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Geotechnical investigation and testing — Identification and classification of soil —

Part 2: Principles for a classification

Reconnaissance et essais géotechniques — Dénomination, description et classification des sols —

Partie 2: Principes pour une classification

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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ISO 14688-2 was prepared by Technical Committee ISO/TC 182, *Geotechnics*, Subcommittee SC 1, *Geotechnical investigation and testing*.

ISO 14688 consists of the following parts, under the general title *Geotechnical investigation and testing — Identification and classification of soil*:

— *Part 1: Identification and description*

— *Part 2: Principles for a classification*

— *Part 3: Electronic exchange of data on identification and description of soil*

Geotechnical investigation and testing — Identification and classification of soil —

Part 2: Principles for a classification

1 Scope

This part of ISO 14688, together with ISO 14688-1, establishes the basic principles for the identification and classification of soils on the basis of those material and mass characteristics most commonly used for soils for engineering purposes. The relevant characteristics may vary and therefore, for particular projects or materials, more detailed subdivisions of the descriptive and classification terms may be appropriate.

Identification and description of soil are covered by ISO 14688-1.

The classification principles established in this part of ISO 14688 permit soils to be grouped into classes of similar composition and geotechnical properties and, with respect to their suitability for geotechnical engineering purposes, such as

— foundations,

— ground improvements,

— roads,

— embankments,

— dams, and

— drainage systems.

This part of ISO 14688 is applicable to natural soil and similar man-made material *in situ* and redeposited, but it is not a classification of soil by itself.

Identification and description of rock are covered by ISO 14689-1.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 3310-1, *Test sieves — Technical requirements and testing — Part 1: Test sieves of metal wire cloth*

ISO 3310-2, *Test sieves — Technical requirements and testing — Part 2: Test sieves of perforated metal plate*

ISO 14688-1, *Geotechnical investigation and testing — Identification and classification of soil — Part 1: Identification and description*

ISO 14689-1, *Geotechnical investigation and testing — Identification and classification of rock — Part 1: Identification and description*

3 Terms and definitions

For the purposes of this document, the terms and definitions of ISO 14688-1 and the following apply.

3.1
soil classification
assignment of soil into soil groups on the basis of certain characteristics, criteria and genesis

3.2
soil group
a particular collection of soils of similar composition and geotechnical properties

3.3
uniformity coefficient
C_U
measure of the shape of the grading curve within the range from d_{10} to d_{60}
$C_U = d_{60}/d_{10}$

NOTE d_{10} and d_{60} are the particle sizes corresponding to the ordinates 10 % and 60 % by mass of the percentage passing.

3.4
coefficient of curvature
C_C
measure of the shape of the grading curve within the range from d_{10}, d_{30} to d_{60}
$C_C = (d_{30})^2/(d_{10} \cdot d_{60})$

3.5
water content
w
mass of water which can be removed from the soil, usually by drying, expressed as a percentage of the dry mass

3.6
liquid limit
w_L
water content at which a fine soil passes from the liquid to the plastic condition, as determined by the liquid limit test

3.7
plastic limit
w_P
water content at which a fine soil becomes too dry to be in a plastic condition, as determined by the plastic limit test

3.8
plasticity index
I_P
numerical difference between the liquid limit and plastic limit of a fine soil
$I_P = w_L - w_P$

3.9
liquidity index
I_L
numerical difference between the natural water content and the plastic limit expressed as a percentage ratio of the plasticity index
$I_L = (w - w_P)/I_P$

3.10
consistency index
I_C
numerical difference between the liquid limit and the natural water content expressed as a percentage ratio of the plasticity index
$I_C = (w_L - w)/I_P$

3.11
density index
I_D
⟨coarse soils (sands and gravels)⟩ index dependent upon the void ratio (e) and the void ratios corresponding to the minimum density (e_{max}) and the maximum density (e_{min}), as measured in the laboratory
$I_D = (e_{max} - e)/(e_{max} - e_{min})$

3.12
undrained shear strength
c_u
shear resistance of soil in the undrained condition

3.13
void ratio
ratio of the volume of voids to the volume of solids of a soil

3.14
compressibility index
C_c
compressibility index is defined according to the relation

$$C_c = -\frac{\Delta e}{\lg\left[(\sigma' + \Delta\sigma')/\sigma'\right]} = -\frac{\Delta e}{\Delta(\lg\sigma')}$$

NOTE Δe is the change in void ratio (negative value when Δe decreases) and $\frac{\Delta e}{\Delta(\lg\sigma')}$ is the change in void ratio Δe for a relative increase of effective stress from $\lg\sigma'$ to $\lg(\sigma' + \Delta\sigma')$.

4 Principles of soil classifications

4.1 General

Soils shall be classified into soil groups on the basis of their nature which is the composition only, irrespective of their water content or compactness, taking into account the following characteristics:

— particle size distribution (grading);

— plasticity;

— organic content;

— genesis.

NOTE Some principles for soil classification are given in Annex A.

4.2 Fractions

Soil is a mixture of materials of different particle size, which are grouped into fractions as specified in ISO 14688-1.

Classification of coarse and very coarse soils is to be based on the particle size distribution alone (see 4.3 and Table 1).

Table 1 — Classification of very coarse soil

Fraction	Percent by mass	Term
Boulders	< 5	low boulder content
	5 to 20	medium boulder content
	> 20	high boulder content
Cobbles	< 10	low cobble content
	10 to 20	medium cobble content
	> 20	high cobble content

NOTE The classification of very coarse soils requires a very large sample. It is not possible to recover representative samples from boreholes to use this classification.

In the case of soils composed of both fine and coarse material, classification is to be based on both plasticity and particle size distribution (see 4.3 and 4.4).

4.3 Particle size distribution (grading)

The particle sizes and their distribution in a soil are determined by mechanical analysis carried out as follows:

— the separation of the coarser fractions by sieving on a series of standard sieves according to ISO 3310-1 and ISO 3310-2;

— the determination of the finer fractions by an accepted process (e.g. sedimentation, optical methods).

NOTE An example of how this can be done is given in Annex B.

The results of the sieving and sedimentation process are plotted as a grading curve.

When designating the coarse fractions, a distinction may be drawn between well graded, poorly graded and gap-graded particle size distributions. In this connection the coefficient of curvature (C_C) and the uniformity coefficient (C_U) provide quantitative means for describing the shape of the grading curve. If certain grain sizes are absent, the term gap-graded is used. The median d_{50} of the grading curve, together with C_U and C_C may also be used to indicate the particle size grading (see Table 2).

Table 2 — Shape of grading curve

Shape of grading curve	C_U	C_C
Multi-graded	> 15	$1 < C_C < 3$
Medium-graded	6 to 15	< 1
Even-graded	< 6	< 1
Gap-graded	Usually high	Any (usually $< 0{,}5$)

4.4 Plasticity

The fine fractions of soil, represented by clay and silt and containing clay minerals (see also ISO 14688-1), both alone or in mixtures with coarser material, are usually classified according to their plasticity characteristics. This is carried out on the basis of laboratory tests to determine the liquid limit w_L and plastic limit w_P.

The degree of plasticity of fine soils should be classified using the following terms:

a) non-plastic;

b) low plasticity;

c) intermediate plasticity;

d) high plasticity.

4.5 Organic content

When soils with organic constituents are classified according to their organic content (see Table 3), a distinction is to be made between organic soils and mineral soils with an organic content.

Table 3 — Classification of soils with organic constituents

Soil	Organic content ($\leqslant$ 2 mm) % of dry mass
Low-organic	2 to 6
Medium-organic	6 to 20
High-organic	$>$ 20

Classification of coarse and composite organic soils accumulated *in situ* is based on the type of organic matter and that of organic soils, on the genetic origin and the degree of decomposition of the organic constituents.

5 Other principles suitable for soil classification

5.1 General

There is a variety of quantifying terms which can be used to describe soils which include density, undrained shear strength and consistency index.

5.2 Correlations of density terms for sands and gravels

The terms used for the classification of density index I_D are very loose, loose, medium dense, dense and very dense (see Table 4). Density index can be related to the results of field tests (see, for example, EN 1997-2). Such field tests are, for example, Dynamic Probing (DP) according to ISO 22476-2, Standard Penetration Test (SPT) according to ISO 22476-3, cone penetration tests (CPT) according to ISO 22476-1 and pressuremeter tests (PMT) according to ISO 22476-4, ISO 22476-6 and ISO 22476-8. These documents are being prepared.

Table 4 — Correlations to classify density terms

Term	Density index I_D %
Very loose	0 to 15
Loose	15 to 35
Medium dense	35 to 65
Dense	65 to 85
Very dense	85 to 100

5.3 Undrained shear strength of fine soils

The terms to be used for the designation of the undrained shear strength according to the results of laboratory and field tests are given in Table 5.

Table 5 — Undrained shear strength of fine soils

Undrained shear strength of clays	Undrained shear strength c_u kPa
Extremely low	< 10
Very low	10 to 20
Low	20 to 40
Medium	40 to 75
High	75 to 150
Very high	150 to 300
Extremely high[a]	> 300
[a] Materials with shear strength greater than 300 kPa may behave as weak rocks and should be described as rocks according to ISO 14689-1.	

NOTE When making an immediate (field) examination, the strength is estimated by manual tests or measured by a simple field test, e.g. pocket penetrometer or small vane apparatus.

Fine soils may also be classified according to their sensitivity, the ratio between the undisturbed and remoulded undrained shear strengths. The sensitivity is low (< 8), medium ($8 - 30$) or high (> 30); soils with sensitivities > 50 are described as quick clays.

5.4 Consistency index

Terms to be used for the designation of the consistency index (I_C) of silts and clays where appropriate, are given in Table 6.

Table 6 — Consistency index I_C of silts and clays

Consistency of silts and clays	Consistency index I_C
Very soft	$<$ 0,25
Soft	0,25 to 0,50
Firm	0,50 to 0,75
Stiff	0,75 to 1,00
Very stiff	$>$ 1,00

These subdivisions may be approximate, particularly in materials of low plasticity. Also, the strength of a clay may not be constant at a given consistency index. The liquidity index may be used as an alternative.

5.5 Other suitable parameters

Some other parameters may be used for soil classification for specific purposes such as:

— dry density;

— clay activity;

— mineralogical nature,

— saturation index;

— permeability;

— compressibility index C_C;

— swelling index;

— carbonate index.

Annex A
(informative)

Principles of soil classifications

The most common approach to classification is to divide the soils on the basis of particle size grading and plasticity. The division is made on the relative size fractions present for the coarser soil fractions, determined on the whole sample, and on the plasticity of the finer fractions (e.g. Table A.1).

The principles for establishing classifications to suit particular geological conditions or engineering problems are given in this standard.

Extensions or amplification of these principles at national or project level are possible and an example is given in Table A.1.

Particular classifications would normally be expected to quantify the boundaries or rules for categorization.

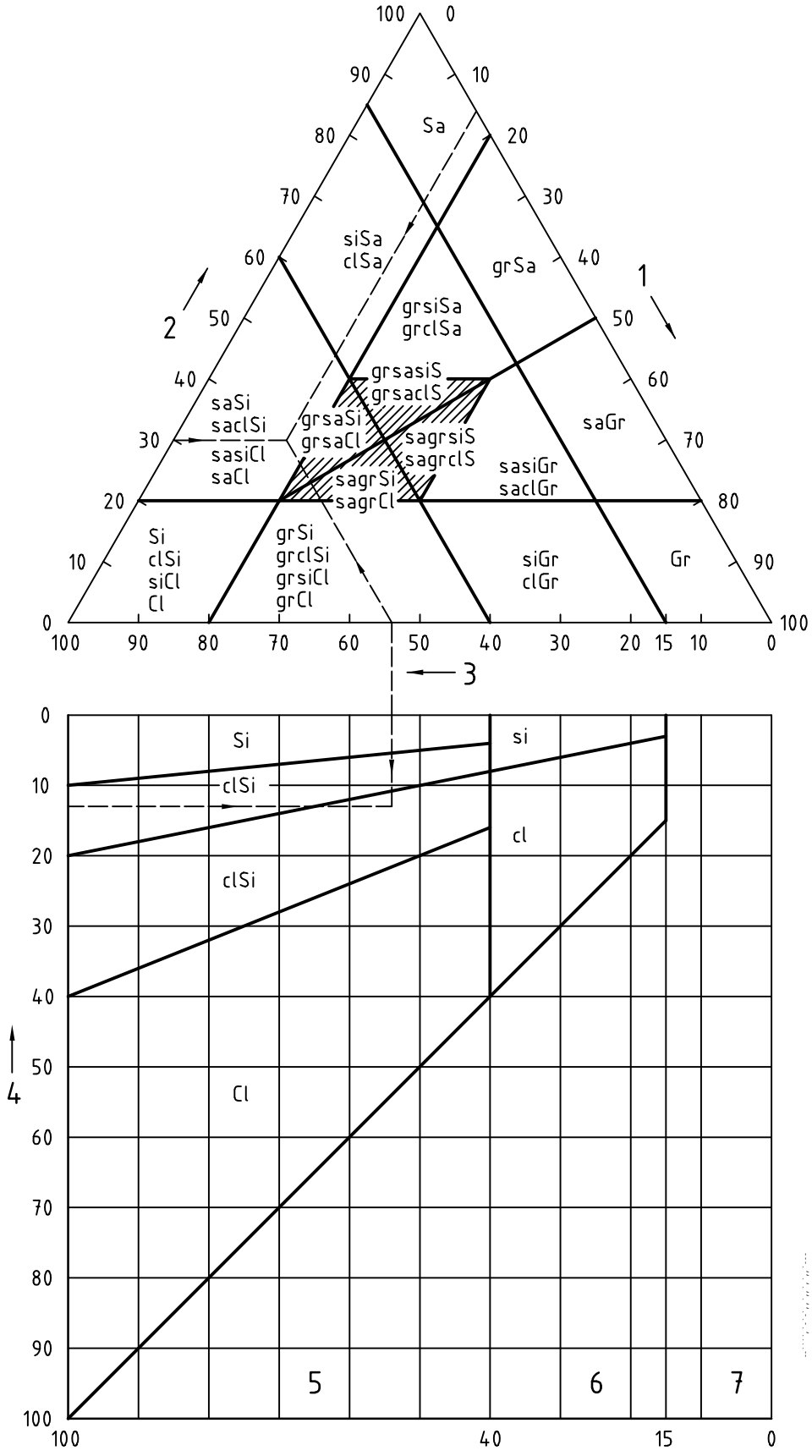
Table A.1 — Principles of a classification of soils

Criterion	Soil group	Quantification	Denomination into groups of similiar properties			Further subdivision as appropriate by
Wet soil does not stick together	very coarse	most particles > 200 mm	Bo	xBo		Requires special consideration
				boCo	coBo	
		most particles > 63 mm	Co	saCo, grCo	sagrCo	
	coarse	most particles > 2 mm	Gr		cosaGr	Particle size (grading) Shape of grading curve Relative density Permeability
				coGr		
				saGr, grSa	sasiGr, grsiSa	
		most particles > 0,063 mm	Sa	siGr, clGr orSa	siSa, clSa, saclGr	(Mineralogy) (Particle shape)
Wet soils sticks together	fine	low plasticity dilatant	Si	saSi	sagrSi saclSi	Plasticity Water content Strength, sensitivity Compressibility, stiffness (Clay mineralogy)
				clSi, siCl		
		plastic non-dilatant	Cl		sagrCl	
				orSi, orCl		
Dark colour, low density	organic		Or	saOr, siOr	clOr	Requires special consideration
Not naturally	Made ground	deposited	Mg	xMg	Man-made material	Requires special consideration
					Relaid natural materials	As for natural soils
Key to symbols *Soil* Boulders Cobbles Gravel Sand Silt Clay Organic Made ground	*Principal* Bo Co Gr Sa Si Cl Or Mg	*Secondary or tertiary component* bo co gr Gr(gr) and Sa(sa) can be subdivided into fine F(f), medium M(m) sa or coarse C(c) si cl or – x any combination of components				Cases requiring special consideration should be classified according to national or project requirements

Annex B
(informative)

Example of a classification of soils, based on grading alone

Figure B.1 and Table B.1 give an example of a possible soil classification, based on grading alone.



Key

1 gravel content (2 mm to 63 mm)

2 sand content (0,063 mm to 2 mm)

3 fines content (< 0,063 mm)

4 clay content in % of mass of coarse and fine soil (grain size < 63 mm)

5 fine soils (silt and clay)

6 mixed-grained soils (silty or clayey gravel and sand)

7 coarse soils (gravel and sand)

S soil

See also Table A.1.

Figure B.1 — Classification of soils, based on grading alone

Table B.1 — Guiding values for the division of mineral soils on a basis of the contents of various fractions

Fraction	Content of fraction in wt % of material ⩽ 63 mm	Content of fraction in wt % of material ⩽ 0,063 mm	Name of soil	
			Modifying term	Main term
Gravel	20 to 40		gravelly	
	> 40			gravel
Sand	20 to 40		sandy	
	> 40			sand
Silt + clay (fine soil)	5 to 15	< 20	slightly silty	
		⩾ 20	slightly clayey	
	15 to 40	< 20	silty	
		⩾ 20	clayey	
	> 40	< 10		silt
		10 to 20	clayey	silt
		20 to 40	silty	clay
		> 40		clay

Bibliography

[1] ISO 22476-1, *Geotechnical investigation and testing — Field testing — Part 1: Electrical cone and piezocone penetration tests*

[2] ISO 22476-2, *Geotechnical investigation and testing — Field testing — Part 2: Dynamic probing*

[3] ISO 22476-3, *Geotechnical investigation and testing — Field testing — Part 3: Standard penetration test*

[4] ISO 22476-4, *Geotechnical investigation and testing — Field testing — Part 4: Menard pressuremeter test*

[5] ISO 22476-6, *Geotechnical investigation and testing — Field testing — Part 6: Self-boring pressuremeter test*

[6] ISO 22476-8, *Geotechnical investigation and testing — Field testing — Part 8: Full displacement pressuremeter test*

[7] EN 1997-2, *Eurocode 7: Geotechnical design — Part 2: Design assisted by laboratory testing*

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