel,
SC-SM – silty, clayey sand.

With fine-grained soils, the USCS defines the first secondary fraction as the one which contains more than 30% of coarse grains. In this classification the fraction is not marked, rather the word "sandy" or "gravelly" is added before the group name.

According to the ESCS, the second secondary fraction, which influences the engineering properties of the soil, is that which, in a coarse-grained soil sample, contains more than 15% of other coarse-grained fractions. It is marked with a symbol consisting of the first two letters of the fraction name, in lowercase, before the secondary fraction, or before the primary fraction if there is no first secondary fraction:

sasiGr – sandy, silty gravel,
saclGr – sandy, clayey gravel,
grsiSa – gravelly, silty sand,
grclSa – gravelly, clayey sand,
saGr – sandy gravel,
grSa – gravelly sand.

When it comes to fine-grained soils, according to the ESCS, the second secondary fraction does not exist.

According to the USCS, the second secondary fraction, is that which, in a coarse-grained soil sample, contains more than 15% of other coarse-grained fractions. In this classification the fraction is not marked, rather the words "with sand" or "with gravel" are added after the group name.

With fine-grained soils, the USCS defines the second secondary fraction as the one which contains between 15% and 30% of coarse grains. In this classification the fraction is not marked, rather the words "with sand" or "with gravel" are added after the group name.

Coarse-grained soils are additionally marked with respect to their grading level. According to the ESCS, symbols of coarse-grained soils with less than 15% of fine grains are supplemented with the following capital letters:

W – well graded sand or gravel,
M – medium-graded sand or gravel,

P – poorly graded sand or gravel.

According to the USCS, symbols of coarse-grained soils with less than 12% of fine grains are supplemented with the following capital letters:

W – well graded sand or gravel,

P – poorly graded sand or gravel.

Fine-grained soils are additionally marked with respect to their plasticity. According to the ESCS, symbols of fine-grained soils are supplemented with the following capital letters:

L – low plasticity,

I – intermediate plasticity,

H – high plasticity.

According to the USCS, symbols of fine-grained soils are supplemented with the following capital letters:

L – low plasticity,

H – high plasticity.

According to the ESCS, presence of organic matter in coarse-grained or fine-grained soil samples is marked by adding the small letters "or" in front of the symbol.

According to the USCS, presence of organic matter in a sample of coarse-grained soil is not marked by a symbol, but rather by adding the words "with organic fines" before the group name.

In line with the USCS, presence of organic matter in a sample of fine-grained soils is marked by substituting the symbol of the principal fraction (C or M) with a capital "O".

4 SOIL GROUP NAME

According to the ESCS, names of soil groups are consistent with the symbols of soil groups, so that every symbol represents a soil group. Examples of group symbols and names:

SaP – poorly graded sand,

SiI – intermediate plasticity silt,

grSaM – medium graded gravelly sand,

sasiGrW – well graded sandy, silty gravel,

grSiL – low plasticity gravelly silt,

orsaClH – high plasticity organic sandy clay.

According to the USCS, one soil group symbol can represent several soil group names. Examples of group symbols and names:

CL – lean clay,
- lean clay with sand,
- lean clay with gravel,
- sandy lean clay,
- sandy lean clay with gravel,
- gravelly lean clay,
- gravelly lean clay with sand.

SM – silty sand,
- silty sand with organic fines,
- silty sand with gravel,
- silty sand with gravel and organic fines.

5 CLASSIFICATION PROCEDURES

Procedures for the ESCS and USCS are fairly similar. They are carried out in five steps for coarse-grained and fine-grained soils.

Step one is determining, based on the results of a sieving experiment, whether the principal fraction of the soil is coarse-grained or fine-grained soil.

Step two is determining, for coarse-grained soils, based on percentage, whether the principal fraction is sand or gravel. According to the ESCS, with fine-grained soils the liquid limit w_L determines whether the principal fraction is soil of low, intermediate or high plasticity. According to the USCS, it determines whether the principal fraction is soil of low or high plasticity.

Step three is determining, for coarse-grained soils, based on percentage, whether there is a first secondary fraction of fine-grained soil. According to the ESCS, with fine-grained soils, the liquid limit w_L and the plasticity index I_P determine whether the principal fraction is clay or silt. According to the USCS, they determine whether the principal fraction is clay, silt or silty clay.

Step four is determining, for coarse-grained soils, the grading level of the principal fraction, except when there is a first secondary fraction of fine-grained soil whose fines percentage is higher than 15% (ESCS) or 12% (USCS). According to the ESCS, if there is a first secondary fraction of fine-grained soil, the liquid limit w_L and the plasticity index I_P are used to determine whether the principal fraction is clay or silt. According to the USCS, they determine whether the principal fraction is clay, silt or silty clay. With fine-grained soils, the percentages are used to determine whether there is a first secondary fraction of coarse-grained soil.

Step five is determining, for coarse-grained soils, based on percentage, whether there is a second secondary fraction of coarse-grained soil. With fine-grained soils, according to the ESCS, if there is a first secondary fraction, it determines which coarse-grained fraction is the dominant one. According to the USCS, with fine-grained soils, if there is a first secondary fraction of coarse-grained soil, it determines whether there is a second secondary fraction of coarse-grained soil.

Having carried out all five steps, a decision is made regarding the symbol and name of soil group.

6 EXAMPLES OF COMPARISON OF USCS AND ESCS USING CLASSIF

Both classifications use the same input data, which enables simple comparison of obtained results. Below are some examples illustrating the similarities and differences between the USCS and ESCS.

Unified and European Soil Classification System (USCS i ESCS)

Organic soil (y/n)	n

% gravel	72.00
% sand	10.00
% fines	18.00

D_{60}	0.52
D_{30}	0.17
D_{10}	0.08
c_u	6.500
c_c	0.695

w_L	42.00
w_P	22.00
I_P	20.00

Unified Soil Classification System (USCS)

Coarse-grained soil (less than 50% fines)
Gravel (percent of gravel is greater than percent of sand)
Gravel with more than 12% fines
fines are clay
Percent of sand less than 15% doesn't have influence on group name

Group Name	Symbol
Clayey gravel	GC

European Soil Classification System (ESCS)

Coarse-grained soil (less than 50% fines)
Gravel (percent of gravel is greater than percent of sand)
Gravel with more than 15% fines
fines are clay
Percent of sand less than 15% doesn't have influence on group name

Group Name	Symbol
Clayey gravel	clGr

References

ASTM D 2487-11: Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System) ASTM International, West Conshohocken, PA, 2011.

EN ISO 14688-2:2004: Geotechnical investigation and testing – Identification and classification of soil – Part 2: Principles for a classification. CEN, 2004.

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Figure 3. Soil Classification using CLASSIF - example 1

Unified and European Soil Classification System (USCS i ESCS)

Organic soil (y/n)	n

% gravel	8.00
% sand	88.00
% fines	4.00

D_{60}	0.52
D_{30}	0.17
D_{10}	0.08
c_u	6.500
c_c	0.695

w_L	42.00
w_P	32.00
I_P	10.00

Unified Soil Classification System (USCS)

Coarse-grained soil (less than 50% fines)
Sand (percent of gravel is less than or equal to percent of sand)
Sand with less than 5% fines
Poorly graded sand
Percent of gravel less than 15% doesn't have influence on group name

Group Name	Symbol
Poorly graded sand	SP

European Soil Classification System (ESCS)

Coarse-grained soil (less than 50% fines)
Sand (percent of gravel is greater thanpercent of sand)
Sand with less than 5% fines
Poorly graded sand
Percent of gravel less than 15% doesn't have influence on group name

Group Name	Symbol
Poorly graded sand	SaP

References

ASTM D 2487-11: Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System) ASTM International, West Conshohocken, PA, 2011.

EN ISO 14688-2:2004: Geotechnical investigation and testing – Identification and classification of soil – Part 2: Principles for a classification. CEN, 2004.

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Figure 4. Soil Classification using CLASSIF - example 2

Unified and European Soil Classification System (USCS i ESCS)

Organic soil (y/n)	n

% gravel	20.00
% sand	25.00
% fines	55.00

D_{60}	0.52
D_{30}	0.17
D_{10}	0.08
c_u	6.500
c_c	0.695

w_L	42.00
w_P	22.00
I_P	20.00

Unified Soil Classification System (USCS)

Fine-grained soil (more than or equal to 50% fines)
Liquid limit less than 50%
Lean clay
Percent of coarse greater than or equal to 30% (% sand >= % gravel)
Percent of gravel equal to or greater than 15% have influence on group name

Group Name	Symbol
Sandy lean clay with gravel	CL

European Soil Classification System (ESCS)

Fine-grained soil (more than or equal to 50% fines)
Liquid between 35% and 50%
Clay
Percent of coarse greater than or equal to 15%
% sand >= % gravel

Group Name	Symbol
Sandy intermediate plasticity clay	saCIl

References

ASTM D 2487-11: Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System) ASTM International, West Conshohocken, PA, 2011.

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Figure 5. Soil Classification using CLASSIF - example 3

Unified and European Soil Classification System (USCS i ESCS)

Organic soil (y/n)	y

% gravel	12.00
% sand	25.00
% fines	63.00

D_{60}	0.52
D_{30}	0.17
D_{10}	0.08
c_u	6.500
c_c	0.695

w_L	55.00
w_P	22.00
I_P	33.00

Unified Soil Classification System (USCS)

Fine-grained soil (more than or equal to 50% fines)
Liquid limit greater than or equal to 50%
Organic clay
Percent of coarse greater than or equal to 30% (% sand >= % gravel)
Percent of gravel less than 15% doesn't have influence on group name

Group Name	Symbol
Sandy organic clay	OH

European Soil Classification System (ESCS)

Fine-grained soil (more than or equal to 50% fines)
Liquid limit greater than or equal to 50%
Organic clay
Percent of coarse greater than or equal to 15%
% sand >= % gravel

Group Name	Symbol
Organic sandy high plasticity clay	orsaClH

References

ASTM D 2487-11: Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System) ASTM International, West Conshohocken, PA, 2011.

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Figure 6. Soil Classification using CLASSIF - example 4

7 CONCLUSIONS

The following systems can be used to classify soils: the Unified Soil Classification System (USCS), in line with US standard ASTM D 2487-11, and the European Soil Classification System (ESCS), which uses soil descriptions and symbols in line with European standard EN ISO 14688-1 and is based on the principles of soil classification in line with European standard EN ISO 14688-2. Procedures for soil classification are very similar; names of soil groups are relatively similar, whereas the symbols of soil groups are completely different. Simple and fast classification of soil in line with the USCS and ESCS can be done by using the CLASSIF program.

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