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ROCK AND SOIL DESCRIPTION AND CLASSIFICATION FOR ENGINEERING GEOLOGICAL MAPPING REPORT BY THE IAEG COMMISSION ON ENGINEERING GEOLOGICAL MAPPING

DESCRIPTION ET CLASSIFICATION DES ROCHES ET DES SOLS POUR LA CARTOGRAPHIE GEOTECHNIQUE RAPPORT DE LA COMMISSION DE L'AIGI SUR LA CARTOGRAPHIE GEOTECHNIQUE

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Preface

In 1976 UNESCO published a guide to the preparation of engineering geological maps prepared by the Commision on Engineering Geological Maps of the International Association of Engineering Geology. That guidebook gave a brief outline of the principles of classification of rocks and soils for engineering geological mapping. The present report presents a more detailed treatment of this topic, and deals with the description and classification of rock and soil materials and rock and soil masses for mapping purposes.

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1. Introduction

1.1 Principles of Classification and Description of Rocks and Soils on Engineering Geological Maps

Classification of rocks and soils on engineering geological maps should be based on the principle that the physical or engineering geological properties of a rock in its present state are dependent on the combined effects of mode of origin, subsequent diagenetic, metamorphic and tectonic history, and on weathering processes. This principle of classification makes it possible not only to determine the reasons for the lithological and physical characteristic of soils and rocks, but also for their spatial distribution. This is a basic principle of engineering geological mapping as of other geological mapping and implies not only the classification of individual rock samples but also the use of many individual rock samples, field observations and measurements to delineate uniform and continuous rock units (UNESCO-IAEG, 1976).

The following classification, based on lithology and mode of origin, is suggested: (a) engineering geological type (ET): (b) lithological type (LT): (c) lithological complex (LC): (d) lithological suite (LS). There will be different degrees of homogeneity for each unit.

The engineering geological type has the highest degree of physical homogeneity. It should be uniform in lithological character and physical state. These units can be characterized by statistically determined values derived from individual determinations of physical and mechanical properties and are generally shown only on large-scale maps.

A lithological type is homogeneous throughout in composition, texture and structure, but usually is not uniform in physical state. Reliable values of average mechanical properties cannot be given for the entire unit; usually only a general idea of engineering properties, with a range of values, can be presented. These units are used on large-scale, and where possible, on medium-scale maps.

A lithological complex comprises a set of genetically related lithological types developed under specific palaeogeographical and geotectonic conditions. Within a lithological complex the spatial arrangement of lithological types is uniform and distinctive for that complex, but a lithological complex is not necessarily uniform in either lithological character or physical state. In consequence, it is not possible to define the physical and mechanical properties of the whole lithological complex, but only to give data on the individual lithological types comprising the complex and to indicate the general behaviour of the whole lithological complex. The lithological complex is used as a mapping unit on medium-scale and some small-scale maps.

The lithological suite comprises many lithological complexes that developed under generally similar palaeogeographical and tectonic conditions. It has certain common lithological characteristics throughout which impart a general unity to the suite and serve to distinguish it from other suites. Only very general engineering geological properties of a lithological suite can be defined. These units are only used on small-scale maps.

A full description of a soil or rock for engineering purposes involves the assignation of the appropriate geological name together with as much detailed information as can be gained from the examination of a sample or exposure. The description may be systematic if a limited range of standard descriptive terms is used and for ease of application each descriptor may be classified. On the other hand, a classification should place the soil or rock in a limited number of groups each with definable properties, which can give a good guide to engineering performance.

At present not enough is known of the relations between engineering properties and lithological characteristics to establish a unified classification system for both soil and rock units on engineering geological maps. In such a classification each class would represent a soil or rock unit with a narrow range of engineering properties. Consequently, a three-part approach to engineering geological description and classification has been adopted, involving:

(i) a taxonomic classification of rock and soil units delineated on engineering geological maps at various scales, namely engineering geological types, lithological types, lithological complexes, lithological suites (UNESCO/IAEG 1976).

(ii) a lithological classification, and the assignment of fundamental lithological names to rock and soil units.

(iii) a description of rock and soil material and mass and the assignment of descriptive names for rock and soil types.

There is an obvious need to make the classifications and descriptions simple so that they can be readily understood and applied, even by those with limited geological knowledge. It should be emphasized that although the classifications proposed for rock and soil are very different, the suggested methods for the description of rock and soil are the same, both as materials and in the mass.

1.2 Bases for the Classification of Rocks and Soils for Engineering Purposes

In geological terms a **rock** is a naturally occurring aggregate of minerals, and so includes loose aggregates, which would be called soils by an engineer, and the harder, solid materials which would be stone in layman's terms or rock to the engineer. The geological name often reflects the physical state of the aggregate, for example **sand**, and the equivalent lithified state is indicated by adding 'stone' to the name of the loose aggregate, that is for example **sandstone.** This distinction only applies to rocks of one genetic group, namely the sedimentary rocks. Both igneous and metamorphic rocks can only exist in the solid state, except some pyroclastics, or rocks which have been transformed by weathering agencies. If weathering has progressed for enough, then rocks from both of these groups may be converted entirely to soils and, for example, a highly weathered granite will be a residual soil and hence will have engineering properties similar to those of the appropriate engineering soil. In the same way a sandstone can revert to a sand.

Although it is logical to classify rocks in geological terms regardless of physical state, it has to be accepted that there is a clear difference in the engineering properties, and hence engineering behaviour, of those rocks which the engineer would call engineering soils, and other natural materials. This distinction has both a practical and an historic basis: a quantitative approach to the behaviour of soils as foundation materials and in excavantions, and when used as construction materials, lead to the development of the science of Soil Mechanics in which theory and experimental data were applied to practical engineering design (Terzaghi, 1925).

A similar quantitative approach to the design of engineering structures in rock: the science of rock mechanics, has developed rapidly only in the last two decades.

Although, as has been explained above, both soil and rock are covered by the single geological term 'rock', there is a clear distinction to be made between the engineering behaviour of the two. Division may be made, for example, on the basis of hardness or strength (Piteau, 1970), porosity and density (Duncan, 1969), permeability and compressibility: all important engineering properties. But there is the problem, in attempting too precise a definition, of the gradation in properties that is known to exist between soil and rock, making a more qualitative definition preferable.

An early Working Party (Anon. 1972b), concerned with the description of soils and rocks for engineering geological mapping has used as a guide to the distinction between soil and rock the following quotation: "Soil is an aggregate of mineral grains that can be separated by such gentle means as agitation in water. Rock, on the other hand, is a natural aggregate of minerals connected by strong and permanent cohesive forces. Since the terms 'strong' and 'permanent' are subject to different interpretations, the boundary between soil and rock is necessarily an arbitrary one" (Terzaghi and Peck, 1967, p. 4) leading to the recognition of soft rocks or hard soils at the transition from rock to engineering soil. In this report the terms soil and rock are used in the senses defined here.

Rocks, using the term in the geological sense, may be divided into three major groups: igneous, sedimentary and metamorphic, depending upon the processes active in their formation. Engineering soils, of various genetic types, for example alluvial, aeolian and glacial, occupy an important position in the sedimentary group. To these three groups must be added a fourth: residual soils formed by the weathering of rocks, and a fifth: made ground or fill not involving natural materials.

A number of criteria are used in classification, including chemical and related mineralogical composition, grain size, texture and fabric, which also provide a firm basis for the identification of rocks for engineering purposes. The most important criterion is grain size because of the ease with which it can be quantified in engineering soils, or estimated for rocks. In rocks the predominant grain size, or range of grain sizes, is used as a means of subdivision of each genetic group. Contrast this with engineering soils where as little as 35 per cent of fine constituents, the clay and silt sizes, determines the engineering classification and much less may have an important influence on engineering properties. It is this aspect, more than any other, coupled with the ability to determine grading readily, that necessitates and justifies the separate methods for the description and classification of soils and rocks as adopted here.

2. A Lithological Classification of Rocks

The classification of rocks (Table 1) is based on the determination of:

(i) Genetic group:
  Sedimentary: detrital, chemical/organic
  Metamorphic
  Igneous

(ii) Structure
  Bedded
  Foliated
  Massive

(iii) Predominant grain size
  Very coarse-grained: Greater than 60 mm
  Coarse-grained : 2 to 60 mm
  Medium-grained : 0.06 to 2 mm
  Fine-grained : 0.002 to 0.06 mm
  Very fine-grained : Less than 0.002 mm
  Glassy/Amorphous

(iv) Composition (mineralogical)
  Rock grains
  Quartz
  Feldspars and feldspathoids
  Mafic (dark coloured) and related minerals
  Clay minerals
  Carbonates
  Salts: siliceous and carbonaceous materials
  Glass

PYROCLASTIC	IGNEOUS				GENETIC GROUP	PREDOMINANT GRAIN SIZE (mm)
MASSIVE					Usual Structure	
At least 50% of grains are of igneous rock	Quartz, feldspars, micas, dark minerals		Feldspar; dark minerals	Dark minerals	Composition	
	Acid	Intermediate	Basic	Ultrabasic		
Rounded grains AGGLOMERATE	PEGMATITE			Pyroxenite Peridotite	Very coarse-grained	60
Angular grains VOLCANIC BRECCIA	GRANITE	DIORITE	GABBRO		Coarse-grained	2
TUFF			DOLERITE		Medium-grained	0.06
Fine-grained TUFF	RHYOLITE	ANDESITE	BASALT		Fine-grained	0.002
Very fine-grained TUFF					Very fine-grained	
	VOLCANIC GLASSES				GLASSY AMORPHOUS	

Table 1: Classification of rock types: igneous

DETRITAL SEDIMENTARY						CHEMICAL/ ORGANIC	GENETIC GROUP	PREDOMINANT GRAIN SIZE (mm)
BEDDED							Usual Structure	
Grains of rock, quartz, feldspar and clay minerals				At least 50% of grains are of carbonate		Salts, carbonates, silica, carbonaceous	Composition	
RUDACEOUS	Grains are of rock fragments Rounded grains: CONGLOMERATE Angular grains: BRECCIA			LIMESTONE (undifferentiated)	Calci-rudite	SALINE ROCKS Halite Anhydrite Gypsum	Very coarse-grained	60
							Coarse-grained	2
ARENACEOUS	Grains are mainly mineral fragments SANDSTONE Grains are mainly mineral fragments				Calc-arenite	CALCAREOUS ROCKS LIMESTONE DOLOMITE	Medium-grained	0.06
ARGILLACEOUS or LUTACEOUS	MUDSTONE SHALE: fissile mudstone	SILTSTONE 50% fine-grained particles	Marlstone		Calci-siltite		Fine-grained	0.002
		Claystone 50% very fine grained particles			CHALK Calci-lutite		Very fine-grained	
						SILICEOUS ROCKS Chert Flint CARBONACEOUS ROCKS LIGNITE COAL	GLASSY AMORPHOUS	

Table 1: Classification of rock types: sedimentary

Rock names are given to particular combinations of these features and correct naming requires recognition of the four attributes listed above; accuracy and facility in this sphere can only come with training.

A simple, technically useful classification of fundamental rock types in each genetic group is given in Table 1. It is unified only with respect to grain size. The selected grain size categories are not those used in geology but are those used in the engineering classification of soils. This radical departure from conventional usages was felt to be justified as a means of simplicifation of rock classification and to give consistency between rock and soil classifications. The limits of the size ranges in the finer soils define marked changes in the engineering properties of those soils (Glossop and Skempton, 1945) and are therefore well established in engineering usage. Any step towards unification should take account of this, and consequently the conventional size classes used in geological classifications were slightly adjusted to conform to the soil classification.

Rock names were mainly selected from those used in non-specialist geological text books, and in many cases are not used strictly but as a general term for a broad group of related rock types.

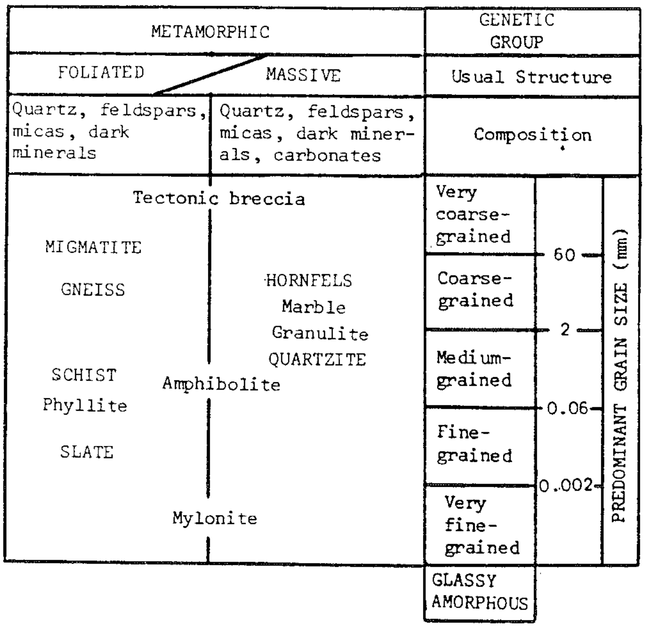

Table 1: Classification of rock types: metamorphic

3. Description of Rocks für Engineering Purposes

Description of rock involves the following steps:

(i) Determination of the fundamental rock name: the 'lithological rock name';

(ii) Description of the properties of the rock material;

(iii) Description of additional properties necessary to describe the features of the rock mass.

The properties of the rock mass are controlled partly by the properties of the rock material, but in many rock masses structural features substantially control the engineering properties. Such features include structures and discontinuities such as joints and bedding plane partings, and the distribution of rock and soil materials in the weathering profile.

The three steps listed above provide a 'descriptive rock name' from which engineering properties may more readily be inferred than from a 'lithological rock name'.

3.1 The Descriptive Rock Name

In a rock description the main characteristics should be given in the following order:

- Rock name
  - Supplementary petrographic properties
- Rock material properties
  - Colour
  - Texture
    - Grain size
    - Other textural features and fabric
  - State of weathering
    - State of alteration
  - Strength
- Rock Mass Properties
  - Structure
  - Discontinuities
  - Weathering profile

The descriptive scheme has been modified from that recommended in Anon. (1972b) The main differences are in the treatment of state of weathering and the weathering profile, and an expansion in the description of structure. Structural aspects have been dealt with more thoroughly by Anon. (1977) and also in I.S.R.M. (1977).

3.1.1 The Lithological Name: The lithological rock name is of primary importance because it indicates the genetic rock group and provides basic information on mineral composition and grain size. Supplementary petrographic properties may be used where necessary to qualify the rock name, signifying for example a relative abundance of a particular mineral — biotite granite — or indicating minor admixtures of other lithological types. These supplementary features may be extremely useful as a means of discriminating between different rocks that have the same lithological name. Minor constituents may also have an important effect on the mechanical and physical properties of rocks, and should be carefully considered.

The rock name is selected from the classification tables (Table 1) and these are the only rock names that are recommended for use. In arriving at a name for a rock, there is no substitute either for geological knowledge or for an aid to identification that is reliable and easy to apply.

LIGHTNESS	CHROMA	HUE
Light	pinkish	pink
Dark	reddish	red
	yellowish	yellow
	brownish	brown
	greenish	green
	bluish	blue
		white
	greyish	grey
		black

Table 2: Terms for lightness, chroma and hue which may be used in combination for colour description

3.2 Description of Rock Material

3.2.1 Colour: Rock colour can be quantitatively evaluated using, for example, the Rock Color Chart published by the Geological Society of America (Anon. 1963). As an alternative it is recommended that the following simple system (Anon. 1972b), which serves to limit the subjectivity of an estimation, should be used. One term is selected, as required, from each column (Table 2), and combined as a colour assessment.

Examples of use are: light yellowish brown, dark reddish brown, dark brown, etc. If necessary colour differences can be emphasized separately by the use of terms such as spotted, dappled, mottled, streaked, for example light yellowish brown spotted with dark brown.

3.2.2 Texture: Of the textural elements used for description and classification, the most important is grain size which, for the predominant size of grain, can be classified semiquantitatively. From Table 1 the relations between rock names and grain sizes can be understood. It will be recalled that the class boundaries have been fixed at limits of grain size grades adopted for engineering soils, that is the boundaries between clay, silt and sand sizes that are justified and determined by the differences in the physical behaviour of those soils (Glossop and Skempton, 1945).

Because grain size considerably affects the physical properties of a rock it should always be indicated directly in the rock description rather than relying on the grain size implication in the rock name.

It is usually sufficient to estimate grain size by eye, which may be aided by a hand lens in the case of fine-grained and amorphous rocks. The limit of unaided vision is approximately 0.06 mm.

Many other aspects of rock texture may be used to amplify the description, such as:

3.2.2.1 *Relative grain size:* for example uniform, non-uniform, porphyritic

3.2.2.2 *Grain shape:* may be described by reference to the general form of the particles, their angularity which indicates the degree of rounding at edges and corners, and their surface characteristics (Table 3).

FORM	equidimensional
	flat
	elongated
	flat and elongated
	irregular
ANGULARITY	angular
	subangular
	subrounded
	rounded
SURFACE CHARACTERISTICS	rough
	smooth

Table 3: Terms used in the description of grain shape

3.2.2.3 *Fabric:* the spatial arrangement of grains in the rock may show a preferred orientation or lack of it, and may produce patterns by non-uniform arrangements of grains, crystals and groundmass.

3.2.2.4 *Porosity:* the size, shape, orientation of pore or void spaces should be described.

3.2.3 State of Weathering: Description of the state of weathering of rock material is of particular importance in describing engineering rocks because weathering has profound effects on the physical and mechanical properties of rock material. In any description there needs to be a statement whether or not the rock material is considered to be either in a fresh state or is weathered. Weathering effects may be described in terms of discoloration, chemical decomposition or physical disintegration.

The extent of particular weathering effects may be sub-divided using such qualifying terms, for example 'highly decomposed', 'extremely discoloured', 'slightly disintegrated', as will aid the description of the material being examined. These descriptive qualifying terms may be quantified if necessary by estimation from drill core or in the natural exposure (Table 4).

TERM	DEGREE OF CHANGE (per cent)
Fresh	0
Slightly	Over 0 - 10
Moderately	10 - 35
Highly	35 - 75
Extremely	Over 75

Table 4: Terms for the description of the degree of weathering of rock material

Depending on the character and distribution of the weathering changes, and the extent to which a rigid rock framework is retained, the weathered rock material may assume the characteristics of an engineering soil at an early stage.

Extremely weathered rock material will almost certainly be an engineering soil, and may be classed as a residual soil if the original rock fabric has collapsed or changed so as to remove most traces of the original fabric.

Examples of use are: fresh rock; slightly decomposed; moderately disintegrated; highly discoloured. Usually combinations occur: highly disintegrated and moderately decomposed, etc.

3.2.4 State of Alteration: The terms used for weathering of rock material may be used where appropriate as in many instances the effects of alteration may not be easily distinguishable from those brought about by weathering. Wherever possible common terms should be used, e. g. slightly kaolinised, highly mineralised; the terms may be quantified using the scale in Table 4.

3.2.5 Strength: The uniaxial compression test gives a reliable indication of the strength of rock material, although the test results are dependent on the moisture content of the specimen, any anisotropy in the material, and the test procedure adopted. A scale of strength is given in Table 5.

As an alternative method of strength testing for use in the field, the point load test (Broch and Franklin, 1972; ISRM, 1977) is recommended. Provided that individual test results are normalised to a standard specimen thickness of 50 mm, and the recommended test procedures

TERM	COMPRESSIVE STRENGTH (MPa)
Weak	1.5*- 15
Moderately strong	15 - 50$^+$
Strong	50 - 120
Very strong	120 - 230
Extremely strong	Over 230

*Rocks with a strength under 1.25 MPa are, as a rule, hard soils and should be tested accordingly

$^+$Soft rocks are weaker than 50 MPa; strong rocks are stronger than 50 MPa

Table 5: A scale of strength for dry rock material

are followed, this test provides a good estimate of unconfined compressive strength. The relation:

$$UCS = 25\ PLS$$

where UCS is the unconfined compressive strength and PLS is the point load strength, has been demonstrated repeatedly and can be accepted as a reasonably reliable approximation.

The piston-press test, devised by Srejner, Petrova and Jakusev (1958) and described by Matula (1969), is a quick method of determining the strength and deformation properties of rock materials. Test values show a very close correlation with the results of the standard unconfined compressive strength performed on cubes of rock.

3.3 Description of the Rock Mass

3.3.1 Structure: The structure of the rock mass is related to the larger scale interrelations of textural features and the association of one or more rock types in the mass. Terms used to describe sedimentary rocks include bedded, interbedded, laminated, folded, etc; metamorphic rocks may be cleaved, foliated, schistose, banded, gneissose, lineated, folded; igneous rocks may be massive, flow banded, etc.

The problem of the association of more than one rock type in a rock mass is difficult to deal with because, for example, in a sequence of sedimentary rocks one lithological type may be more susceptible to weathering than another, and the presence of a highly weatherable rock in a sedimentary sequence may have an enhancing effect on the susceptibility of other rock types to weathering. In addition, the properties of an interbedded rock mass may depend more on one rock type than on the other.

3.3.2 Discontinuities: A discontinuity is a surface within the rock mass that is open or potentially openable under the stress levels applicable in engineering because the tensile strength across the surface is lower than that of the rock material. Thus a discontinuity is not necessarily a plane of physical separation within the rock mass.

Discontinuities have many modes of origin, but two main types may be recognised: those that occur in sets, for example bedding planes, joints, cleavages, foliations, and those that are unique, for example individual joints or faults. Of these, bedding planes, cleavages and foliations are discontinuities only when there is a parting or substantial weakening of the rock across them. Similarly joints and fault planes may be healed by introduced minerals or by alteration along them.

Description of discontinuities is aimed at determining their nature, orientation, spacing persistence, rouhgness, wall strength, aperture, filling, seepage, number of sets, and block size (I.S.R.M., 1977)

3.3.2.1 Orientation: a compass and clinometer is used to measure the dip, the maximum inclination from the horizontal, and the strike direction, the horizontal direction, of the planar feature being measured with reference to magnetic or true north. Alternatively, the dip and aip direction of the plane may be determined.

A large number of orientation measurements may be plotted as a 'joint rosette' or as poles on a Schmidt stereographic net. Such plots enable the number of joint sets, and their mean orientations, to be determined.

3.3.2.2 Spacing: the term refers to the mean or modal spacing of a set of joints, that is the perpendicular distance between adjacent discontinuities.

Descriptive terms for discontinuity spacing are given in Table 6.

TERM	SPACING
Very widely spaced	Over 2 m
Widely spaced	600 mm - 2 m
Medium spaced	200 mm - 600 mm
Closely spaced	60 mm - 200 mm
Very closely spaced	Under 60 mm

Tab. 6: Discontinuity spacing

3.3.2.3 Persistence: is a measure of the areal extent of a discontinuity from its inception to its termination in solid rock or against another discontinuity. For major joints, the plane may extend beyond the limits of the exposure and then the maximum trace length or area should be recorded.

3.3.2.4 Roughness: a discontinuity surface may be planar, undulating or stepped and descriptive terms (Table 7) are based on two scales of observation:

Small scale	(several centimetres)
Large scale	(several metres)

TERM	CATEGORY
Rough (or irregular), stepped	I
Smooth, stepped	II
Slickensided, stepped	III
Rough (or irregular), undulating	IV
Smooth, undulating	V
Slickensided, undulating	VI
Rough (or irregular), planar	VII
Smooth, planar	VIII
Slickensided, planar	IX

Table 7 Roughness categories for discontinuity surfaces (ISRM, 1977)

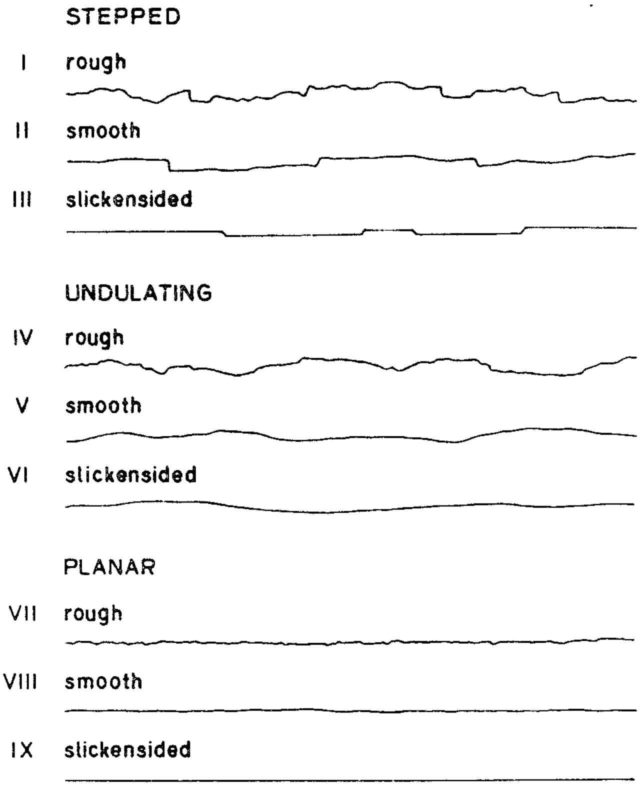

Fig. 1: Typical profiles for the roughness categories for discontinuity surfaces (Based on I.S.R.M. 1977, Fig. 17)

Typical roughness profiles in each category are illustrated in Figure 1.

3.3.2.5 Wall Strength: the shear strength of a discontinuity may be significantly affected by the condition or strength of the rock material forming the walls of the discontinuity, especially where infilling is small or absent and wall roughness is significant. Wall strength may be measured in terms of compressive strength, which may be lower than the fresh rock material strength due to weathering or alteration of the walls.

The stage of weathering of the rock material may be described in terms of degree of discoloration, decomposition and disintegration from the fresh state (Dearman, 1974, 1976). An estimate of unconfined compressive strength may be obtained using the Schmidt Hammer value (Hucka, 1965; Deere and Miller, 1966), or a simple manual penetration test (Anon, 1957), as appropriate to the material.

TERM	APERTURE
Very wide	Over 200 mm
Wide	60 - 200 mm
Moderately wide	20 - 60 mm
Moderately narrow	6 - 20 mm
Narrow	2 - 6 mm
Very narrow *****************	Over 0 - 2 mm **************
Tight	Zero

Table 8: Aperture of discontinuity surfaces

3.3.2.6 Aperture: the mean perpendicular distance between adjacent walls of a discontinuity, in which the space is infilled with air or water, is referred to as the aperture. The mean separation may be described using the terms in Table 8.

3.3.2.7 Infilling: the infilling between discontinuity surfaces may be soil introduced into the opening, minerals such as calcite, or in the case of faults clay gouge or breccia. The width of an infilled discontinuity, the perpendicular distance from wall to wall, is important in conjunction with the roughness in determining the resistance to shear along the discontinuity.

The infilling material should be identified and described. Strength of the infill may be assessed visually and manually (I.S.R.M., 1977), or should be measured.

3.3.2.8 Seepage: water flow and free moisture visible in individual discontinuities should be described and the rate of flow estimated.

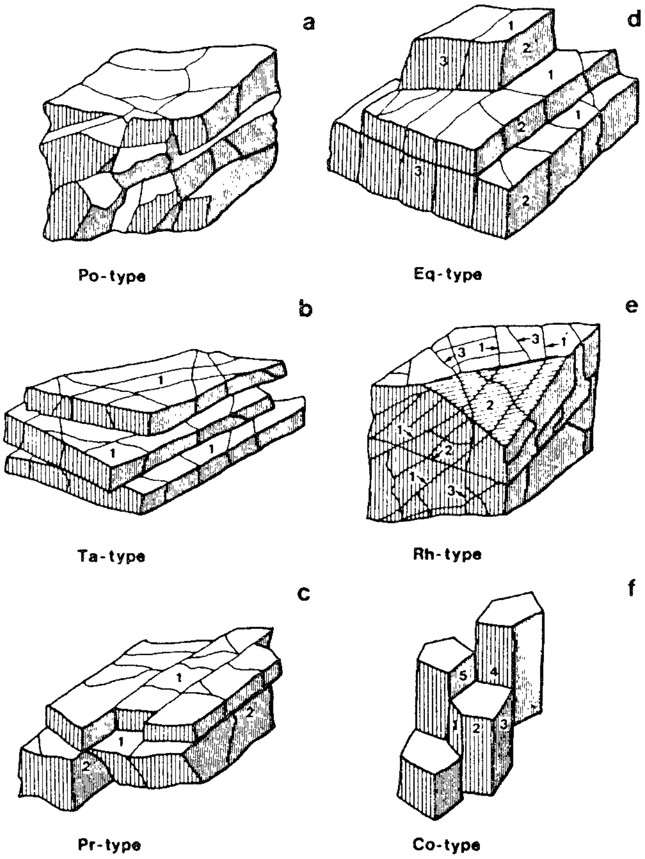

Fig. 2: Rock mass block shape; a classification based on numbers of sets of persistent discontinuities and their orientation.

a Polyhedral blocks. Irregular discontinuities without arrangement into distinct sets, and of small persistence.
b Tabular blocks. One dominant set of parallel discontinuities (1), for example bedding planes, with other non-continuous joints; thickness of blocks much less than length or width.
c Prismatic blocks. Two dominant sets of discontinuities (1 and 2), approximately orthogonal and parallel, with a third irregular set; thickness of blocks much less than length or width.
d Equidimensional blocks. Three dominant sets of discontinuities (1, 2 and 3), approximately orthogonal, with occasional irregular joints, giving equidimensional blocks.
e Rhomboidal blocks. Three (ore more) dominant, mutally oblique, sets of joints (1, 2 and 3), giving oblique-shaped, equidimensional blocks.
f Columnar blocks. Several, usually more than three, sets of continuous, parallel joints (1, 2, 3, 4, 5) crossed usually by irregular joints; length much greater than other dimensions.

3.3.2.9 Number of Sets: discontinuities may be irregular, of small persistence, without any arrangement into distinct sets: they are then referred to as non-systematic. On the otherhand, systematic joints will usually be persistent, with individual joints in each set parallel or subparallel. Systematic joints may be present in one or more sets, and influence rock mass blockiness and block size.

3.3.2.10 Block Size and Shape: the spacing of discontinuities may be described with reference to the size and shape of rock blocks bounded by discontinuities and by the relative persistence of different discontinuity sets. Matula and Holzer (1978) have given models of rock mass blockiness, illustrated in Fig. 2. These may be described as follows:

On weathering, each of these block-forms will be modified by rounding of the sharp edges, and the eventual formation of spheroidal blocks; the original joint pattern may survive the weathering process.

The size of the blocks bounded by discontinuities may be described using the terms in Table 9.

TERM	AVERAGE DIMENSION
Very large	Over 2 m
Large	600 mm - 2 m
Medium	200 mm - 600 mm
Small	60 mm - 200 mm
Very small	Under 60 mm

Table 9 Terms for the description of block size in the rock mass

3.3.3 The Weathering Profile: Weathering of the rock mass may be described in terms of the distribution and relative proportions of fresh rock and discoloured, decomposed and disintegrated rock, and the effects on discontinuities.

Weathering eventually converts rock to an engineering soil and the weathering profile may be described in terms of three basic units: rock, rock-and-soil, and soil. In rock masses consisting of one rock type these units will form a distinct succession with rock at depth being overlain in turn by rock-and-soil and soil at the surface if a complete weathering profile has been developed and subsequently preserved.

It may be found convenient to subdivide each unit to give six distinct weathering grades, and the justification for doing so is given in Dearman (1974). A typical scale of weathering grades applicable to a weathering profile in rock is given in Table 10; the grades are transition al, and it may be necessary to subdivide a grade for a particular application (Irfan and Dearman, 1978).

Geological structures, and in particular faults, may have influenced the form of the weathering profile by permitting penetration of weathering agencies deep into otherwise fresh rock. This eventuality had been foreseen in the grading scheme proposed for rock cores (Anon, 1970) with the recognition of the need for Grade 1B: "Faintly weathered; weathering limited to the surface of major discontinuities".

Alternation of different rock types in differing proportions in a rock mass may be most conveniently dealt with by ignoring the lithological variations and applying the weathering grade criteria set down in Table 10.

Term	Description	Grade
Fresh	No visible sign of rock material weathering; perhaps slight discoloration on major discontinuity surfaces.	I
Slightly weathered	Discoloration indicates weathering of rock material and discontinuity surfaces.	II
Moderately weathered	Less than thirty five per cent of the rock material is decomposed and/or disintegrated to a soil. Fresh or discoloured rock is present either as a continuous framework or as corestones.	III
Highly weathered	More than thirty five per cent of the rock material is decomposed and/or disintegrated to soil. Fresh or discoloured rock is present either as a discontinuous framework or as corestones.	IV
Extremely weathered	All rock material is decomposed and/or disintegrated to soil. The original mass structure is still largely intact.	V
Residual soil	All rock material is converted to soil. The mass structure and material fabric are destroyed. There is a large change in volume, but the soil has not been significantly transported.	VI

Table 10 Weathering grades for the rock mass

4. A Classification of Soils for Engineering Purposes

The classification of soils into a number of Soil Groups is based on:

(i) Grading of the constituent particles, and

(ii) Plasticity of that fraction of the material consisting of particles finer than 0.425 mm. The selected maximum size is a convenient B.S. Test Sieve size within the medium sand particle size range (Fig. 3).

Determinations, following existing classifications, are made on disturbed samples, and the characteristics are independent of the condition in which the soil occurs in the ground, and disregard the influence of structure of the soil mass. The soil classification can give a good guide to how the disturbed soil will behave as a construction material, for instance in embankments, at various moisture contents.

Grading and plasticity may be estimated in the field, or determined under laboratory conditions. The classification is carried out on material nominally finer than 60 mm; boulders and cobbles larger than this size are picked out and recorded as a percentage of the whole sample.

The soil classification given in Table 11 is modified from the Unified Soil Classification (USC) devised by Casagrande (Anon, 1957) and the British Soil Classification for Engineering Purposes (BSCS) (Anon, 1980). The Unified Soil Classification and similar classifications from other countries are given in Appendix E.

Soils are divided into three main classes: coarse soils, fine soils and organic soils. A coarse soil contains less than 35 per cent of grains finer than 0.06 mm, and coarse soils are additionally subdivided into sands and gravels on the basis of grain size (Table 11). A fine soil contains more than 35 per cent of grains finer than 0.06 mm, and fine soils are subdivided into silts and clays with 65—100 per cent fines.

Grading and plasticity are divided into a number of clearly defined ranges, each of which may be referred to by a descriptive name and letter:

MAIN DIVISION OF SOIL GROUPS		FINES Percentage finer than 0.06 mm	SOIL GROUPS	GROUP SYMBOLS	SUB-GROUP SYMBOLS	SOIL NAME
COARSE SOILS more than 35 per cent of the material less than 60 mm is larger than 0.06 mm	GRAVEL More than 50 per cent of coarse materials is larger than 2 mm	0—5	GRAVEL	G	GW GP GPu GPg	GRAVEL, well graded GRAVEL, poorly graded GRAVEL, uniformly graded GRAVEL, gap graded
		5—35	GRAVEL, silty	GM	GML etc.	GRAVEL, silty, of low plasticity
			GRAVEL WITH FINES	GF		
			GRAVEL, clayey	GC	GCL etc.	GRAVEL, clayey, of low plasticity
	SAND More than 50 per cent of coarse materials is smaller than 2 mm	0—5	SAND	S	SW SP SPu SPg	SAND, well graded SAND, poorly graded SAND, uniformly graded SAND, gap graded
		5—35	SAND, silty	SM	SML etc.	SAND, silty, of low plasticity
			SAND WITH FINES	SF		
			SAND, clayey	SC	SCL etc.	SAND, clayey, of low plasticity
FINE SOILS more than 35 per cent of the material less than 60 mm is larger than 0.06 mm	SILTS and CLAYS, Gravelly or Sandy	35—65	SILT, gravelly	MG	MLG etc.	SILT, gravelly, of low plasticity
			FINE SOIL, gravelly	FG		
			CLAY, gravelly	CG	CLG etc.	CLAY, gravelly, of low plasticity
			SILT, sandy	MS	MSL etc.	SILT, sandy, of low plasticitiy
			FINE SOIL, sandy	FS		
			CLAY, sandy	CS	CLS etc.	CLAY, sandy, of low plasticity
	SILTS and CLAYS	65—100	SILT (M-Soil) FINE SOIL CLAY	M F C	ML etc. CL CI CH CV CE	SILT of low plasticity CLAY of low plasticity CLAY of intermediate plasticity CLAY of high plasticity CLAY of very high plasticity CLAY of extremely high plasticity
ORGANIC SOILS	ORGANIC Sand, silt or clay			Descriptive letter O suffixed to any symbol		
PEAT	Predominantly plant remains which may be fibrous or amorphous			Pt		

Table 11: Soil classification for engineering geological mapping (Note: Material coarser than 60 mm is removed and recorded as **cobbles** (60—200 mm) or **boulders** (over 200 mm)

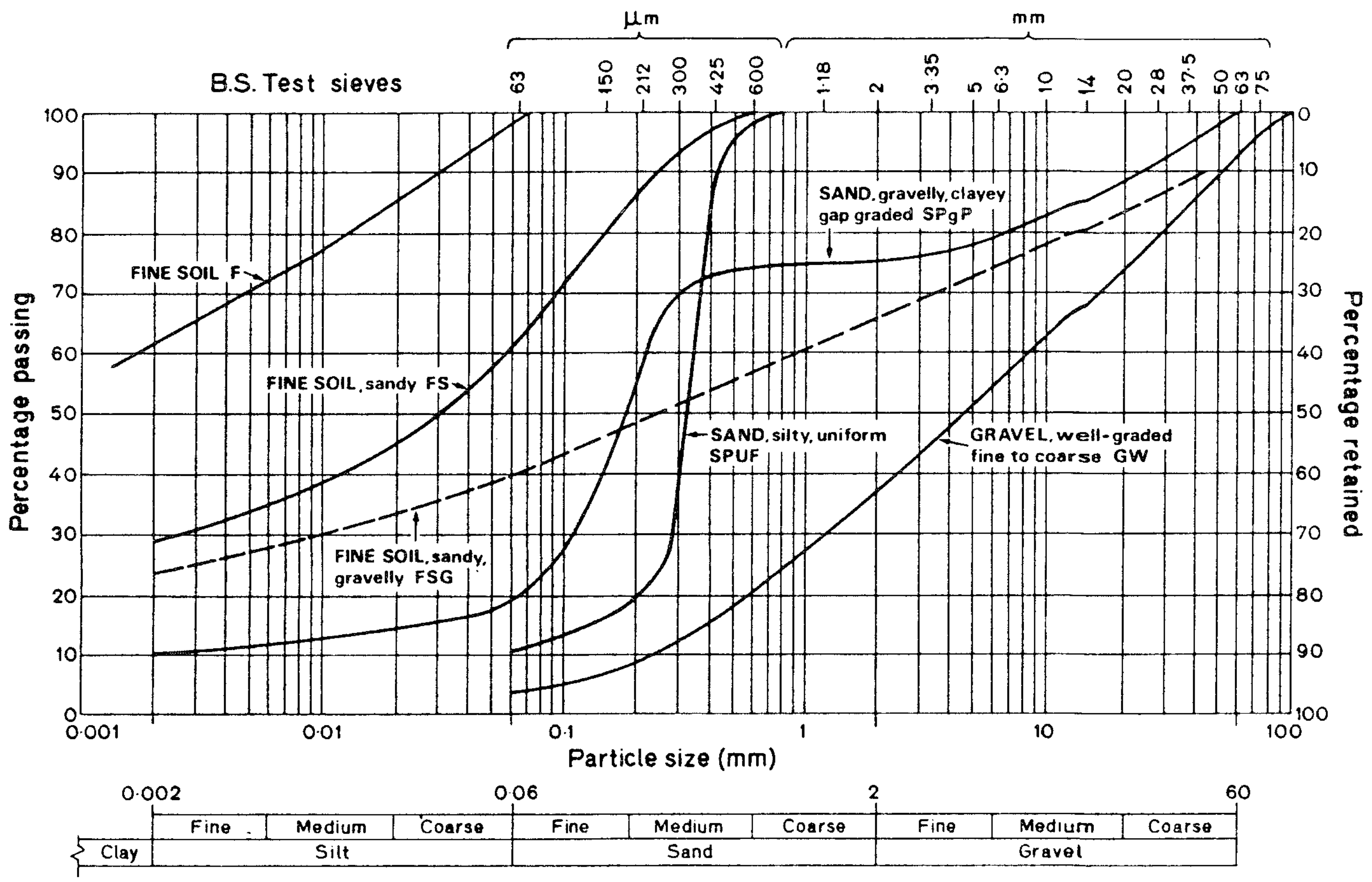

Fig. 3: Grading chart for soils with grading curves for selected soil types.

Coarse components		
Main Terms	GRAVEL	G
	SAND	S
Qualifying Terms	Well graded	W
	Poorly graded	P
	Uniformly graded	Pu
	Gap graded	Pg
Fine components		
Main Terms	FINE SOIL, FINES — may be differentiated into M or C:	F
	SILT (M — soil) — plots below A-line of plasticity chart (Fig. 4)	M
	CLAY — plots above A-line (fully plastic)	C
Qualifying Terms	Of low plasticity*	L
	Of intermediate plasticity	I
	Of high plasticity	H
	Of very high plasticity	V
	Of extremely high plasticity	E
Organic components		
Main Term	Peat	Pt
Qualifying Term	Organic — may be suffixed to any symbol	0

The particle size distribution, if determined by laboratory test, may be plotted on a grading chart (Fig. 3). The grading curve will assist in determining the proportions of different materials present in the soil, and thus the designation of the soil.

5. Description of Soils for Engineering Purposes

The fundamental soil name provides information on the grading characteristics of the soil, and is usually a combination of a basic soil type with secondary admixtures of other basic soil types. Supplementing the fundamental name are descriptive terms for characteristics of the soil material and the soil mass.

In a soil description the main characteristics should be given in the following order:

Soil Name

- Including minor constituents
- Genetic type

Soil material
- Colour
- Texture
  - Particle shape and composition
- State of weathering
- Strength
  - Consistency
  - Undrained shear strength
  - Moisture condition
  - Relative density
  - Compactness

Soil mass properties
- Structure
- Discontinuities
- Weathering profile

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*) See Table 16 for range of liquid limits. Qualifying terms applied when the fine soil content is significant.

M, SILT (M, soil), below A-line
C, CLAY, above A-line
} M and C may be combined as F, FINE SOIL

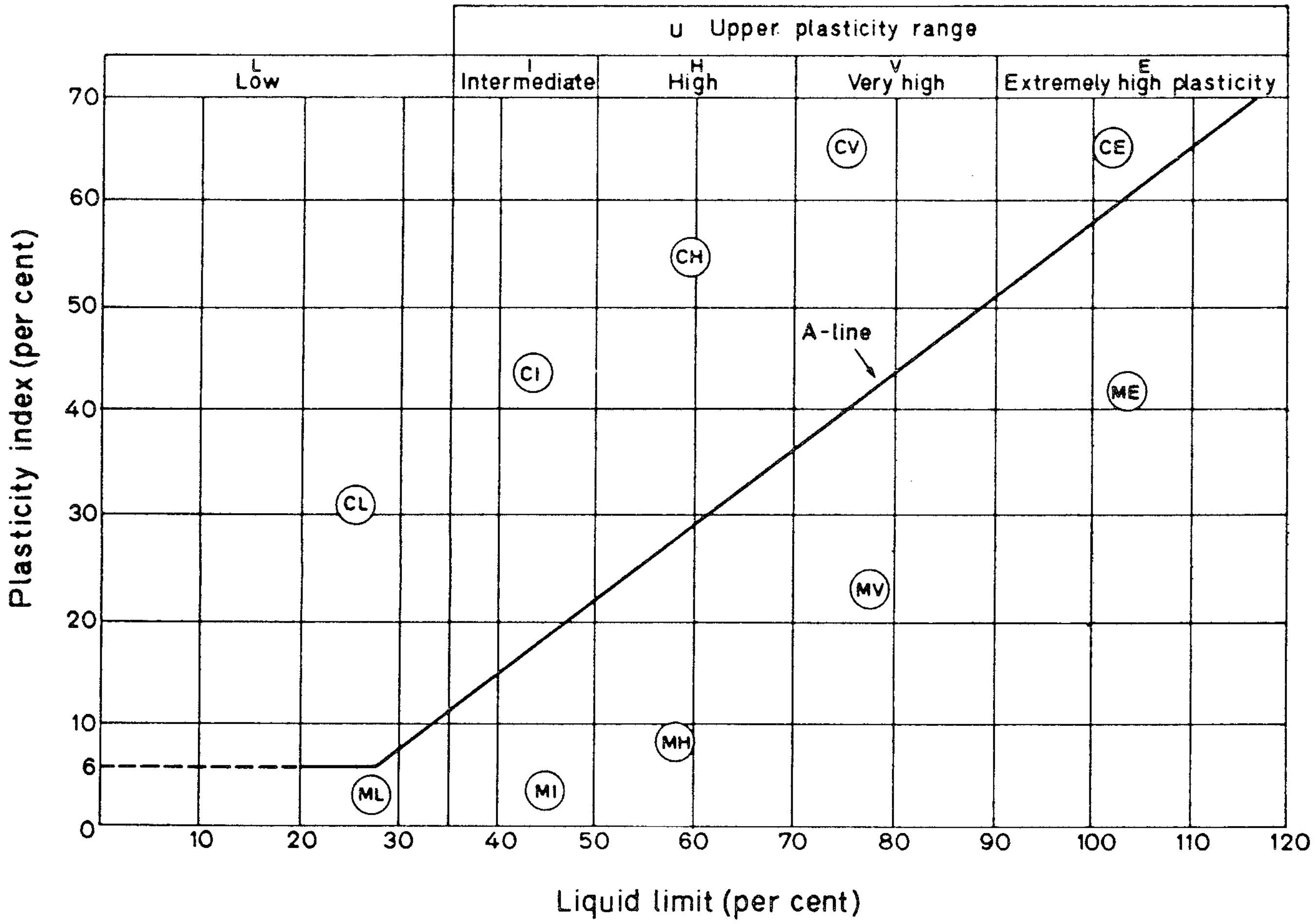

Fig. 4: The plasticity chart for the classification of soils and the finer part of coarse soils.

5.1 The Descriptive Soil Name

5.1.1 Basic Soil Types: Basic soil types are named after soil particle sizes falling within specified limits (Table 12).

5.1.2 Composite Soil Types: Most soils are composite types, containing a range of basic soil types. The proportion by weight of each component is then used as the basic for naming the soil (Table 11).

5.1.3 Coarse composite soils: As noted in the classification table (Table 11), a coarse soil contains 65 per cent or more of coarse soil in the particle size range 0.06 to 60 mm: the sand and gravel sizes. Composition of the coarse fraction may be described using the terms in Table 13.

The gravel and sand sizes may be subdivided into coarse, medium and fine (Table 12) and the type of grading can be specified (Soil Name in Table 11). Fine soils are absent.

5.1.4 Very Coarse Composite Soils: boulders and cobbles. In very coarse soils over 50 per cent of the material is very coarse grained, i. e. over 60 mm. Table 14 gives descriptive terms for these soils.

TERM	DESCRIPTION
GRAVEL	up to 5% sand
GRAVEL, Sandy	5-35% sand
GRAVEL/SAND	approximately equal proportions of gravel and sand
SAND, Gravelly	5-35% gravel
SAND	up to 5% gravel
Percentages are of the whole material less boulders and cobbles, and are approximate estimates in a field description	

Table 13: Description of sand and gravel composite soil types

SOIL NAME	QUALIFYING TERM	PARTICLE SIZE
Boulders		Over 200 mm
Cobbles		60 - 200 mm
Gravel	Coarse	20 - 60 mm
	Medium	6 - 20 mm
	Fine	2 - 6 mm
Sand	Coarse	0.6 - 2 mm
	Medium	0.2 - 0.6 mm
	Fine	0.06 - 0.2 mm
Silt	Coarse	0.02 - 0.06 mm
	Medium	0.006 - 0.02 mm
	Fine	0.002 - 0.006 mm
Clay		Under 0.002 mm

Table 12: Particle size distribution for basic, single component, soil types

MAIN NAME	QUALIFYING NAME	DESCRIPTION
BOULDERS or BOULDER GRAVEL	Cobbly	Over 50 per cent of very coarse material is over 200 mm, boulder size
COBBLES or COBBLE GRAVEL	Bouldery	Over 50 per cent of very coarse material is cobble size, 60-200 mm
COBBLE/BOULDER GRAVEL		Equal proportions of cobble and boulder sizes

Table 14: Descriptive terms for very coarse soils

5.1.5 Mixtures of Very Coarse Soils with Finer Materials (i. e. coarse and fine soils). Very coarse grained mixtures with finer materials may be described on the basis of approximate estimates of composition (Table 15).

TERM	DESCRIPTION
BOULDERS (or COBBLES) with some finer material	5-20% finer material
BOULDERS (or COBBLES) with much finer material	20-50% finer material
FINER MATERIAL with many BOULDERS (or COBBLES)	50-20% boulders (or cobbles)
FINER MATERIAL with some BOULDERS (or COBBLES)	20-5% boulders (or cobbles)

Table 15: Descriptive terms for mixed very coarse and finer grained soils

The name of the finer material, which may be gravel, sand or silt, or mixtures of these, should be given (Table 11), e. g. SAND, gravelly, with some boulders; CLAY, sandy, with some cobbles.

5.1.6 Organic Soils: Organic clays, silts and sands contain appreciable quantities of organic vegetable matter, may have a marked odour and a dark gray, dark brown or dark bluish-grey colour. Fine soils with large amounts of organic matter usually plot below the A-line (Fig. 4) as organic silts, and have high to extremely high liquid limits.

Peat consists predominantly of plant remains which may be fibrous or amorphous.

5.1.7 Plasticity: Clay and silt, alone and in mixtures with coarse material, may be classified in terms of plasticity (Table 16).

TERM	RANGE OF LIQUID LIMIT (%)
Of low plasticity	under 35
Of intermediate plasticity	35 - 50
Of high plasticity	50 - 70
Of very high plasticity	70 - 90
Of extremely high plasticity	Over 90

Table 16: Terms for the description of plasticity of fine soils and fine soils fractions in coarse soils

As an alternative, a classification may be made in terms of plasticity index (Table 17).

TERM	PLASTICITY INDEX (%)
Non-plastic	under 1
Slightly plastic	1 - 7
Moderately plastic	7 - 17
Highly plastic	17 - 35
Extremely plastic	over 35*

*for very "fat" clays

Table 17: Terms for the description of plasticity index classes for fine soils and fine soil fractions in coarse soils.

5.1.8 Genetic Type of Deposit: Descriptive soil names are usefully supplemented by reference to the type of deposit described where this is not evident from the name of the geological formation. Examples are: alluvium, eluvium, colluvium, talus, scree, loess, till, moraine, boulder clay, outwash, aeolian, dune, beach sand, marine, deltaic, tidal swamp, swamp, lagoonal, littoral.

5.2 Description of Soil Material

5.2.1 Colour: Soil colour may be evaluated quantitatively using the Munsell Soil Color Chart (Munsell, 1941) or the simple system recommended for rocks (Table 2).

5.2.2 Particle Shape and Composition: Where appropriate, particle shape may be described by reference to the general form of the particles, their angularity which indicates the degree of rounding at corners and edges, and their surface caracteristics (Table 18).

FORM	Equidimensional Flat Elongated Flat and elongated Irregular
ANGULARITY	Angular Subangular Subrounded Rounded
SURFACE CHARACTERISTICS	Rough Smooth

Table 18: Terms for the description of particle shape

The surface of particles may be polished, etched, pitted, honeycombed, as examples of additional descriptive terms.

Composition of particles visible to the naked eye or under a hand lens may be described. Larger particles are usually rock fragments and may be so described (Table 1). Sand and finer grains are usually individual mineral grain, for example, mica, quartz, feldspar. Gravel and sand particles may be coated with mineral matter, for example limonite, calcite. Crystals, often of large size, may be present: gypsum in clay, pyrite in chalk. Shells may be an important constituent of soils.

5.2.3 State of Weathering: The same terms applied to rock may be used to describe the weathering of soil material: namely, discoloration, decomposition, and disintegration. Descriptive terms, quantified as in Table 4, imply changes from fresh soil, but the resultant products of the progressive weathering of soils are also engineering soils that may be individually described in the recommended manner.

TERM	FIELD TEST
Very soft	Exudes between fingers when squeezed in hand
Soft	Can be moulded by light finger pressure
Firm	Can be moulded by strong finger pressure
Stiff	Cannot be moulded by fingers; can be indented by the thumb
Very stiff or hard	Can be indented by thumb nail

Table 19: Field tests for the consistency of fine soils

Most obvious of the changes will be discoloration in fine soils, and discoloration, colour-banding, cracking, disintegration and decomposition of individual mineral and rock fragments in coarse soils.

5.2.4 Strength: Strength may be estimated by simple field tests on disturbed and undisturbed samples or by laboratory tests on undisturbed samples.

For the fine soils, with over 35 per cent of silt and clay size, consistency may be estimated using simple manual tests (Table 19) on disturbed samples.

Undrained shear strength of fine soils may be classified and described as in Table 20, and the strength values are directly related to the estimations made by the simple manual tests given in Table 19.

TERM	UNDRAINED SHEAR STRENGTH kN/m^2
Very soft	under 20
Soft	20 - 40
Firm	40 - 75
Stiff	75 - 150
Very stiff	over 150

Table 20: Classification of fine soils in terms of undrained shear strength

If numerical, laboratory values for moisture content (m), liquid limit (LL), and plastic limit (PL) are available, the physical state of fine soils can be closely expressed by the consistency index:

$$\text{Consistency Index CI} = \frac{LL-m}{LL-PL}$$

A scale in terms of consistency index is given in Table 21.

TERM	CONSISTENCY INDEX
Very soft	less than 0.05
Soft	0.05 - 0.25
Firm	0.25 - 0.75
Stiff	0.75 - 1.00
Very stiff or hard	over 1.00

Table 21: Classification of fine soils in terms of consistency index

For coarse soils (Table 11), the compactness of the soil material may be estimated using the simple field tests specified in Table 22.

TERM	FIELD TEST
Loose	Can be excavated with a spade; 50 mm wooden peg*can be easily driven
Dense	Requires pick for excavation; 50 mm wooden peg hard to drive
Slightly cemented	Visual examination; pick removes lumps which can be abraded

Table 22: Field test and descriptive terms for the compactness of coarse soils (gravels and sands)

*) The peg should be of square cross-section and sharpened to a 100 mm long point.

The relative density of sands and gravels may be determined by the Standard Penetration Test. A scale in terms of N-values is given in Table 23.

TERM	SPT N-values Blows/300 mm penetration
Very loose	0 - 4
Loose	4 - 10
Medium dense	10 - 30
Dense	30 - 50
Very dense	over 50

Table 23: Standard penetration test N-values and descriptive terms for coarse soils

Relative density of sands and gravels may also be determined from the void ratio (e_n) of the soil **in situ** and the void ratios corresponding to the loosest (e_{min}) and densest (e_{max}) laboratory states for a given soil. Relative density, classified in Table 24, is derived from:

$$I_D = \frac{e_{max} - e_n}{e_{max} - e_{min}} \times 100$$

5.3 Description of the Soil Mass

The description of the soil mass requires information additional to the description of the soil as a material.

A soil mass should first be described as a soil material, or as a combination or mixture of soil types, followed by information of engineering significance concerning the soil mass. Such information includes:

(i) the geological structure and the distribution of soil types in the soil mass
(ii) the characteristics of discontinuities in the soil mass
(iii) the weathering profile

Features of the soil mass can only be determined by field observation of pits, trenches, and larger excavations; from natural exposures; or from a sufficient number of undisturbed samples.

TERM	RELATIVE DENSITY (%)
Very loose	less than 20
Loose	20 - 33
Medium dense	33 - 66
Dense	66 - 90
Very dense*	90 - 100

*Usually weakly cemented

Table 24: Relative density of sands and gravels

5.3.1 Structure: the larger aspects of structure are related to folding and faulting of stratified and interstratified deposits. Beds, layers and lenses of different soil types may be present, and individual layers may be gradational from one soil type to another. Folding and faulting introduce gross defects into the soil mass, and interstratification causes heterogeneity and anisotropy, all of which may be more important from the viewpoint of engineering properties than the properties of individual types of soil material.

Special bedding characteristics should be described, for example disturbed bedding, cross bedding, and structures associated with bedding surfaces such as ripple marks. Thin laminae of silt in clay, or fine sand in silt, as two examples, give rise to partings that separate easily. Intercalations and lenses of softy clayey or organic matter, or of soluble materials, should be described in detail because of their very important influence on engineering properties and the behaviour of the soil mass.

Pedological features, such as roots and root-holes penetrating the soil mass, should be described.

5.3.2 Discontinuities: Discontinuities in soils, including fissures and shear planes, should be described and quantified using the terms already given for rocks (I.S.R.M., 1977).

5.3.3 The Weathering Profile: Weathering of the soil mass should be described in the same way as for rock (3.2.3), including the gradation to rock if the soil profile has resulted from weathering of rock. However, Table 10 has to be modified if it is to be generally applicable to all soils, other than very stiff or hard, jointed and fissured fine soils. Weathering grades for the soil mass are proposed in Table 25. Relics of the original soil of weathering grades I and II are present in grades III and IV, corresponding to the corestones in the rock mass weathering grade classification (Table 10).

6. Additional Geological Information for Rock and Soil Description

Wherever possible the following additional information should be given.

6.1 Geological Formation

The name of the geological formation can usually be found on published geological maps, and should be given in the form determined by local custom, for example London Clay, Bannisdale Slates, Morrison Formation.

6.2 Age

The age of the formation should be stated in terms of System, Series, Stage or whatever stratigraphical subdivisions are available.

TERM	DESCRIPTION	GRADE
Fresh	No visible sign of soil material weathering; perhaps slight discoloration on major discontinuity surfaces.	I
Slightly weathered	In fine soils, discoloration indicates weathering of soil material and discontinuity surfaces; there is not a marked change in consistency of the discoloured soil. Relics of fresh soil may be present. In coarse soils, individual fragments and discontinuities are discoloured; there is no marked change in relative density.	II
Moderately weathered	In fine soils, the soil is discoloured; less than thirty five per cent of the soil will show a marked change in consistency; relics of Grades I and/or II are present. In coarse soils, less than thirty five per cent of the soil has markedly lower relative density.	III
Highly weathered	In fine soils, the soil is discoloured and more than thirty five per cent of the soil will show a marked change in consistency; relics of Grade II are present. In coarse soils, more than thirty five per cent of the soil has markedly lower relative density.	IV
Extremely weathered	In fine soils, the soil is discoloured, relics of Grade II are absent; the soil shows a marked change in consistency from the fresh soil. In coarse soils, there is a marked decrease in relative density.	V

Table 25: Weathering grades for the soil mass

7. Made Ground

Made ground may be of two types that are conveniently referred to as "engineered fill" and "non-engineered fill".

7.1 Engineered Fill

Excavated natural soils may be used as construction materials particularly for embankments, as general fill in large-scale cut-and-fill grading operations for housing developments, or dumped as ground fill wherever volumes available are in excess of engineering requirements. It is possible to carry out classification tests on such materials and to describe them using the proposals in Sections 4 and 5.

Run of quarry rock material as produced by blasting, or aggregates prepared by controlled crushing and grading, may similarly be used as construction materials. Although difficult to sample if the particle size is very large, these engineering materials may also be classified and described using Sections 4 and 5.

7.2 Non-engineered Fill

Except where natural soils and rock aggregates have been used as construction materials, it is seldom possible to carry out classification tests on materials in heaps or that have been used to infill excavations. This is particularly the case where urban demolition has taken place, or where excavations or areas of low-lying ground have been used for garbage disposal, and the dumping of industrial wastes of all kinds.

A clear and complete description is therefore of the greatest importance, and in addition to describing normal soil constituents should include details of the following.

7.2.1 Mode of Origin: The fill may have been placed as a single dumped layer or as many thin layers with or without blanketting of each layer by natural soils. Modes of origin include household and industrial garbage, industrial wastes of all kinds including waste-solids, chemicals and liquids, and general demolition debris from urban renewal. Fill may be layered or 'cross-bedded', depending upon the method of placement.

7.2.2 Presence of Larger Objects: Masses of masonry, reinforced concrete, steel girders may be present.

7.2.3 Voids: Urban fill may obscure partly filled or unfilled cellars of previously existing buildings, sewers and other underground pipes, empty oil drums and other hollow objects including tyres, dumped automobiles, refrigerators etc.

7.2.4 Chemical and Organic Matter: Many areas of non-engineered fill may represent the sites of disused quarries and clay pits that have been used for the storage and disposal of solid and liquid chemical wastes which may be inorganic or organic in character.

7.2.5 Toxic Materials Including Gases: Acid wastes may react with limestone and concrete to produce carbon dioxide. Decomposing plant and animal matter will evolve methane, ammonia and other toxic gases. The dumped materials may themselves be toxic (7.2.4).

7.2.6 Age: Most easily dated are old newspapers magazines and calendars which provide an indication of the maximum age of the deposit.

7.3 Effects of Non-engineered Fill on Adjacent in Situ Rocks and Soils.

Industrial liquids, leachates formed by percolation of meteoric water through the fill, and other solutions, may percolate into adjacent and underlying rocks and soils. Resultant reaction with, or precipitation within the **in situ** rock and soil mass may bring about extensive alteration, masking their original character.

8. Use of Description and Classification of Rock and Soil Units for Engineering Geological Mapping.

Engineering geological mapping is based, not on the lithostratigraphic units in conventional geological mapping, but on the recognition of homogeneous lithological units that in any one area may have a range of geological ages. The degree of homogeneity is related to the scale of the map, and an internationally acknowledged set of taxonomic units (UNESCO/IAEG, 1976) based on lithology has been established. The lithological engineering geological units are:

Engineering Geological Type	ET
Lithological Type	LT
Lithological Complex	LC
Lithological Suite	LS

Each unit has been defined (UNESCO/IAEG, 1976, p. 12 and Section 7.2), and these definitions are expanded in the following sections.

8.1 The Engineering Geological Type

The engineering geological type is the mapping unit applied at the largest map scales and to the interpretation of site investigations carried out by means of boreholes, pits and trenches. Each distinctive rock or soil type can be described in terms of a descriptive name (Sections 3.1 and 5.1) using all, or a selction of, the descriptive terms listed in the accompanying tables.

Each mapping unit is thus defined semiquantitatively in terms of those descriptive parameters that are classified, as for example in terms of material strength and discontinuity spacing. The engineering geological types has the highest degree of physical homogeneity of the four mapping units, has a single fundamental rock or soil name and is characterised by uniformity of lithological character and physical state. Furthermore, each unit can be characterised by statistically determined values from individual determinations of physical and mechanical properties (as listed in Appendix A and B).

In mapping a granite, for example, a typical descriptive rock name for one engineering geological type would be:

GRANITE, light yellowish-brown, medium grained, slightly discoloured, strong, massive, very widely jointed, with stained, rough, tight joints in two orthogonal sets giving very large prismatic (Prl-type) blocks, slightly weathered.

Another part of the same granite mass would be distinguished as another engineering geological type on the basis of being, for example, moderately weathered, or with medium spaced joints (Pr3-type blocks).

In the same way, a distinctive part of an exposure of clay in the wall of an exploration trench could be described as:

CLAY, marine, yellowish-brown, fresh, firm, thinly bedded and closely fissured, of high plasticity.

And other parts of the clay outcrop could, for example, be distinguished in terms of colour differences, or differences in plasticity, or differences in consistency.

Engineering geological types are the mapping units used for large-scale mapping, where the highest degree of discrimination is required between rock and soil masses with distinctive engineering properties.

8.2 The Lithological Type

The lithological type comprises a number of closely related engineering geological types such as the same granite in different stages of weathering, i. e. the differing units in the weathering profile. Although each engineering geological type can be closely defined, characterisation of the corresponding lithological type is limited to providing only a general idea of engineering geological properties, with a range of values presented.

A lithological type, therefore, is homogeneous throughout only in composition, texture and structure, but not necessarily in physical state. A granite could be medium-grained and massive throughout, but different parts might vary in some or all of the other material and mass properties.

Lithological types are the mapping units used for large and medium-scale mapping, and serve to distinguish the rock types present at an engineering site, and their distribution over the site.

8.3 Lithological Complex

A lithological complex comprises a number of genetically related lithological types that have developed under the same palaeogeographical and geotectonic conditions. Consequently, it is not possible to define the physical and mechanical properties of the whole lithological complex, but only to provide information on the individual lithological types and to give an indication of the general engineering geological behaviour of the complex.

The lithological complex is used as a mapping unit on medium-scale and some small-scale maps.

An example of a lithological complex is the Chalk of Europe. The whole of the Chalk succession is a lithological complex which may be subdivided into a number of lithological types: white chalk with flints; white chalk, grey chalk, chalk rock, marlstone. In this case all the lithological types are calcareous to varying degrees.

Another example is provided by the Productive Coal Measures of North-East England in which a dominant sandstone lithological type is associated with subordinate shale and coal lithological types, the whole forming on lithological complex.

8.4 The Lithological Suite

A lithological suite comprises a group of lithological complex that have formed under generally similar palaeogeographical and geotectonic conditions. Each suite has certain lithological characteristics throughout which impart a general unity to the suite and serve to distinguish it from other suites. Only very general engineering geological properties can be defined for a lithological suite.

Lithological suites are only mapped at small scales, and their distribution in any particular region can usually be inferred from a geological map of the same scale and an understanding of the geologcial history.

9. Methods for the Characterisation of Rock and Soil Mapping Units

Classification of rocks and soils (Sections 2 and 4) results in the recognition of three genetic groups: magmatic (major intrusive, minor intrusive, effusive, pyroclastic); metamorphic (regional, contact, dynamic, hydrothermal); and sedimentary (unconsolidated and consolidated, clastic, carbonaceous, chemical, biogenic). Within each genetic group subdivisions are made on the basis of a semiquantitative grain-size classification (very coarse-grained, coarse-grained, medium-grained, fine-grained, very fine-grained and amorphous). The lithological classification, also taking account of structure and mineral content, provides a name for the particular rock or soil type.

For the purpose of mapping, a lithological classification is sufficient at the scale of delimiting the lithological types, and hence for the lithological complex and the lithological suite because of the hierarchical nature of the classification. Discrimination between different lithological types of the same rock, for example within a granite or a sandstone complex, can be achieved by the use of one or more of the descriptive terms for colour, grain size, bedding spacing in sedimentary rocks and soils, and minor lithological characteristics.

Problems presented by interstratified sediments can be dealt with by describing each lithological type, and giving an estimate of the relative proportions of the two or more types. At a sufficiently large-scale it would even be possible, and indeed might be necessary, to recognise and map separate engineering geological types within two or more lithological types present. On the otherhand, at smaller scales interstratified sediments would be dealt with as distinctive elements in a lithological complex.

Classification of mapping units at the scale of the engineering geological type, as opposed to description of each unit, requires assessment of a number of attributes to give a smaller number of classes or grades which are to the mapping units. This assessment demands discrimination between those attributes that are unique and those that are interrelated, if the number of distinct mapping units is to remain manageable.

9.1 Characterisation of the Engineering Geological Type

As similar criteria can be applied to the description and classification of both rocks and soils, in this and subsequent sections reference will be made only to rocks.

For an individual lithological type, marked differences in physical and mechanical properties will be related to internal and external geological processes that have affected the rocks. These processes are:

a) weathering (and/or alteration), leading to variations in strength of the rock material, and discontinuity spacing in the rock mass.
b) tectonic activity, for example faulting, leading to variation in discontinuity spacing and possibly controlling the distribution of weathering grades in rock mass.

Parallel changes in colour and texture may also occur, thus embracing all the terms used in the description of the rock material and the rock mass.

Recognition of differences in physical state within one lithological type leads to the establishment of a number of distinct engineering geological types. For mapping to be effective, the number of mapping units for each engineering geological type needs to be small. Consequently, the variables that may be applied to each engineering geological type listed in the descriptive rock name need to be evaluated with respect to their dependence and relation one to another if the number of variables is to be reduced to an acceptable level.

Changes in colour and texture are related to weathering changes, and from the list of descriptive terms for rock (3.2, 3.3) three important variables are the state of weathering, strength and discontinuity spacing. Each of these may be classified (Tables 4, 5 and 6) into five or six classes.

Mapping could be undertaken in terms of engineering geological types distinguished by weathering grade assessment (Table 10), and each weathering grade could be characterised by a full descriptive name. Another approach may be the distinction of rock blocks of different size and shape (Section 3.3.2.10, Table 9 and Fig. 2).

A difficult problem concerns the method, or methods, to be adopted for the mapping process for without either complete, or nearly complete exposure or the availability of a sufficient number of cored or accessible boreholes it is impossible to determine the distribution of weathering grades, types of blockiness, or other characteristics of the physical state of the rock mass. If geological information is not available, then indirect methods of assessing variations in engineering geological properties have to be used.

9.2 Indirect Characterisation of Engineering Geological Types

Indirect methods, such as geophysical methods (Horsky and Muller, 1978), provide the only hope of determining **in situ** variations in the rock mass where exposures or borehole coverage are inadequate. However, unless the geological conditions are known, for example the types of rock or soil present and their distribution, then the indirect methods can only discriminate between variations in physical mass properties, such as apparent resistivity or seismic velocity. Variations in physical properties of the mass can thus be used as a means of classification independent of either a geological or engineering geological classification. The classes so determined are representative of rock and soil mass disintegration grades and not of true engineering geological types.

9.2.1 Velocity Index: A general quantitative index for the character of the in situ mass is provided by the field: laboratory velocity ratio (Onodera, 1963; Deere and Miller, 1966; Deere, Merrit and Coon, 1969). The method depends on the assumption that laboratory test cylinders, taken for example from site investigation drill cores, are free from the physical defects of the rock mass and are thus representative of the rock material. The field velocity is less than the laboratory velocity because of the defects present in the rock mass. In general there is a reduction in velocity of seismic waves with decrease in discontinuity spacing and changes in other discontinuity properties (3.3.2) and also with increase in weathering grade (Iliev, 1970).

The velocity index provides a measure of the degree of fracturing, weathering and moisture content of the rock. Velocity index may be specified as the simple ratio of field: laboratory velocity, but is usually given in terms of the square of the field: laboratory ratio which is then directly proportional to the field: laboratory dynamic moduli.

Deere et al. (1969) have proposed an engineering classification for the rock mass based either on determination of velocity index or on Rock Quality Designation (RQD) determined by logging core (Table 26).

RQD (per cent)	Velocity Index $(V_F/V_L)^2$	Description
0-25	0-0.2	Very poor
25-50	0.2-0.4	Poor
50-75	0.4-0.6	Fair
75-90	0.6-0.8	Good
90-100	0.8-1.0	Excellent

Table 26: Classification of the rock mass in terms of RQD and Velocity Index

Rock Quality Designation, a measure of the degree of brokenness of the rock **in situ**, is determined by counting only the combined length of pieces of unweathered core greater than or equal to four inches in length as a percentage of the length of the coring interval.

9.2.2 Seismic Wave Attenuation: A more sensitive parameter to variations of rock quality than velocity index would probably be provided by seismic wave attenuation determinations.

9.2.3 Apparent Resistivity: Apparent resistivity of the ground is primarily dependent on porosity, fracturing, degree of saturation and the salinity of the pore-water. The method provides a means of discriminating variations in those properties within an individual lithological type which might give rise to distinctive engineering geological types.

For the method to be effective, there must be a strong contrast between engineering geological types, for example contrasts occasioned by shatter zones of high porosity in igneous and metamorphic rocks, and by weathered rock overlying fresh igneous and metamorphic rocks.

Two methods of resistivity surveying are in common use. Variation in resistivity with depth below a selected point is akin to electrical boring. It is used to determine depth to watertable, depth to bedrock below superficial deposits, and depth to other lithological changes. Determination of variation of resistivity at a fixed depth at different points along a traverse is electrical profiling. A map of variations in apparent resistivity can be derived from a set of electrical profiles, akin to a pattern of boreholes to a standard depth.

9.3 Characterisation of the Engineering Geological Type in Terms of Significant Engineering Properties

For the purpose of engineering design, important properties of the rock or soil mass are strength, deformability, permeability and durability. Determination of each of these properties as a characteristic of individual engineering geological types requires **in situ** testing in a borehole or other type of excavation. Many **in situ** tests need sophisticated instrumentation and, because of the inherently high costs, can usually only be carried out in limited numbers on large projects.

Commonly used **in situ** tests are listed in Appendix C (13.3) and Appendix D (13.4).

Mapping in terms of engineering properties depends on the determination of the relation between recognised engineering geological types and engineering properties. The geological assessment can then be used to extend the area, or volume, of applicability of the appropriate engineering property over, for example, the foundation area of a dam (Knill and Jones, 1965; Lane, 1964; Horsky and Müller, 1978), or other large structures (Ward and Burland, 1968; Ward, Burland and Gallois, 1968; Bondarik and Goraltchouk, 1978).

It is not appropriate here to elaborate on the methods of testing commonly used, or on the interrelations between the results and distinctive engineering geological types that may be used for mapping purposes.

9.4 Characterisation of the Lithological Type

An altogether broader approach is required for the characterisation of the Lithological Type as is brougth out in a typical description of a mapping unit: MUDSTONE, micaceous, light greyish brown, fine to very fine-grained, thinly bedded (UNESCO/IAEG, p. 21). This description is semiquantitative and could include additional data, for example, on variations in discontinuity spacing, weathering grade and strength present in the map unit.

Methods of delimiting mapping units are based on recognition of distinctive rock and soil types, that is the conventional geological approach to mapping is adopted. Mapping units may be characterised by information acquired by field observation and measurements; by boring and sampling followed by systematic laboratory testing; by geophysical testing, and by limited **in situ** testing.

9.5 Characterisation of the Lithological Complex

Map units are delimited by areal mapping with facies-analysis, as used in conventional geological mapping. Each map unit may be characterised by lithological (petrographical), geophysical and geotechnical investigations, backed up by boring and sampling and laboratory determinations of physical and mechanical properties.

Characterisation is broadly based and very general on account of the number of distinct lithological types usually present in a lithological complex.

9.6 Characterisation of the Lithological Suite

At this, the smallest scale of engineering geological mapping, determination of mapping units is made from existing small-scale geological maps, from general reconnaissance mapping, and by photogeological interpretation. Characterisation is made on the known physical and mechanical properties of the lithological types and complexes present.

9.7 Methods of Representation of Rock and Soil Characteristics in Engineering Geological Mapping

On the map and its legend, semiquantitatively and quantitatively assessed rock properties are represented in different ways.

(a) On maps, boundaries may be drawn around units which are homogeneous in terms of, for example, a defined degree of plasticity, consistency, or relative density, or of such characteristics as degree of jointing or weathering grade. Quantitative assessments can also be expressed by lines of equal values (isolines) over the area mapped. Both types of map are examples of analytical maps (UNESCO/IAEG, 1976, p. 12).

(b) The quantitative rock and soil characteristics can be tabulated in so-called enlarged legends — these are mainly produced to accompany maps of engineering geological conditions (UNESCO/IAEG, 1976, pp. 39—43), where apart from groundwater, relief and geodynamic processes, particular attention is paid to the delineation, representation and characterisation of the distribution, properties and physical state of rock units (ET, LT, LC or LS, depending on map scales).

(c) The quantitative characteristics of rock material can be given most fully in the explanatory text, memoir or report accompanying the map. As a rule such information is dealt with in chapters dealing with individual rock units and their properties. Usually arranged in stratigraphical sequence, the rock examples thus receive a comprehensive, technical evaluation which, apart from detailed discussion of individual characteristics, also summarizes their properties in annotated tables, graphs and diagrams.

10. Examples of the Use of Rock and Soil Descriptions on Enlarged Map Legends

In Sections 1 and 8 the four types of engineering geological mapping unit are defined, and examples of typical descriptive rock names are given for large-scale mapping. The degree of detail used in the description of mapping units depends on the type of mapping unit used which in turn is related to the scale of the map. Detailed descriptions may be confined to a descriptive memoir accompanying the maps, but on many maps the description of the map units may be usefully extended to include all available details of material and mass characteristics.

In the following sections, examples are given to supplement the description of the maps units which accompany Fig. 1 in the published guide to engineering geological mapping (UNESCO/IAEG, 1976). One important development from these proposals, is that in the descriptive rock name (3.1) and soil name (5.1), the lithological rock or soil name is placed first, followed by material properties and then by mass properties.

10.1 Descriptions of Engineering Geological Types

Rock and soil units exposed in a foundation excavation near a sea coast could expose, in sequence from the surface downwards, the following engineering geological types: glacial till, beach gravels, extremely weathered granite, slightly weathered granite. An adequate description of each type would include some or all of the main characteristics listed in Sections 3 and 5, for example:

SILT, clayey with some cobbles and boulders (Glacial Till, Devensian, Pleistocene), dark brown, slightly weathered, stiff massive, with medium spaced, vertical polygonal joints.

GRAVEL, sandy (Beach Sand, Pre-Devensian, Pleistocene?), light brown, slightly weathered, loose, with faint lamination.

GRANITE, biotite (Middle Devonian), dark reddish brown, uniformly coarse-grained, extremely disintegrated, weak, massive, with widely spaced joints, weathering grade V.

GRANITE, biotite (Middle Devonian), dark reddish brown, uniformly coarse-grained, slightly weathered with widely spaced joints and equidimensional blocks (Eg2), very strong, massive, weathering grade II.

Such semiquantitative descriptions may be adequate for mapping purposes but if considered necessary may be extended to provide much more information on material and mass properties. An extended description of one of the above engineering geological types is given below:

SILT, clayey, of low plasticity, with some flat, subrounded, smooth, grooved and facetted cobbles and boulders of dolerite, granite and schist (Glacial Till), dark brown becoming dark yellowish brown near the surface, slightly weathered with light-grey 20 mm thick selvedges to joints for up to 2 m below surface, stiff, firm in light-grey joint selvedges, massive with no bedding or other structures, polygonal vertical joint sets, medium spaced (200—600 mm), dying out 3 m below surface, smooth and planar except where cobbles and boulders are intersected, aperture very narrow, dry, medium columnar blocks up to 2 m long bounded by horizontal joints (Co3-type).

In the same way the description of the GRAVEL and the two types of GRANITE could be extended to take account of all the semiquantitative and quantitative features determined, using the descriptive terms given in the appropriate sections of the report.

10.2 Descriptions of Lithological Types

It has already been made clear (Section 9.4) that a less detailed description is adequate for Lithological Types, and for this purpose the descriptions of Engineering Geological Types given in Section 10.1 could be abbreviated as follows:

SILT, clayey with some cobbles and boulders (Glacial Till, Devensian, Pleistocene), dark brown, stiff to firm, massive, with vertical polygonal Co3-t type blocks.

GRAVEL, sandy (Beach Sand, Pre-Devensian, Pleistocene?), light brown, loose, faintly laminated.

GRANITE, biotite, (Middle Devensian), reddish brown, uniformly coarse-grained, massive, weathering grades II and V present.

11. Conclusions

The purpose of this report is to present recommendations for a standard method for the description and classification of rocks and soils for use in engineering geological mapping.

A unified method for desribing both rocks and soils is proposed, taking into account a selected, limited number of material and mass properties. Each of the respective material and mass properties is classified, and a description may be based on actual values of each property, statistically determined mean values, or classes or combinations of classes for each property.

There are many properties of rocks and soils that may be determined by laboratory tests. These are listed in Appendix A (13.1) and Appendix B (13.2). The properties listed may be classified and used either for additional descriptive purposes or for direct classification. There are also properties of the soil and rock mass that may be determined by **in situ** testing (Appendix C, 13.3; Appendix D, 13.4).

Lithological classification is based on the main genetic groups of rocks: igneous, sedimentary and metamorphic, but sedimentary rocks and soils are classified separately because of the fundamentally different methods of classification for rock and soil adopted for engineering purposes. The classification of rocks, including sedimentary rocks, is a simplified geological classification, whereas the classification of engineering soils is essentially an engineering classification based on particle size analysis and the influence of particle size grading on engineering properties.

An engineering geological classification of rocks and soils for engineering geological mapping, related to the scale of the map, involves the Engineering Geological Type at the largest scale, and at progressively smaller scales the Lithological Type, the Lithological Complex and the Lithological Suite.

Characterisation of the Engineering Geological Type, and hence its recognition as a mapping unit, depends on the assessment of engineering geological and engineering properties. Conventional engineering geological methods may be used to characterise Lithological Types and simpler methods are used for the characterisation of the Lithological Complex and the Lithological Suite.

Departure from standard geological techniques is marked by the acceptance of distinctive mapping units recognised on the basis of similarity of lithology and lithological associations regardless of geological age differences.

The Engineering Geological Type is the mapping unit that is most distinctively engineering geological in character. From the point of view of engineering behaviour, the Engineering Geological Type is the largest engineering unit that can be expected to have uniform engineering design characteristics. Engineering design properties of the rock mass, as distinct from rock material, are determined by a limited number of relatively expensive **in situ** tests. Correlation between the results of the **in situ** tests and an engineering geological description of the rock or soil mass enables the limited test results to be applied to the whole mapped outcrop of each individual, homogeneous Engineering Geological Type that has been tested.

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13. APPENDICES

13.1 APPENDIX A: A list of laboratory tests on soil which may be used for the characterisation for engineering geological types.

13.1.1 Soil Classification Test

Moisture content
Liquid and plastic limits (Atterberg Limits)
Cone penetration limit
Linear shrinkage
Specific gravity
Particle size distribution: sieving
sedimentation

13.1.2 Soil Chemical Tests

Organic matter
Sulphate content of soil and groundwater
pH value
Carbonate content
Chloride content

13.1.3 Soil Compaction Tests

Dry density of soil
Dry density/moisture content
Relative density of cohesionless soil

13.1.4 Soil Strength Tests

Triaxial compression: undrained
: undrained with measurement of pore-water pressure
: consolidated undrained
: consolidated undrained with measurement of pore-water pressure
: consolidated drained
: multi-stage triaxial test
: free-end test

Unconfined compressive strength

Laboratory vane shear

Direct shear-box : immediate
: consolidated immediate
: drained

Residual shear strength : multiple reversal shear box
: triaxial test with preformed shear surface
: shear-box with preformed shear surface

Ring shear test

13.1.5 Soil Deformation Tests

Consolidation : one-dimensional consolidation properties (Oedometer Test)
: triaxial consolidation
: Rowe consolidation cell

Elastic modulus

13.1.6 Soil Permeability Tests

Constant head permeability test
Falling head permeability test
Triaxial permeability test
Rowe consolidation cell test

13.1.7 Soil Corrosivity Tests

Bacteriological tests
Redox potential

13.2 APPENDIX B: A list of laboratory tests on rock which may be used for the characterisation of engineering geological types

13.2.1 Rock Classification Tests

Saturation moisture content
Bulk density
Moisture content
Porosity
Thin section examination
Slake durability
Carbonate content
Swelling test

13.2.2 Dynamic Tests

Seismic velocity
Dynamic modulus

13.2.3 Rock Strength Tests

Point load test
Uniaxial compression
Indirect tensile strength, diametral compression
Brazilian Test
Triaxial compression: undrained
: undrained, with measurement of pore-water pressure
Direct shear box

13.2.4 Rock Deformation Tests

Static elastic modulus
Creep tests : undrained
: constant load
: triaxial

13.2.5 Rock Permeability Tests

Triaxial cell
Centrifugal
Radial

13.2.6 Rock Durability Tests

Sulphate soundness test
Freeze-thaw test
Slake durability test

13.3 APPENDIX C: A list of **in situ** tests on soils which may be used for the characterisation of engineering geological types

13.3.1 Soil Strength Tests

Standard penetration test
Cone penetration test
Vane test
Plate load test
Pressuremeter test
In situ shear tests

13.3.2 Soil Deformation Tests

Plate load test
Pressuremeter test

13.3.3 Soil Permeability Tests

Variable head tests
Constant head test
Pumping tests

13.3.4 Soil Density

Bulk density : Sand replacement method
: Core cutter method
: Rubber balloon method
: Nuclear method

13.3.5 **In situ** Stress Measurements

13.4 APPENDIX D: A list of **in situ** tests on rocks which may be used for the characterisation of engineering geological types

13.4.1 Rock Strength Tests

Plate load test
Pressuremeter test
In situ shear test

13.4.2 Rock Deformation Tests

Plate load tests
Pressuremeter test

13.4.3 Rock Permeability Test

Packer test
Pumping tests

13.4.5 In situ Stress Measurements

14. APPENDIX E: Other Standard Soil Classifications

Because there is no international soil classification system, other national systems are presented here.

14.1 The Unified Soil Classification System (UCS)

The Unified Soil Classification System, developed in the United States (Casagrande, 1948; Anon., 1960; USBR, 1963), is recognised the world over, and is a textural-plasticity type of soil classification system (cf Section 4). In general two primary soil groups are recognised; the coarse-grained or granular group and the fine-grained group; a subsidiary third group is the highly organic (peaty) group.

Classification on the basis of laboratory test results requires the determination of grain size analysis and the determination of liquid and plastic limit. With experience it can also be used as the basis of a field classification. Details of the Unified System are set out in Table 27, and the classification is given in detail and discussed in Liu (1970), Anon. (1972a) and Schroeder (1975). The UCS is used in Australia.

14.2 French Classification of Soils

The French Soil Classification is similar to the British Soil Classification for Engineering Purposes (BSCS) (Section 4), but includes two classes (Class E and F, Table 28) that are not considered in the BSCS. One is for rock materials which change to soil when used as 'engineered-fill' (Section 7.1). The other includes soils with soluble minerals and so-called 'non-engineered fill' (Section 7.2).

14.2.1 Principles on which the classification is based

Les sols sont répartis en six classes, définies en fonction des caractéristiques intrinsèques qui influent le plus sur leur comportement à la mise en oeuvre et par conséquent sur les conditions d'utilisation à respecter pour obtenir des remblais et des couches de forme de qualité normale.

Les difficultés d'extraction ne sont pas prises en compte dans cette classification.

Chaque classe est divisée en sous-classes en fonction des caractéristiques intrinsèques les plus importantes pour chaque classe, toujours du point de vue de la mise en oeuvre.

Dans chaque sous-classe on distingue un certain nombre de cas pour tenir compte de l'état du matériau en place; la teneur en eau est le paramètre d'état le plus important pour les sols; on considère aussi la densité et la friabilité pour les roches évolutives.

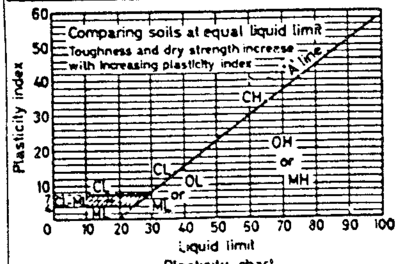
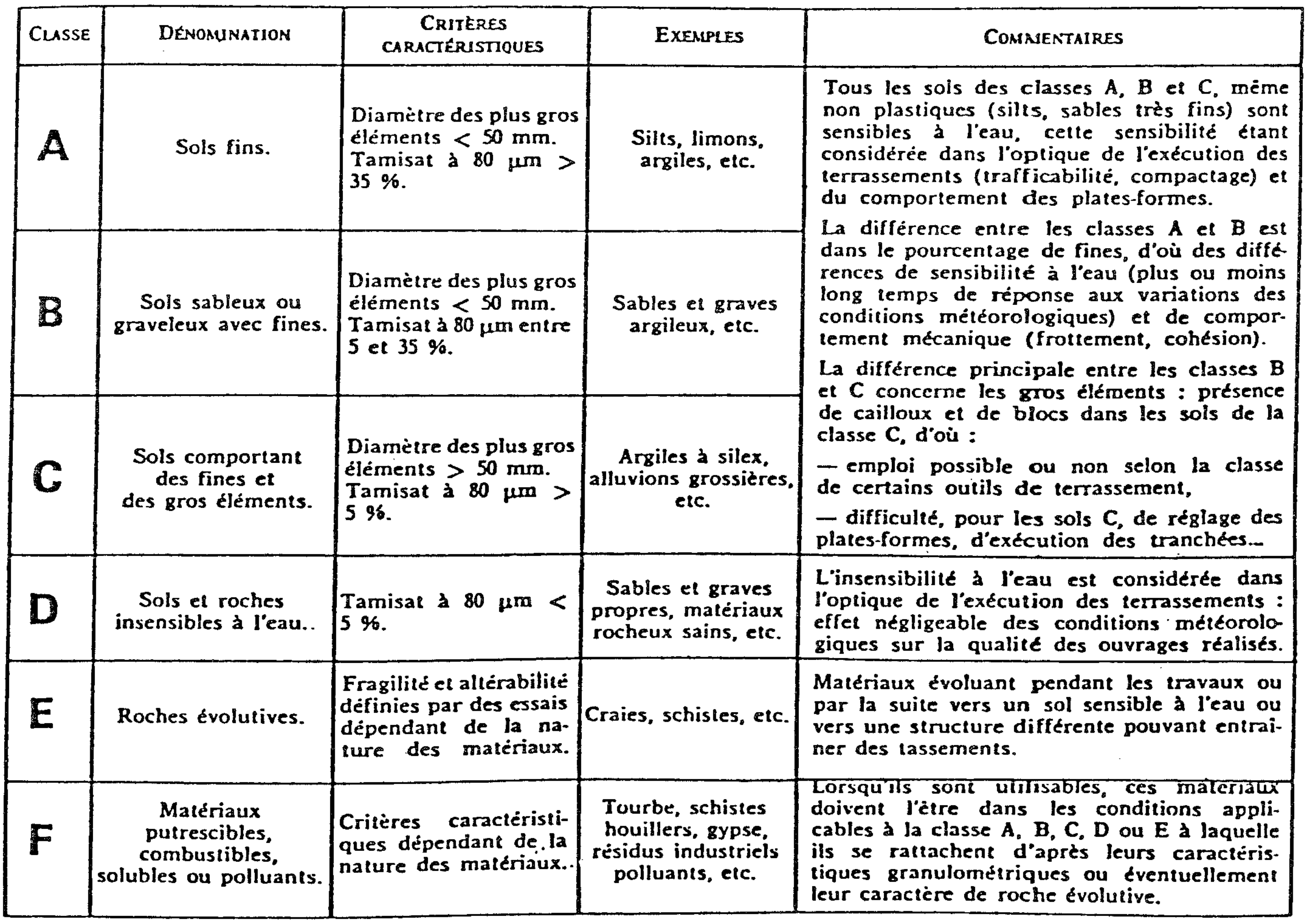
Field identification procedures (Excluding particles larger than 3 in. and basing fractions on estimated weights)								*Group symbols* 1	*Typical names*	*Information required for describing soils*	*Laboratory classification criteria*			
Coarse grained soils *More than half of material is larger than No. 200 sieve size*[1]	(The No. 200 sieve size is about the smallest particle visible to naked eye)	*Gravels* *More than half of coarse fraction is larger than No. 4 sieve size*	*(For visual classification, the ¼ in. size may be used as equivalent to the No. 4 sieve size)*	*Clean gravels (little or no fines)*	Wide range in grain size and substantial amounts of all intermediate particle sizes			*GW*	Well graded gravels, gravel-sand mixtures, little or no fines	Give typical name; indicate approximate percentages of sand and gravel; maximum size; angularity, surface condition, and hardness of the coarse grains; local or geologic name and other pertinent descriptive information; and symbol in parentheses For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions and drainage characteristics *Example*: *Silty sand*, gravelly; about 20% hard, angular gravel particles ½-in. maximum size; rounded and subangular sand grains coarse to fine, about 15% non-plastic lines with low dry strength; well compacted and moist in place; alluvial sand; (*SM*)	Use grain size curve in identifying the fractions as given under field identification	Determine percentages of gravel and sand from grain size curve Depending on percentage of fines (fraction smaller than No. 200 sieve size) coarse grained soils are classified as follows: Less than 5% *GW, GP, SW, SP* More than 12% *GM, GC, SM, SC* 5% to 12% *Borderline* cases requiring use of dual symbols	$CU = \frac{D_{60}}{D_{10}}$ Greater than 4 $Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3	
					Predominantly one size or a range of sizes with some intermediate sizes missing			*GP*	Poorly graded gravels, gravel-sand mixtures, little or no fines				Not meeting all gradation requirements for *GW*	
				Gravels with fines (appreciable amount of fines)	Non-plastic fines (for identification procedures see *ML* below)			*GM*	Silty gravels, poorly graded gravel-sand-silt mixtures				Atterberg limits below 'A' line, or *PI* less than 4	Above 'A' line with *PI* between 4 and 7 are *borderline* cases requiring use of dual symbols
					Plastic fines (for identification procedures, see *CL* below)			*GC*	Clayey gravels, poorly graded gravel-sand-clay mixtures				Atterberg limits above 'A' line, with *PI* greater than 7	
		Sands *More than half of coarse fraction is smaller than No. 4 sieve size*		*Clean sands (little or no fines)*	Wide range in grain sizes and substantial amounts of all intermediate particle sizes			*SW*	Well graded sands, gravelly sands, little or no fines				$CU = \frac{D_{60}}{D_{10}}$ Greater than 6 $Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3	
					Predominantly one size or a range of sizes with some intermediate sizes missing			*SP*	Poorly graded sands, gravelly sands, little or no fines				Not meeting all gradation requirements for *SW*	
				Sands with fines (appreciable amount of fines)	Non-plastic fines (for identification procedures, see *ML* below)			*SM*	Silty sands, poorly graded sand-silt mixtures				Atterberg limits below 'A' line or *PI* less than 4	Above 'A' line with *PI* between 4 and 7 are *borderline* cases requiring use of dual symbols
					Plastic fines (for identification procedures, see *CL* below)			*SC*	Clayey sands, poorly graded sand-clay mixtures				Atterberg limits shows 'A' line with *PI* greater than 7	
Fine grained soils *More than half of material is smaller than No. 200 sieve size*		*Identification procedures on fraction smaller than No. 40 sieve size*												
					Dry strength (crushing characteristics)	*Dilatancy (reaction to shaking)*	*Toughness (consistency near plastic limit)*							
		Silts and clays liquid limit less than 50			None to slight	Quick to slow	None	*ML*	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity	Give typical name; indicate degree and character of plasticity, amount and maximum size of coarse grains; colour in wet condition, odour if any, local or geologic name, and other pertinent descriptive information, and symbol in parentheses For undisturbed soils add information on structure, stratification, consistency in undisturbed and remoulded states, moisture and drainage conditions *Example*: *Clayey silt*, brown; slightly plastic; small percentage of fine sand; numerous vertical root holes; firm and dry in place; loess; (*ML*)		 Plasticity chart for laboratory classification of fine grained soils		
					Medium to high	None to very slow	Medium	*CL*	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays					
					Slight to medium	Slow	Slight	*OL*	Organic silts and organic silt-clays of low plasticity					
		Silts and clays liquid limit greater than 50			Slight to medium	Slow to none	Slight to medium	*MH*	Inorganic silts, micaceous or dictomaceous fine sandy or silty soils, elastic silts					
					High to very high	None	High	*CH*	Inorganic clays of high plasticity, fat clays					
					Medium to high	None to very slow	Slight to medium	*OH*	Organic clays of medium to high plasticity					
Highly organic soils					Readily identified by colour, odour, spongy feel and frequently by fibrous texture			*Pt*	Peat and other highly organic soils					

Table 27: The Unified Soil Classification System (No. 200 sieve size is 0.074 mm; No. 4 sieve size is 4.76 mm)

14.2.2 Definition of classes: general features



CLASSE	DÉNOMINATION	CRITÈRES CARACTÉRISTIQUES	EXEMPLES	COMMENTAIRES
A	Sols fins.	Diamètre des plus gros éléments < 50 mm. Tamisat à 80 µm > 35 %.	Silts, limons, argiles, etc.	Tous les sols des classes A, B et C, même non plastiques (silts, sables très fins) sont sensibles à l'eau, cette sensibilité étant considérée dans l'optique de l'exécution des terrassements (trafficabilité, compactage) et du comportement des plates-formes. La différence entre les classes A et B est dans le pourcentage de fines, d'où des différences de sensibilité à l'eau (plus ou moins long temps de réponse aux variations des conditions météorologiques) et de comportement mécanique (frottement, cohésion). La différence principale entre les classes B et C concerne les gros éléments : présence de cailloux et de blocs dans les sols de la classe C, d'où : — emploi possible ou non selon la classe de certains outils de terrassement, — difficulté, pour les sols C, de réglage des plates-formes, d'exécution des tranchées...
B	Sols sableux ou graveleux avec fines.	Diamètre des plus gros éléments < 50 mm. Tamisat à 80 µm entre 5 et 35 %.	Sables et graves argileux, etc.	
C	Sols comportant des fines et des gros éléments.	Diamètre des plus gros éléments > 50 mm. Tamisat à 80 µm > 5 %.	Argiles à silex, alluvions grossières, etc.	
D	Sols et roches insensibles à l'eau..	Tamisat à 80 µm < 5 %.	Sables et graves propres, matériaux rocheux sains, etc.	L'insensibilité à l'eau est considérée dans l'optique de l'exécution des terrassements : effet négligeable des conditions météorologiques sur la qualité des ouvrages réalisés.
E	Roches évolutives.	Fragilité et altérabilité définies par des essais dépendant de la nature des matériaux.	Craies, schistes, etc.	Matériaux évoluant pendant les travaux ou par la suite vers un sol sensible à l'eau ou vers une structure différente pouvant entraîner des tassements.
F	Matériaux putrescibles, combustibles, solubles ou polluants.	Critères caractéristiques dépendant de la nature des matériaux..	Tourbe, schistes houillers, gypse, résidus industriels polluants, etc.	Lorsqu'ils sont utilisables, ces matériaux doivent l'être dans les conditions applicables à la classe A, B, C, D ou E à laquelle ils se rattachent d'après leurs caractéristiques granulométriques ou éventuellement leur caractère de roche évolutive.

Table 28: Definition of soil classes

14.2.3 Detailed classification tables for soil classes A to F

The tables on the following pages give a detailed classification for each of the soil classes A to F.

14.2.3.1 Fine soils: Class A

Sous-classe	Sols les plus fréquemment rencontrés	Caractères principaux	Classement d'après l'état du sol		
			Moyens d'évaluation de l'état	Cas possibles	Commentaires
A_1 $I_p < 10$	Limons peu plastiques. Loess. Silts alluvionnaires. Sables fins peu pollués. Arènes peu plastiques. Sols à micro-fossiles poreux. Cendres volantes.	Ces sols changent totalement de consistance pour de faibles variations de w ou pour de faibles variations de compacité si w est proche de w_p. Le temps de réaction aux variations de l'environnement hydrique et climatique est relativement court, mais la perméabilité pouvant varier dans de larges limites selon la granulométrie et la plasticité, ce temps de réaction peut aussi varier largement. Les moins plastiques de ces sols ont un comportement mécanique particulier (possibilité de rupture fragile : fissuration).	L'état du sol est déterminé par sa teneur en eau w. On peut : — mesurer w et la comparer à w_{OPN} ; — ou déterminer le CBR immédiat ; — ou évaluer visuellement la consistance du matériau. L'indice de plasticité est trop faible pour utiliser l'indice de consistance.	A_1h Teneur en eau élevée (h = humide).	En raison de la rapidité des variations de consistance de ces sols, une certaine marge de sécurité doit être prise. On peut considérer en moyenne que w est élevée si : $w > w_{OPN} + 1$ ou CBR < 8
				A_1m Teneur en eau moyenne (m = moyenne).	La marge de w moyenne pour ces sols est relativement faible ; en moyenne : $w_{OPN} - 2 < w < w_{OPN} + 1$ ou $8 <$ CBR < 25.
				A_1s Teneur en eau faible (s = sec).	On peut considérer en moyenne que w est faible si : $w < w_{OPN} - 2$ ou CBR > 25.
A_2 I_p 10 à 20	Sables fins argileux. Limons. Argiles et marnes peu plastiques. Arènes.	Le caractère moyen des sols de cette sous-classe fait qu'ils se prêtent à l'emploi de la plus large gamme d'outils de terrassement (si la teneur en eau n'est pas trop élevée) et d'essais de laboratoire et de chantier.	L'état du sol est déterminé par sa teneur en eau w. On peut évaluer l'état du sol par les mêmes moyens que pour les sols A_1, à savoir : — w comparée à w_{OPN}, — ou CBR immédiat, — ou évaluation visuelle de la consistance, auxquels s'ajoute l'indice de consistance I_c pour les sols les plus plastiques de la sous-classe.	A_2h Teneur en eau élevée.	On peut considérer en moyenne que w est élevée si : $w > w_{OPN} + 2$ ou CBR < 5 ou $I_c < 1$
				A_2m Teneur en eau moyenne.	En moyenne si : $w_{OPN} - 2 < w < w_{OPN} + 2$ ou $5 <$ CBR < 15 ou $1 < I_c < 1{,}2$
				A_2s Teneur en eau faible.	En moyenne si : $w < w_{OPN} - 2$ ou CBR > 15 ou $I_c > 1{,}2$
A_3 I_p 20 à 50	Argiles. Marnes. Limons très plastiques.	Ces sols sont très cohérents à teneur en eau moyenne et faible et collants ou glissants à l'état humide, d'où difficultés de mise en œuvre sur chantier (et de manipulation en laboratoire). Leur perméabilité très réduite rend très lentes leurs variations de teneur en eau en place. Une augmentation de teneur en eau assez importante est nécessaire pour changer notablement leur consistance.	L'état du sol est déterminé par sa teneur en eau w. L'évaluation de l'état se fait par les mêmes moyens que pour les sols A_2, mais pour les sols les plus cohérents de la sous-classe A_3 (soit par plasticité élevée, soit par w faible) les essais donnent des résultats fortement dispersés en fonction du fractionnement du matériau et du degré d'homogénéité de la teneur en eau.	A_3h Teneur en eau élevée.	On peut considérer en moyenne que w est élevée si : $w > w_{OPN} + 4$ ou CBR < 3 ou $I_c < 0{,}9$
				A_3m Teneur en eau moyenne.	La lenteur des variations de consistance permet de considérer comme moyenne une gamme de teneur en eau relativement large (peu d'évolution de consistance en cours de mise en œuvre) ; en moyenne : $w_{OPN} - 4 < w < w_{OPN} + 4$ ou $3 <$ CBR < 15 ou $0{,}9 < I_c < 1{,}3$
				A_3s Teneur en eau faible.	En moyenne si : $w < w_{OPN} - 4$ ou CBR > 15 ou $I_c > 1{,}3$
A_4 $I_p > 50$	Argiles et marnes très plastiques.	Ces sols sont très fortement cohérents et presque imperméables ; s'ils changent de teneur en eau, c'est extrêmement lentement et avec d'importants retraits ou gonflements.	Ces sols n'étant pas normalement utilisés, les moyens d'évaluation de leur état ne sont pas décrits ici.		

Table 29: Classification A. Fine soils
D less than 50 mm; More than 35 % smaller than 80 μm.

14.2.3.2 Sandy and gravelly soils with fines: Class B

SOUS-CLASSE			SOLS LES PLUS FRÉQUEMMENT RENCONTRÉS	CARACTÈRES PRINCIPAUX	CLASSEMENT D'APRÈS L'ÉTAT DU SOL		
< 80 µm	> 2 mm	ES			MOYENS D'ÉVALUATION DE L'ÉTAT	CAS POSSIBLES	COMMENTAIRES
5 à 12 %	< 30 %	B_1 > 35	Sables silteux.	Leurs fines étant en pourcentage limité et peu ou pas plastiques, ces sols se comportent comme des sols insensibles à l'eau.	Voir classe D.		Voir classe D.
		B_2 < 35	Sables argileux (peu argileux).	La plasticité de leurs fines rend ces sols sensibles à l'eau. Leur temps de réaction aux variations de l'environnement hydrique et climatique est court, tout en pouvant varier assez largement (fonction de la perméabilité).	L'état du sol est déterminé par sa teneur en eau w. On peut : — mesurer w et la comparer à w_{OPN}. — ou déterminer le CBR immédiat (sauf dans le cas de w faible), — ou évaluer visuellement la consistance du sol.	B_2h Teneur en eau élevée.	On peut considérer en moyenne que w est élevée si : $w > w_{OPN} + 2$ ou $CBR < 8$
						B_2m Teneur en eau moyenne.	En moyenne si : $w_{OPN} - 1 < w < w_{OPN} + 2$ ou $CBR > 8$ sans être très élevé.
						B_2s Teneur en eau faible.	En moyenne si : $w < w_{OPN} - 1$ le CBR est inadapté à l'identification de ces sols à teneur en eau faible.
	> 30 %	B_3 > 25	Graves silteuses.	Cf. ci-dessus B_1.	Voir classe D.		Voir classe D.
		B_4 < 25	Graves argileuses (peu argileuses).	La plasticité de leurs fines rend ces sols sensibles à l'eau. Ils sont plus graveleux que les sols B_2 et leur fraction sableuse est plus faible. Pour cette raison ils sont en général assez perméables pour pouvoir s'essorer en dépôt provisoire. Ils réagissent très rapidement aux variations de l'environnement hydrique et climatique (humidification - drainage, séchage).	L'état du sol est déterminé par sa teneur en eau w. On peut comme pour les sols B_2 : — comparer w à w_{OPN}. — ou déterminer le CBR immédiat (sauf cas w faible), — ou évaluer visuellement la consistance. Pour les plus grossiers des sols B_4 on atteint les limites des essais Proctor et CBR. Dans le cas où le sol est sous la nappe, les caractéristiques de la nappe sont à prendre en compte (possibilités de rabattement par pompage).	B_4h Teneur en eau élevée.	On peut considérer en moyenne que w est élevée si : $w > w_{OPN} + 2$ ou $CBR < 8$
						B_4m Teneur en eau moyenne	En moyenne si : $w_{OPN} - 1 < w < w_{OPN} + 2$ ou $CBR > 8$ sans être très élevé.
						B_4s Teneur en eau faible.	En moyenne si : $w < w_{OPN} - 1$ le CBR est inadapté à l'identification de ces sols à teneur en eau faible.
						B_4i Sol immergé sous la nappe (i = immergé).	On distingue ce cas de celui de w élevée car des conditions particulières d'extraction sous l'eau peuvent s'y appliquer et permettre des utilisations intéressantes (cf. indications relatives à ce cas dans les chapitres relatifs à l'utilisation en remblai et en couche de forme).

Table 30: Classification B. Sandy and gravelly soils with fines
D less than 50 mm; Under 80 μm fraction between 5 and 35 %

SOUS-CLASSE		SOLS LES PLUS FRÉQUEMMENT RENCONTRÉS	CARACTÈRES PRINCIPAUX	CLASSEMENT D'APRÈS L'ÉTAT DU SOL		
< 80 µm	I_p			MOYENS D'ÉVALUATION DE L'ÉTAT	CAS POSSIBLES	COMMENTAIRES
12 à 35 %	B_5 $I_p < 10$	Sables et graves très silteux.	La proportion de fines et la faible plasticité de ces dernières rapprochent beaucoup le comportement de ces sols de celui des sols A_1.	Voir classe A_1.	B_5h	Voir classe A_1.
					B_5m	
					B_5s	
	B_6 $I_p > 10$	Sables et graves argileuses (très argileux).	L'influence des fines est prépondérante ; le comportement du sol se rapproche de celui du sol fin ayant même plasticité que les fines du sol (définies pour les limites d'Atterberg comme étant les < 400 µm). Cependant, la présence de la fraction sableuse et graveleuse les rend plus rapidement sensibles à l'influence de l'eau, la fraction fine plastique (sur laquelle l'eau agit surtout) étant réduite.	L'état du sol est déterminé par sa teneur en eau w, à laquelle peut s'ajouter éventuellement la densité ou la cohésion en place pour les plus plastiques. L'état peut être évalué par les mêmes moyens que pour les sols fins, à savoir : — w comparée à w_{OPN}, ou CBR immédiat, ou indice de consistance des < 400 µm, ou évaluation visuelle. Il faut faire des réserves pour les essais Proctor et CBR si la fraction graveleuse est importante.	B_6h Teneur en eau élevée.	On peut considérer en moyenne que la teneur en eau de ces sols est élevée si : $w > w_{OPN} + 2$ ou CBR < 8 ou $I_c < 1$
					B_6m Teneur en eau moyenne.	En moyenne si : $w_{OPN} - 2 < w < w_{OPN} + 2$ ou CBR > 8 sans être très élevé ou $1 < I_c < 1{,}2$
					B_6s Teneur en eau faible.	En moyenne si : $w < w_{OPN} - 2$ ou $I_c > 1{,}2$

Table 30: continued

14.2.3.3 Mixtures of very coarse soils with finer materials: Class C

SOUS-CLASSE		SOLS LES PLUS FRÉQUEMMENT RENCONTRÉS	CARACTÈRES PRINCIPAUX	CLASSEMENT D'APRÈS L'ÉTAT DU SOL.		
< 80 µm	D			MOYENS D'ÉVALUATION DE L'ÉTAT	CAS POSSIBLES	COMMENTAIRES
Elevé (> 10 à 20 % selon que la granulométrie est plus ou moins continue).	C_1 (pas de condition sur D pour la classe C_1)	Argiles à silex. Argiles à meulière. Eboulis. Moraines. Roches altérées. Alluvions grossières.	Le pourcentage de fines (< 80 µm) définissant cette classe correspond au fait que les gros éléments sont noyés dans la fraction plastique du matériau ; le comportement global du sol se rapproche donc de celui de cette fraction. Si la granulométrie du sol est nettement discontinue le tamisat à 80 µm doit atteindre environ 20 % ; si elle est plus continue, ce tamisat est plus faible. Le comportement de la fraction fine dépend de sa plasticité (cf. caractères principaux des sols de la classe A).	L'état du sol est déterminé par la teneur en eau de la fraction inférieure à 20 mm ; on peut : — déterminer le CBR immédiat sur cette fraction ; ou mesurer sa teneur en eau et la comparer à w_{OPN} ; ou évaluer visuellement la consistance du matériau.	C_1h Teneur en eau élevée.	Les limites entre les teneurs en eau élevée, moyenne et faible sont fonction de la plasticité de la fraction fine du sol (cf. classe A). Le plus souvent on peut considérer que w est élevée si : CBR < 3 ou $w > w_{OPN} + 4$
					C_1m Teneur en eau moyenne.	Le plus souvent si : 3 < CBR < 15 ou $w_{OPN} - 2 < w < w_{OPN} + 4$
					C_1s Teneur en eau faible.	Le plus souvent si : CBR > 15 ou $w < w_{OPN} - 2$
Faible (< 10 à 20 % selon que la granulométrie est plus ou moins continue).	C_2 D < 250 mm	Argiles à silex. Argiles à meulière. Eboulis. Moraines. Roches altérées. Alluvions grossières.	Lorsque ces sols sont dans un état relativement compact il y a contact entre les éléments de la fraction granulaire. La fraction fine intervient cependant sur le comportement, notamment en rendant le sol peu perméable et en réduisant la profondeur d'action des compacteurs.	L'état du sol dépend de la teneur en eau de la fraction < 20 mm, mais il est difficile en pratique de déterminer cette teneur en eau (volume important de matériau à manipuler, risque de manque de représentativité des prélèvements). C'est pourquoi aucune valeur chiffrée ne figure dans la colonne « commentaires ». En pratique l'évaluation de la consistance de la fraction plastique se fait par examen direct du sol.	C_2h	
					C_2m	
					C_2s	
Faible (< 10 à 20 % selon que la granulométrie est plus ou moins continue).	C_3 D > 250 mm	Argiles à silex. Argiles à meulière. Eboulis. Moraines. Roches altérées. Alluvions grossières.	Mêmes caractères que les sols C_2, avec en plus la présence de gros éléments constituant un obstacle au régalage des couches et au réglage des plates-formes.	L'état du sol dépend de la teneur en eau de la fraction < 20 mm, mais il est difficile en pratique de déterminer cette teneur en eau (volume important de matériau à manipuler, risque de manque de représentativité des prélèvements). C'est pourquoi aucune valeur chiffrée ne figure dans la colonne « commentaires ». En pratique l'évaluation de la consistance de la fraction plastique se fait par examen direct du sol.	C_3h	
					C_3m	
					C_3s	

Table 31: Classification C. Mixtures of very coarse soils with finer materials
D more than 50 mm; Under 80 µm fraction more than 5 %

14.2.3.4 Coarse and very coarse soils: Class D

Sous-classe		Sols les plus fréquemment rencontrés	Caractères principaux	Classement d'après l'état du sol		
D	> 2 mm			Moyens d'évaluation de l'état	Cas possibles	Commentaires
< 50 mm	D_1 < 30 %	Sables alluvionnaires propres. Sables de dune.	Ces sols sont sans cohésion et perméables. Leur granulométrie souvent mal graduée et de petit calibre les rend très érodables et d'une traficabilité difficile.			
	D_2 > 30 %	Graves alluvionnaires propres. Sables.	Ces sols sont sans cohésion et perméables. Après compactage ils sont d'autant moins érodables et d'autant plus aptes à supporter le trafic qu'ils sont bien gradués.			
D_3 50 < D < 250		Graves alluvionnaires propres. Matériaux rocheux non évolutifs.	Matériaux sans cohésion et perméables inadaptés au malaxage en vue d'un traitement et pouvant poser des problèmes d'exécution de tranchée ou de réglage.			
D_4 D > 250		Graves alluvionnaires propres. Matériaux rocheux non évolutifs.	Matériaux sans cohésion et perméables. Posent des problèmes de réglage et d'exécution de tranchée.			

Table 32: Classification D. Coarse and very coarse soils
Under 80 μm fraction less than 5 %

14.2.3.5 Rocks which become soils on working and placing as 'engineered fill': Class E

Note préliminaire
Les matériaux de cette classe constituent la transition entre les matériaux rocheux et les sols. Ils peuvent se définir par les caractères suivants:

- ils possèdent à l'état naturel une résistance due à leur structure, celle-ci comportant des liaisons autres que celles due à la présence d'argile ou à la capillarité;
- cette résistance, tout en étant généralement plus élevée que celle d'un sol, est cependant suffisamment faible pour ne pas résister à toutes les manipulations de mise en oeuvre ou aux nouvelles conditions d'environnement introduites par les travaux.

Le fait de terrasser ces matériaux entraîne des modifications de leur structure et, par conséquent, de leur comportement géotechnique; pour cette raison ils sont dits »évolutifs«.

L'évolution de ces matériaux, qui consiste en une destruction partielle ou totale des liaisons de structure, se fait principalement selon deux processus:

- par action mécanique externe (écrasement, attrition), soit en cours d'exécution des travaux sous l'effet des engins de chantier, soit ultérieurement, au sein du remblai, sous l'effet des charges statiques ou dynamiques;
- par modification interne, les liaisons étant détruites au sein du matériau par suite de différents phénomènes tels qu'efforts internes dus au gonflement de l'argile éventuellement présente, dissolution du ciment créant les liaisons, ou autres phénomènes physico-chimiques.

Pratiquement deux conséquences de l'évolution de ces matériaux peuvent être néfastes:

- le sol résultant de cette évolution peut avoir des caractéristiques géotechniques inadaptées aux conditions dans lesquelles il est réutilisé (sensibilité à l'eau, compactage, propriétés mécaniques nécessaires à la stabilité des remblais, etc.);
- la destruction progressive de la structure naturelle des blocs présents dans les remblais peut entraîner un réarrangement du matériau et par conséquent des tassements, qui résultent soit du comblement des vides entre blocs, soit du fait que la densité du matériau produit par la destruction des blocs est plus élevée que celle des blocs eux-mêmes.

On peut classer les roches évolutives en fonction des caratères principaux du sol produit par leur évolution:

- sol essentiellement non argileux fin (sensible à l'eau);
- sol essentiellement non argileux grossier (peu ou pas sensible à l'eau);
- sol argileux.

SOUS-CLASSE	SOLS LES PLUS FRÉQUEMMENT RENCONTRÉS	CARACTÈRES PRINCIPAUX	CLASSEMENT D'APRÈS L'ÉTAT DU SOL				
			MOYENS D'ÉVALUATION DE L'ÉTAT	CAS POSSIBLES			COMMENTAIRES
E_1 Matériaux à structure *fine* fragile avec peu ou pas d'argile.	**Craie** (Matériau rocheux peu compact contenant plus de 95 % de $CaCO_3$)	La craie est un empilement de particules de calcite dont la dimension est de l'ordre du micron à la dizaine de microns. Cet empilement constitue une structure assez fragile d'une forte porosité (environ 40 %) et d'une succion très élevée (pas de drainage en-dessous de pF = 3). Les fines produites par écrasement et attrition peuvent être de très faibles dimensions (1 à 10 µm) et n'ont aucune plasticité ; elles se situent parmi les sols de la classe A_1.	L'état du sol est déterminé par sa densité, sa teneur en eau et sa friabilité.	**CRa** craie dense.			$\gamma_d > 1{,}70$
				Craie peu dense $\gamma_d <$ 1,70	**CRb** teneur en eau faible ou moyenne.		La teneur en eau peut en général être considérée comme moyenne ou faible si elle est inférieure à 20 %.
					Teneur en eau élevée.	**CRc** friabilité faible.	La teneur en eau peut en général être considérée comme élevée si elle dépasse 20 %.
						CRd friabilité forte.	La friabilité s'apprécie par des essais de compactage répétés ou de vibrobroyage [voir documents spécialisés tels que le *Bulletin spécial* V *des Laboratoires des Ponts et Chaussées,* La craie (oct. 1973)].
	Matériaux gréseux fins, loess non remanié, etc.		Les principes ci-dessus sont applicables, au moins en partie, au classement des matériaux E_1 autres que la craie, les valeurs numériques à retenir devant être définies par une étude particulière.				
E_2 Matériaux à structure grossière fragile avec peu ou pas d'argile.	Matériaux gréseux grossiers, poudingues, etc.	L'évolution de ces matériaux donne un sol peu ou pas sensible à l'eau du type **B_1** à **B_4** ou **D**.	En cours d'étude.				
E_3 Matériaux évolutifs argileux.	Marnes. Schistes.	L'évolution de ces matériaux donne un sol argileux dont la fraction fine est du type **A_2**, **A_3** ou éventuellement **A_4**. Selon son stade d'évolution le matériau total se rapproche de la classe **C**, **B** ou **A**.	En cours d'étude.				

Table 33: Classification E. Rocks which become soils on working and placing as 'engineered fill'

14.2.3.6 Materials that are decomposible, combustible, soluble and pollutant: Class F

Sous-classe		Matériaux les plus fréquemment rencontrés	Observations générales
Matériaux putrescibles.	$3\% < MO < 10\%$	Terres végétales. Vases. Ordures ménagères insuffisamment incinérées. Découvertes d'emprunts, de carrières...	L'emploi de ces matériaux pour constituer des couches de forme est à proscrire, mais leur utilisation en remblai de hauteur faible ou moyenne est possible conformément aux conditions de terrassement définies pour la classe granulométrique et de plasticité à laquelle ils se rattachent. On peut améliorer leur qualité géotechnique (nature et état) en les traitant (à la chaux le plus fréquemment), mais du fait de la présence des matières organiques, il peut être nécessaire de traiter à des dosages élevés. Dans tous les cas une étude technico-économique est donc à faire. Le décapage de la terre végétale sous l'assiette des remblais de moyenne et grande hauteur ne doit pas être systématique, mais décidé en fonction des besoins en terre végétale et de la nature et de l'état du terrain naturel (une bonne couverture végétale constitue une couche anticontaminante et drainante et augmente la traficabilité sur un sol mou). Pour les conditions d'utilisation de la terre végétale en vue de l'engazonnement et des plantations, se référer aux documents spécialisés.
	$MO > 10\%$	Mêmes matériaux que ci-dessus. Humus forestier. Ordures ménagères non incinérées. Tourbes. Déchets industriels de papeteries, sucreries, etc.	Ces matériaux ne doivent être utilisés ni en remblai, ni en couche de forme en raison des transformations bio-chimiques qui s'y produisent et qui peuvent provoquer tassements et retraits-gonflements. Par ailleurs, ils possèdent en règle générale de très mauvaises caractéristiques mécaniques qui ne peuvent être améliorées pour un prix actuellement raisonnable par un traitement quelconque. L'observation faite sur le décapage de la terre végétale reste cependant valable lorsque sa teneur en matières organiques dépasse 10 %. L'humus forestier peut pallier à un manque de terre végétale après criblage et amendement et être utilisé pour la protection des talus.
Matériaux combustibles.		Stériles houillers stockés en terrils.	Le carbone restant dans ces matériaux peut s'auto-enflammer lorsqu'ils sont stockés à l'air libre dans un état relativement foisonné. Lorsque cette auto-combustion est terminée ils constituent en général de bons matériaux de remblai et de couche de forme. Si un dépôt de ces matériaux stockés depuis plusieurs mois n'a donné lieu à aucune auto-combustion, son utilisation en remblai et en couche de forme est envisageable, mais doit faire l'objet d'une étude particulière. Une phase importante de cette étude est l'identification des constituants du dépôt, elle peut être grandement facilitée en prenant avis auprès des producteurs de ces matériaux. La deuxième phase de l'étude doit définir les conditions particulières de mise en remblai ; on peut toutefois déjà indiquer que les risques d'évolution par auto-combustion seront d'autant plus faibles que le pourcentage de vides d'air sera lui-même faible. Il conviendra donc de choisir de préférence les terrils comportant une fraction fine suffisante et de réaliser un compactage intense.
Matériaux solubles.	Traces de sel gemme ou plus de 20 % de gypse.	Matériaux se trouvant au contact de nappes de sel gemme $NaCl + MgCl_2$ ou de gypse $CaSO_4$.	Ces matériaux ne doivent pas être normalement utilisés en remblai en raison des risques de tassement et de pollution qui pourraient résulter d'un lessivage provoqué soit par les eaux de ruissellement, soit par des fluctuations de la nappe.
	0 % de sel gemme ou moins de 20 % de gypse.	Marnes infra ou supra-gypseuses.	Ces matériaux peuvent être utilisés en remblai (mais non en couche de forme) étant donné la solubilité relativement faible du gypse dans de tels matériaux compactés. Il conviendra toutefois de les protéger des eaux de ruissellement et des eaux d'infiltration et de ne pas les utiliser dans la partie de l'ouvrage qui peut être en contact avec la nappe.
Matériaux polluants.		Déchets industriels de toutes natures tels que : — boues de décantation, — laitiers à forte teneur en soufre, — résidus obtenus après enrichissement de minerais, — mâchefers contenant des substances toxiques, — sables de fonderie, — dépôts divers.	Ces matériaux, renfermant des produits nuisibles pouvant s'évacuer hors du remblai par dissolution ou percolation, ne doivent pas être mis en remblai dans des conditions normales de terrassement en raison des risques de pollution (des nappes phréatiques essentiellement) qui pourraient en résulter. Il peut être justifié pour des motifs de protection de l'environnement de chercher à « emballer » un matériau polluant dans un remblai. Dans ce cas, il faut entreprendre systématiquement une étude comportant l'identification précise du matériau après information auprès des producteurs, une analyse de l'économie de l'opération et si cette dernière est favorable la définition des règles particulières de terrassement qu'il y aura lieu de prescrire.

Table 34: Classification F. Materials that are decomposible, combustible, soluble and pollutant

14.2.3.7 Summary of classes and subclasses

Sols fins.	D < 50 mm Tamisat à 80 µm > 35 %	$I_p < 10$			A_1
		$10 < I_p < 20$			A_2
		$20 < I_p < 50$			A_3
		$I_p > 50$			A_4
Sols sableux et graveleux avec fines.	D < 50 mm Tamisat à 80 µm entre 5 et 35 %	Tamisat à 80 µm de 5 à 12 %	Refus à 2 mm inférieur à 30 %	ES > 35	B_1
				ES < 35	B_2
			Refus à 2 mm supérieur à 30%	ES > 25	B_3
				ES < 25	B_4
		Tamisat à 80 µm de 12 à 35 %	$I_p < 10$		B_5
			$I_p > 10$		B_6
Sols comportant des fines et des gros éléments.	D > 50 mm Tamisat à 80 µm > 5 %	Tamisat à 80 µm élevé			C_1
		Tamisat à 80 µm faible	D < 250 mm		C_2
			D > 250 mm		C_3
Sols et roches insensibles à l'eau.	Tamisat à 80 µm < 5 %	D < 50 mm	Refus à 2 mm inférieur à 30 %		D_1
			Refus à 2 mm supérieur à 30 %		D_2
		50 mm < D < 250 mm			D_3
		D > 250 mm			D_4
Roches évolutives.	Matériaux à structure fine, fragile avec peu ou pas d'argile.				E_1
	Matériaux à structure grossière, fragile avec peu ou pas d'argile.				E_2
	Matériaux évolutifs argileux.				E_3
Matériaux putrescibles, combustibles, solubles ou polluants.					F

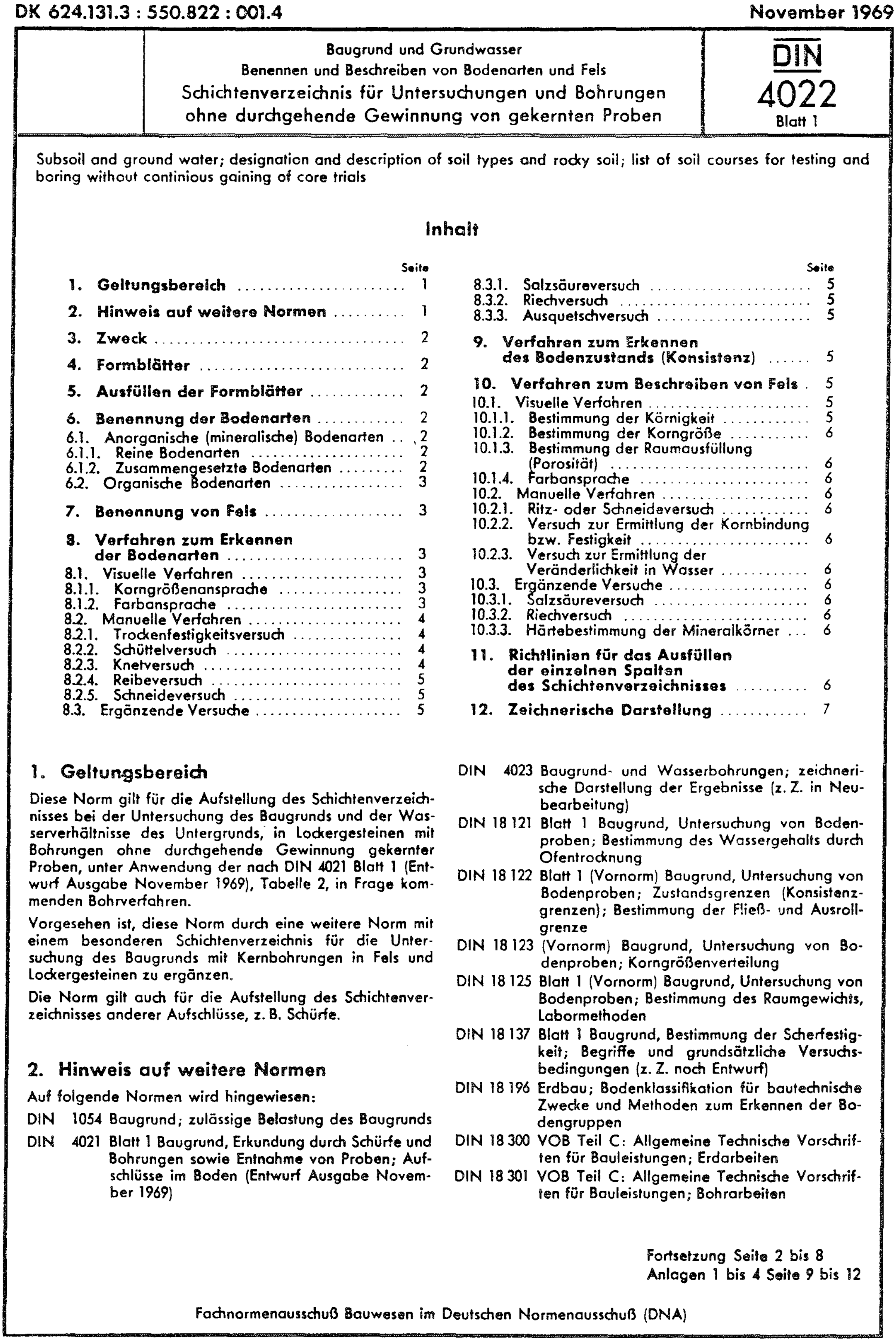
Table 35: Summary table

14.3 The German Soil Classification for Engineering Purposes

In Germany two standards are used. DIN 4022 Part 1 is used for the individual designation and description of soils. DIN 18196 classifies soils into a limited number of groups which are similar with regard to technical properties using precisely defined criteria. Numerous soils with different designation and description can be co-ordinated into individual soil groups.

The German standard DIN 18196 for the engineering classification of soils is similar to approach to the French classification (14.2) and the British BSCS and American UCS.

14.3.1 DIN 4022 Part 1: individual designation and description of soils



DK 624.131.3 : 550.822 : 001.4 **November 1969**

Baugrund und Grundwasser
Benennen und Beschreiben von Bodenarten und Fels
Schichtenverzeichnis für Untersuchungen und Bohrungen ohne durchgehende Gewinnung von gekernten Proben

DIN
4022
Blatt 1

Subsoil and ground water; designation and description of soil types and rocky soil; list of soil courses for testing and boring without continious gaining of core trials

Inhalt

1. Geltungsbereich

Diese Norm gilt für die Aufstellung des Schichtenverzeichnisses bei der Untersuchung des Baugrunds und der Wasserverhältnisse des Untergrunds, in Lockergesteinen mit Bohrungen ohne durchgehende Gewinnung gekernter Proben, unter Anwendung der nach DIN 4021 Blatt 1 (Entwurf Ausgabe November 1969), Tabelle 2, in Frage kommenden Bohrverfahren.

Vorgesehen ist, diese Norm durch eine weitere Norm mit einem besonderen Schichtenverzeichnis für die Untersuchung des Baugrunds mit Kernbohrungen in Fels und Lockergesteinen zu ergänzen.

Die Norm gilt auch für die Aufstellung des Schichtenverzeichnisses anderer Aufschlüsse, z. B. Schürfe.

2. Hinweis auf weitere Normen

Auf folgende Normen wird hingewiesen:

DIN 1054 Baugrund; zulässige Belastung des Baugrunds
DIN 4021 Blatt 1 Baugrund, Erkundung durch Schürfe und Bohrungen sowie Entnahme von Proben; Aufschlüsse im Boden (Entwurf Ausgabe November 1969)
DIN 4023 Baugrund- und Wasserbohrungen; zeichnerische Darstellung der Ergebnisse (z. Z. in Neubearbeitung)
DIN 18 121 Blatt 1 Baugrund, Untersuchung von Bodenproben; Bestimmung des Wassergehalts durch Ofentrocknung
DIN 18 122 Blatt 1 (Vornorm) Baugrund, Untersuchung von Bodenproben; Zustandsgrenzen (Konsistenzgrenzen); Bestimmung der Fließ- und Ausrollgrenze
DIN 18 123 (Vornorm) Baugrund, Untersuchung von Bodenproben; Korngrößenverteilung
DIN 18 125 Blatt 1 (Vornorm) Baugrund, Untersuchung von Bodenproben; Bestimmung des Raumgewichts, Labormethoden
DIN 18 137 Blatt 1 Baugrund, Bestimmung der Scherfestigkeit; Begriffe und grundsätzliche Versuchsbedingungen (z. Z. noch Entwurf)
DIN 18 196 Erdbau; Bodenklassifikation für bautechnische Zwecke und Methoden zum Erkennen der Bodengruppen
DIN 18 300 VOB Teil C: Allgemeine Technische Vorschriften für Bauleistungen; Erdarbeiten
DIN 18 301 VOB Teil C: Allgemeine Technische Vorschriften für Bauleistungen; Bohrarbeiten

Fortsetzung Seite 2 bis 8
Anlagen 1 bis 4 Seite 9 bis 12

Fachnormenausschuß Bauwesen im Deutschen Normenausschuß (DNA)

Table 36: DIN 4022, Page 1

3. Zweck

Diese Norm soll gewährleisten, daß erbohrte und erschürfte Bodenarten und Fels nach Art und Beschaffenheit sowie die Wasserverhältnisse einheitlich gekennzeichnet und daß die Bohr- und Schürfergebnisse in dem Schichtenverzeichnis einheitlich dargestellt werden.

Deshalb werden Formblätter[1]) für das Kopfblatt und das Schichtenverzeichnis vorgeschrieben sowie Beispiele und Richtlinien, nach denen die Formblätter auszufüllen sind.

4. Formblätter

4.1. Die Bohr- und Schürfergebnisse sind in die vorgeschriebenen Formblätter einzutragen und zwar in das Formblatt für das Kopfblatt (Anlage 1) und in dasjenige für das Schichtenverzeichnis (Anlage 2) und gegebenenfalls in ein Fortsetzungsblatt für das Schichtenverzeichnis (wie Anlage 2).

Zur Norm gehören folgende Anlagen:

Anlage 1:	Formblatt für das Kopfblatt (Formblatt 1)
Anlage 2:	Formblatt für das Schichtenverzeichnis (Formblatt 2)
und	Formblatt für die Fortsetzung des Schichtenverzeichnisses (Formblatt 3 — hier nicht abgedruckt, da es sich um das gleiche Formblatt lt. Anlage 2 handelt)
Anlage 3:	Beispiel für ein ausgefülltes Kopfblatt
Anlage 4:	Beispiel für ein ausgefülltes Schichtenverzeichnis

4.2. Wenn bei Bohrungen, die zur Erkundung des Aufbaues der Lockergesteinsschichten dienen, Fels angebohrt wird oder wenn die Tiefenlage des Felsuntergrunds mit solchen Bohrungen ermittelt werden soll und dabei zur Feststellung der Beschaffenheit dieses Felsuntergrunds nur wenig in den Fels eingebohrt wird, sind zum Aufstellen des Schichtenverzeichnisses die Formblätter 1 bis 3 zu verwenden.

5. Ausfüllen der Formblätter

5.1. Das Kopfblatt (Formblatt 1) dient zum Kennzeichnen der Bohrungen nach Ort, Nummer, Objekt, Zeit, Höhenlage, Zweck, Ausführungsart usw. und zum Aufzeichnen der Lageskizze auf der Rückseite des Kopfblattes (siehe Anlage 3). Es ist vom Bohrunternehmer auszufüllen.

5.1.1. Die Lage des Bohrpunktes muß durch eine besondere Lageskizze so genau angegeben werden, daß die Bohr- und Schurfstelle jederzeit wiedergefunden werden kann. Sie soll durch Eintragung des Hoch- und Rechtswertes, der aus der topographischen Karte mit eingezeichneten Planquadraten entnommen werden kann, festgelegt werden.

5.1.2. Der Bohrpunkt (Ansatzpunkt der Bohrung bzw. des Schurfes) ist auf einen Höhenpunkt, am besten auf NN, einzumessen. Bei Bohrungen in Baugruben, Brunnenschächten oder unter Wasser ist zu beachten, daß die Höhe des Ansatzpunktes nicht immer gleich der Geländehöhe ist. Der Unterschied zwischen Geländehöhe und Ansatzpunkt ist anzugeben.

5.1.3. Für das Festlegen der absoluten Lage, Geländehöhe der Bohrung sowie ihrer Bezeichnung ist der Auftraggeber verantwortlich.

5.2. Die Formblätter 2 und 3 für das Schichtenverzeichnis sollen sicherstellen, daß die Eintragungen in einer bestimmten Reihenfolge und unter vollständiger Angabe aller wichtigen Eigenschaften der Bodenarten und Fels sowie aller Feststellungen über die Wasserverhältnisse vorgenommen werden.

Die Formblätter 2 und 3 sind von dem Geräteführer sofort an Ort und Stelle bei Entnahme und Ansprache der Proben vollständig auszufüllen, ausgenommen hiervon sind die Fächer für die geologische Bezeichnung, die Bezeichnung der Bodengruppe nach DIN 18 196 und für die ergänzende Bemerkung zur Benennung und Beschreibung der Schicht. Richtlinien für das Ausfüllen der einzelnen Spalten des Schichtenverzeichnisses siehe Abschnitt 11.

6. Benennung der Bodenarten

Es ist zu unterscheiden zwischen
  anorganischen (mineralischen) und
  organischen
Bodenarten.

6.1. Anorganische (mineralische) Bodenarten

6.1.1. Reine Bodenarten

Für das Benennen der anorganischen Bodenarten wird zwischen Fein- und Grobkornbereich unterschieden.

Der Feinkornbereich oder das Schlämmkorn (≦ 0,06 mm)[2]) wird in folgende weitere Korngrößenbereiche unterteilt:

Feinstkorn oder Ton	≦ 0,002 mm
Schluff	> 0,002 bis 0,06 mm
Feinschluff	> 0,002 bis 0,006 mm
Mittelschluff	> 0,006 bis 0,02 mm
Grobschluff	> 0,02 bis 0,06 mm

Der Grobkornbereich (> 0,06 bis 63 mm)[2]) oder das Siebkorn wird in folgende weitere Korngrößenbereiche unterteilt:

Sand	> 0,06 bis 2 mm
Feinsand	> 0,06 bis 0,2 mm
Mittelsand	> 0,2 bis 0,6 mm
Grobsand	> 0,6 bis 2 mm
Kies	> 2 bis 63 mm
Feinkies	> 2 bis 6,3 mm
Mittelkies	> 6,3 bis 20 mm
Grobkies	> 20 bis 63 mm

Reine Bodenarten bestehen nur aus einem Korngrößenbereich und werden nach diesem benannt.

6.1.2. Zusammengesetzte Bodenarten

Die meisten Böden sind ein inniges Gemisch verschiedener Korngrößenbereiche, wie z. B. Sand und Kies oder Schluff und Sand. Bei der Benennung dieser Gemische ist wie folgt vorzugehen.

6.1.2.1. Mit einem Substantiv (Hauptwort) ist die Bodenart zu nennen, die nach Gewichtsanteilen am stärksten vertreten ist oder die bestimmenden Eigenschaften des Bodens prägt (Hauptanteile).

Die Benennung nach den Gewichtsanteilen ist bei den grobkörnigen Bodenarten angebracht, wenn der Anteil an Körnern mit Durchmesser ≦ 0,06 mm weniger als 5 Gew.-% beträgt.

Die Benennung nach den bestimmenden Eigenschaften ist bei den feinkörnigen und gemischtkörnigen Böden angebracht. Gemischtkörnige Böden enthalten 5 bis 40 Gew.-% Körner mit Durchmesser ≦ 0,06 mm, feinkörnige Böden mehr als 40 Gew.-% Körner mit Durchmesser ≦ 0,06 mm.

6.1.2.2. Sind bei den grobkörnigen Bodenarten zwei Korngrößen mit etwa gleichen Anteilen vertreten (40 bis 60 Gew.-%), so sind die beiden Substantive (Hauptwörter) durch ein „und" zu verbinden, z. B. Kies und Sand.

Die in einem Bodengemisch mit geringerem Anteil (Nebenanteile) vorhandenen Korngrößenbereiche werden mit

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[1]) Die Formblätter sind auf festem Papier, dünnem Durchschlagpapier und Transparentpapier einseitig bedruckt, im Format DIN A 4 und DIN A 5 vom Beuth-Vertrieb GmbH., 1 Berlin 30, Burggrafenstr. 4—7 und 5 Köln, Friesenplatz 16, zu beziehen.

[2]) Nach DIN 66 100 ist der genaue Zahlenwert 0,063. Da Runden zulässig ist, werden unterhalb der Größen von 1 mm gerundete Werte verwendet.

einem bzw. mehreren Eigenschaftswörtern bezeichnet und dem Hauptwort nachgestellt, z. B.

Kies, sandig;
Feinkies, grobsandig;
Grobsand, mittelsandig, feinkiesig.

Sind die in geringerem Maße vertretenen Anteile in besonders geringem oder besonders starkem Umfange vertreten, so wird dem Eigenschaftswort das Beiwort „schwach" oder „stark" vorangesetzt.

Ist die Körnungslinie bekannt, so ist der Grad der Anteile zu kennzeichnen:

als „schwach" bei unter 15 Gew.-%
als „stark" bei über 30 Gew.-%

z. B. Kies, stark grobsandig, schwach feinsandig;
Feinkies, mittelsandig, schwach grobsandig.

6.1.2.3. Die bestimmenden Eigenschaften der fein- und gemischtkörnigen Böden sind vom Ton- und Schluffgehalt abhängig. Bei feinkörnigen Böden kann der Tongehalt, bei gemischtkörnigen Böden der Ton- oder Schluffgehalt auch bei geringerem Gewichtsanteil das Gepräge des Bodens bestimmen. In diesen Fällen sind als Benennung die Hauptwörter

Ton oder Schluff

zu verwenden. Zusätzlich sind für Ton und Schluff Angaben über den Grad der Plastizität nach Abschnitt 8.2.3 und über die Konsistenz nach Abschnitt 9 zu machen. Beträgt der Ton- und Schluffgehalt gemischtkörniger Böden zusammen mehr als 5 Gew.-%, wird aber durch ihn das Verhalten des Bodens nicht bestimmt, so ist bei der Benennung nach Abschnitt 6.1.2.1 oder 6.1.2.2 zu verfahren.

Die Grobanteile werden als Eigenschaftswörter u. U. mit einem Beiwort nach Abschnitt 6.1.2.2 benannt, z. B.

Schluff, schwach feinsandig
Schluff, stark tonig, sandig, kiesig
Ton, schluffig, sandig

6.2. Organische Bodenarten

Die rein organischen Bodenarten setzen sich aus Resten mehr oder wenig stark zersetzter Pflanzen mit Resten tierischen Organismen zusammen. Je nach dem Grad der Zersetzung unterscheidet man „nicht bis mäßig zersetzter Torf", sofern noch Pflanzenreste (Moos und ähnliches) in größerer Menge erkennbar und „stark zersetzter Torf", sofern nur noch lokkere, im einzelnen nicht mehr erkennbare, meist dunkel gefärbte Bestandteile vorhanden sind. Bodenarten mit nennenswertem organischen Anteil, meist von feiner ton- oder schluffähnlicher Beschaffenheit, werden als „Mudden" bezeichnet.

Bei organischen Bodenarten mit mineralischen Anteilen werden diese durch Eigenschaftswörter nach Abschnitt 6.1.2.2 zum Ausdruck gebracht, z. B.

Mudde, tonig
Mudde, stark sandig
Torf, schwach feinsandig.

Treten die organischen Bestandteile als Beimengung auf, so werden die Eigenschaftswörter „torfig" oder „muddig" verwendet, gegebenenfalls auch die Begriffe „schwach" oder „stark". Es kann auch der Sammelbegriff „organisch" gebraucht werden.

Die humushaltige, durchlüftete, Kleinlebewesen enthaltende oberste Bodenschicht wird als Mutterboden bezeichnet. Reiner Humus kommt als Mutterboden nur selten vor. Gewöhnlich ist der Mutterboden eine Mischung aus Humus und mineralischen Bodenarten. Diese können außerdem nach Abschnitt 6.1 und 8 beschrieben werden.

7. Benennung von Fels

Im Rahmen dieser Norm werden alle Festgesteine mit dem Sammelbegriff „Fels" benannt. Die ortsübliche Bezeichnung ist in Spalte 2 Fach f des Schichtenverzeichnisses anzugeben. Die Beschaffenheit wird nach Abschnitt 10 beschrieben.

8. Verfahren zum Erkennen der Bodenarten

Um die eine Schicht repräsentierende Bodenart und ihre Eigenschaften zu beschreiben (Spalte 2 a bis e des Schichtenverzeichnisses), benutzt man visuelle und manuelle Verfahren.

8.1. Visuelle Verfahren

Visuelle Verfahren, d. h. das Betrachten der Bodenart mit dem bloßen Auge, dienen dazu, die Größe der einzelnen Kornteilchen, die eine Bodenart zusammensetzen, zu erkennen und ihre Gewichtsprozente abzuschätzen sowie die Farbe der Bodenart zu bestimmen.

8.1.1. Korngrößenansprache

Man breitet die zu bestimmende Bodenart auf einer Unterlage oder auf der Handfläche aus und vergleicht ihre Korngrößen entweder mit den in einer Korngruppen-Vergleichsnormale (Kornstufenschaulehre) in einzelnen Fächern untergebrachten Korngrößenbereichen oder aber mit der Größe verschiedener Dinge des täglichen Lebens.

Dabei lassen sich nachstehende Korngrößenbereiche unterscheiden:

Kieskornbereich	kleiner als Hühnereier größer als Streichholzköpfe
Grobkies	kleiner als Hühnereier größer als Haselnüsse
Mittelkies	kleiner als Haselnüsse größer als Erbsen
Feinkies	kleiner als Erbsen größer als Streichholzköpfe
Sandkornbereich	kleiner als Streichholzköpfe bis zur Grenze des noch mit dem bloßen Auge erkennbaren Kornes
Grobsand	kleiner als Streichholzköpfe größer als Grieß
Mittelsand	gleich Grieß
Feinsand	kleiner als Grieß, aber das Einzelkorn noch mit dem bloßen Auge erkennbar.

Enthält die Bodenart Bestandteile größer als Hühnereier, so werden diese als Steine bzw. Blöcke (Kopfgröße) bezeichnet.

Schluffkorn und Tonkorn sind nicht mehr mit dem bloßen Auge als Einzelkorn erkennbar. Zu ihrem Erkennen wendet man das manuelle Verfahren nach Abschnitt 8.2 an.

8.1.2. Farbansprache

Die wirkliche Farbe eines Bodens läßt sich nur an frischen Bruchflächen bei vollem Tageslicht erkennen. Dazu bricht man eine frisch entnommene feuchte Bodenprobe sofort nach dem Fördern auseinander und gibt die Farbe bzw. die Farben an. Besonders sind Farbveränderungen des frischen Bodens unter dem Einfluß der Luft zu beachten und zu beschreiben.

Zur möglichst eindeutigen Kennzeichnung der Farbe bzw. der Farben können Farbkarten Verwendung finden[3].

Von besonderer Wichtigkeit ist eine dunkle Färbung des Bodens, da hierdurch oft organische Beimengungen angezeigt werden. Je dunkler eine Bodenart ist, desto höher ist meist ihr organischer Anteil. Hierbei ist allerdings zu beachten, daß aus dem Grad der Dunkelfärbung allein kein sicherer Schluß auf die absolute Menge des organischen Anteils zu ziehen ist, da sich grobkörnige Böden unter dem Einfluß organischer Bestandteile leichter verfärben als feinkörnige Böden; auch können in reinen Mineralböden graue und schwarze Farbtönungen durch Mangan- oder Eisenverbindungen entstehen.

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[3] Siehe z. B. Übersichtskarte RAL—F 2 in Verbindung mit Farbregister RAL 840 HR, zu beziehen durch den Beuth-Vertrieb GmbH., 1 Berlin 30, Burggrafenstr 4—7 und 5 Köln, Friesenplatz 16.

Einen Anhaltspunkt über den Humusgehalt als organischen Anteil vermittelt die nachstehende Zusammenstellung.

	sandige Böden		tonige Böden	
	Humusgehalt Gew.-%	Farbe	Humusgehalt Gew.-%	Farbe
humusarm	$\leqq 1$	deutlich grau	$\leqq 2$	Mineralfarbe
schwach humos	> 1 bis 2	tief grau	> 2 bis 5	
humos	> 2 bis 5		> 5 bis 10	tief grau
stark humos	> 5 bis 10	schwarz	> 10 bis 15	schwarz
sehr stark humos	> 10 bis 15		> 15 bis 20	

Bei Torfen gibt die Farbe einen Hinweis auf ihren Zersetzungsgrad: Je dunkler ein Torf ist und je dunkler er an der Luft wird, desto stärker ist er im allgemeinen zersetzt.

Bei Mudden ist an der frisch entnommenen Probe darauf zu achten, ob sich unter dem Einfluß der Luft rostbraune Farbtönungen bilden: dies weist auf eine Oxydation hin und geschieht vor allem bei vorher grünlich (meist nach Olivgrün hinneigend) gefärbten Mudden.

Eine grünliche Färbung wird durch Eisenoxydulverbindungen verursacht. Da diese bei Zutritt von Luftsauerstoff rasch oxydieren, kann sich die Grünfärbung nur unterhalb des Grundwasserspiegels halten. Im Schwankungsbereich des Grundwassers ist deshalb die Grünfärbung häufig von Rostflecken oder durch eine Braunfärbung mit grauen Flecken durchsetzt.

Am verbreitetsten ist eine gelbe, braune und rote Färbung. Gelbe bis braune Farbtönungen werden durch Eisensalze, braune Farbtönungen durch Eisenoxidhydrat und rote Farbtönungen durch Eisenoxid hervorgerufen. Helle Farben zeigen völlig humusfreie Quarz- und Kalksandböden und außerdem Bleicherdeböden, bei denen im oberflächennahen Bereich die farbgebenden Bestandteile durch sauerstoffreiches Niederschlagwasser im Zusammenwirken mit Humussäure und Kohlensäure ausgelaugt worden sind. Unter der Bleichzone sind die ausgelaugten Bestandteile meist wieder ausgeschieden und rufen eine besonders intensive rostbraune Färbung des Bodens hervor. Bei Rostfarben ist häufig auch eine Verkittung des Bodens zu beobachten.

8.2. Manuelle Verfahren

Manuelle Verfahren, d. h. die Anwendung einfacher Hand- und Fingerversuche dienen dazu, kennzeichnende Angaben über Feinkorn- und Grobkorngehalt und die Plastizität zu erhalten.

Zu den manuellen Verfahren zählen nachstehende Versuche:

a) Trockenfestigkeitsversuch,

b) Schüttelversuch,

c) Knetversuch,

d) Reibeversuch und

e) Schneideversuch.

8.2.1. Trockenfestigkeitsversuch

Aus dem Trockenfestigkeitsversuch ergeben sich Hinweise auf die Plastizität des Bodens und damit auf das Verhalten als Schluff oder Ton.

Die Bodenprobe wird an der Luft, an der Sonne oder im Ofen getrocknet. Ihr Widerstand gegen Zerbröckeln und Pulverisieren zwischen den Fingern gibt einen Hinweis auf die Trockenfestigkeit des Bodens, die durch Art und Menge des Feinkornanteils bedingt wird. Es lassen sich dabei nachstehende Festigkeiten unterscheiden:

a) Keine Trockenfestigkeit, wenn der getrocknete Boden bereits bei geringster Berührung in ein Haufwerk von Einzelkörnern zerfällt;

b) niedrige Trockenfestigkeit, wenn der getrocknete Boden bei leichtem bis mäßigem Fingerdruck pulverisiert werden kann;

c) mittlere Trockenfestigkeit, wenn die getrocknete Probe erst bei Anwendung eines erheblichen Fingerdrucks zerbricht und dabei einzelne, noch zusammenhängende Bruchstücke bildet;

d) hohe Trockenfestigkeit, wenn die getrocknete Probe nicht mehr durch Fingerdruck zerstört werden kann. Sie läßt sich lediglich zwischen den Fingern zerbrechen.

Anmerkung: Keine Trockenfestigkeit zeigen reine Kiese und Sande. Niedrige Trockenfestigkeit zeigen Schluffe, Schluff-Feinsand- bzw. Schluff-Kies-Gemische. Mittlere Trockenfestigkeit zeigen Kies-Ton-, Sand-Ton- und Schluff-Ton-Gemische.

Hohe bis sehr hohe Trockenfestigkeit weisen Tone, Ton-Schluff- und Ton-Sand-Gemische und Ton-Schluff-Sand-Kies-Gemische auf.

8.2.2. Schüttelversuch

Die Empfindlichkeit einer Bodenart gegen das Schütteln ist eine Eigenschaft, die für schluffige Böden charakteristisch ist.

Eine genügend feuchte, nußgroße Probe — wenn zu trocken, vorher mit Wasser durchgeknetet — wird auf der flachen Hand hin- und hergeschüttelt. Tritt dabei Wasser an die Oberfläche aus, so nimmt diese ein glänzendes Aussehen an. Durch Fingerdruck kann man das Wasser wieder zum Verschwinden bringen. Mit zunehmendem Fingerdruck zerkrümelt die Probe; bei erneutem Schütteln fließen die einzelnen Krümel wieder zusammen und der Versuch kann wiederholt werden.

Auf Grund der Reaktionsgeschwindigkeit, mit der das Wasser beim Schütteln und Drücken erscheint und verschwindet, lassen sich nachstehende Unterscheidungen treffen:

a) Schnelle Reaktion, wenn der beschriebene Vorgang sehr rasch abläuft;

b) langsame Reaktion, wenn sich die Wasserhaut .nur langsam bildet und ändert;

c) keine Reaktionen, wenn der Schüttelversuch überhaupt nicht anspricht.

Anmerkung: Sehr feine Sande, schluffige Feinsande, feinsandige Schluffe, Grobschluffe und Gesteinsmehle zeigen eine sehr schnelle Reaktion. Tonige Schluffe und sandig-tonige Schluffe reagieren langsam, schluffige Tone und reine Tone zeigen keine Reaktion.

8.2.3. Knetversuch

Dieser Versuch dient dazu, Angaben über die plastischen Eigenschaften eines Bodens zu erlangen und gibt dadurch ebenfalls Hinweise auf sein Verhalten als Schluff oder Ton.

Die Probe wird so zubereitet, daß sie sich wie eine weiche, aber nicht klebrige Masse verhält. Auf einer glatten Oberfläche oder auf der Handfläche wird die Bodenprobe zu dünnen Röllchen von 3 mm Durchmesser ausgerollt. Aus den Röllchen formt man wiederum einen Klumpen, den man erneut ausrollt. Durch das Ausrollen und Zusammenkneten gibt die Probe ständig Wasser ab, wird immer steifer und zerbröckelt schließlich beim Ausrollen. Von da an kann die Probe nicht mehr ausgerollt, sondern höchstens noch geknetet werden.

Aus der Möglichkeit, die Röllchen wiederum zu einem Klumpen zu formen und ihn so lange zu kneten, bis er zerkrümelt, lassen sich nachstehende Unterscheidungen treffen:

a) Leichte Plastizität, wenn aus den Röllchen kein zusammenhängender Klumpen mehr gebildet werden kann;

14.3.2 DIN 18196. Earthworks; soil classification for engineering purposes and methods for identification of soil-groups

DK 624.131.2 **Juni 1970**

Erdbau
Bodenklassifikation für bautechnische Zwecke und Methoden zum Erkennen von Bodengruppen

DIN 18196

Earthwork; soil-classification for civil engineering purposes and methods for identification of soil-groups

Inhalt

1. Geltungsbereich

Die Norm gilt für den Erdbau.

Für die einheitliche Benennung und Beschreibung von Bodenarten und Fels bei Baugrunduntersuchungen durch Schürfe und Bohrungen siehe DIN 4022 Blatt 1.

Für die Einteilung der Bodenarten und Fels nach ihrer Gewinnbarkeit (lösen, laden, fördern) siehe DIN 18 300.

2. Zweck

Diese Bodenklassifikation ist aufgestellt, um die Bodenarten (Lockergesteine) für bautechnische Zwecke in Gruppen mit annähernd gleichem stofflichen Aufbau und ähnlichen bodenphysikalischen Eigenschaften zusammenzufassen. Innerhalb einer Klassifikationsgruppe kann die jeweilige Beschaffenheit — insbesondere der gemischtkörnigen und bindigen Bodenarten — je nach Wassergehalt oder Lagerungsdichte unterschiedlich sein.

Die Norm enthält die Grundlagen der Klassifikation und die Bestimmungsverfahren zur Einordnung der Bodenarten in Gruppen.

3. Grundlagen der Bodenklassifikation

Die Einordnung einer Bodenart in Bodengruppen wird in dieser Norm allein nach der stofflichen Zusammensetzung und unabhängig vom Wassergehalt und der Dichte des Bodens vorgenommen. Sie hängt im wesentlichen von nachstehenden Merkmalen ab:

a) Korngrößenbereiche,
b) Korngrößenverteilung,
c) plastische Eigenschaften,
d) organische Bestandteile.

3.1. Korngrößenbereiche

Jede Bodenart ist ein Gemisch von Einzelbestandteilen unterschiedlicher Korngrößen, die nach DIN 4022 Blatt 1 in nachstehende Korngrößenbereiche eingeteilt sind:

Feinstkorn oder Ton			$\leqq$ 0,002	mm
Schluff	$>$ 0,002	bis	0,06	mm[1]
Sand	$>$ 0,06[1]	bis	2	mm
Kies	$>$ 2	bis	63	mm
Steine und Blöcke			$>$ 63	mm

Bei der Bodenklassifikation wird bei Schluff und Ton nicht mehr nach den Korngrößen unterschieden, da typische physikalische Eigenschaften und die bautechnische Kennzeichnung dieser Bodengruppen nicht allein von der Korngröße bestimmt werden.

Die organischen Bestandteile einer Bodenart haben keine spezifische Korngröße.

3.2. Korngrößenverteilung

Die Korngrößenverteilung (Körnungsaufbau) gibt Auskunft über die Gewichtsanteile der verschiedenen Korngrößenbereiche in einer Bodenart. Bei der Klassifikation der grobkörnigen Böden unterscheidet man

a) weitgestufte Korngrößenverteilung,
b) enggestufte Korngrößenverteilung,
c) intermittierend gestufte Korngrößenverteilung.

Hierbei ist für den Verlauf der Körnungslinie neben der Ungleichförmigkeitszahl U die Krümmungszahl C_c von Bedeutung. Die Ungleichförmigkeitszahl U ist ein Maß für die Steilheit der Körnungslinie im Bereich von d_{10} bis d_{60}, während die Krümmungszahl C_c auf den Verlauf der Körnungslinie in diesem Bereich hinweist.

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[1] Nach DIN 66 100 ist der genaue Zahlenwert 0,063. Da Rundungen zulässig sind, werden unterhalb der Korngröße von 1 mm gerundete Werte verwendet.

Fortsetzung Seite 2 bis 7

Fachnormenausschuß Bauwesen im Deutschen Normenausschuß (DNA)

Table 37: DIN 18196, Table 1, Soil Classification

Tabelle 1. **Bodenklassifizierung; Gruppeneinteilung der Böden für bautechnische Zwecke (Klassifikation der Lockergesteine)**

1	2	3	4	4	5	6	7
Hauptgruppen	Definition und Bezeichnung					Erkennungsmerkmale	Beispiele
	Korngrößenanteile in Gew.-%		Gruppen		Kurzzeichen Gruppensymbol		
	≤ 0,06 mm	> 2 mm					
Grobkörnige Böden	≤ 5	> 40	Kies	enggestufte Kiese	GE	steile Körnungslinie infolge Vorherrschens eines Korngrößenbereichs	Fluß- und Strandkies Terrassenschotter Moränenkies vulkanische Schlacke und Asche
				weitgestufte Kies-Sand-Gemische	GW	über mehrere Korngrößenbereiche kontinuierlich verlaufende Körnungslinie	
				intermittierend gestufte Kies-Sand-Gemische	GI	treppenartig verlaufende Körnungslinie infolge Fehlens eines oder mehrerer Korngrößenbereiche	
		≤ 40	Sand	enggestufte Sande	SE	steile Körnungslinie infolge Vorherrschens eines Korngrößenbereiches	Dünen- und Flugsand Talsand (Berliner Sand) Beckensand Tertiärsand
				weitgestufte Sand-Kies-Gemische	SW	über mehrere Korngrößenbereiche kontinuierlich verlaufende Körnungslinie	Moränensand Terrassensand Strandsand
				intermittierend gestufte Sand-Kies-Gemische	SI	treppenartig verlaufende Körnungslinie infolge Fehlens eines oder mehrerer Korngrößenbereiche	
Gemischtkörnige Böden	5 bis 40	> 40	Kies-Schluff-Gemische	5 bis 15 Gew.-% ≤ 0,06 mm	GU	weit oder intermittierend gestufte Körnungslinie Feinkornanteil ist schluffig	Verwitterungskies Hangschutt lehmiger Kies Geschiebelehm
				15 bis 40 Gew.-% ≤ 0,06 mm	GŪ		
			Kies-Ton-Gemische	5 bis 15 Gew.-% ≤ 0,06 mm	GT	weit oder intermittierend gestufte Körnungslinie Feinkornanteil ist tonig	
				15 bis 40 Gew.-% ≤ 0,06 mm	GT̄		
		≤ 40	Sand-Schluff-Gemische	5 bis 15 Gew.-% ≤ 0,06 mm	SU	weit oder intermittierend gestufte Körnungslinie Feinkornanteil ist schluffig	Flottsand
				15 bis 40 Gew.-% ≤ 0,06 mm	SŪ		Auelehm Sandlöss
			Sand-Ton-Gemische	5 bis 15 Gew.-% ≤ 0,06 mm	ST	weit oder intermittierend gestufte Körnungslinie Feinkornanteil ist tonig	lehmiger Sand Schleichsand
				15 bis 40 Gew.-% ≤ 0,06 mm	ST̄		Geschiebelehm Geschiebemergel

Table 37: continued

Fortsetzung Tabelle 1

1	2	3	4			5	6			7
Hauptgruppen	Definition und Bezeichnung						Erkennungsmerkmale			Beispiele
	Feinkornanteile in Gew.-% ≤0,06 mm	Lage zur A-Linie (siehe Bild 4)	Gruppen		w_f in Gew.-%	Kurzzeichen Gruppensymbol	Trockenfestigkeit	Reaktion beim Schüttelversuch	Plastizität beim Knetversuch	
Feinkörnige Böden	> 40	w_{fa} ≤ 4 Gew.-% oder unterhalb der A-Linie	Schluff	leicht plastische Schluffe	≤ 35	UL	niedrige	schnelle	keine bis leichte	Löß Hochflutlehm
				mittelplastische Schluffe	35 bis 50	UM	niedrige bis mittlere	langsame	leichte bis mittlere	Seeton Beckenschluff
		w_{fa} ≥ 7 Gew.-% und oberhalb der A-Linie	Ton	leicht plastische Tone	≤ 35	TL	mittlere bis hohe	keine bis langsame	leichte	Geschiebemergel Bänderton
				mittelplastische Tone	35 bis 50	TM	hohe	keine	mittlere	Lößlehm Beckenton Keupermergel
				ausgeprägt plastische Tone	> 50	TA	sehr hohe	keine	ausgeprägte	Tarras Septarienton Juraton
organogene 1) und Böden mit organischen Beimengungen	> 40	w_{fa} ≥ 7 Gew.-% und unterhalb der A-Linie	nicht brenn- oder nicht schwelbar	Schluffe mit organischen Beimengungen und organogene 1) Schluffe	35 bis 50	OU	mittlere	langsame bis sehr schnelle	mittlere	Seekreide Kieselgur Mutterboden
				Tone mit organischen Beimengungen und organogene 1) Tone	> 50	OT	hohe	keine	ausgeprägte	Schlick Klei
	≤ 40			grob- bis gemischtkörnige Böden mit Beimengungen humoser Art		OH	Beimengungen pflanzlicher Art, meist dunkle Färbung, Modergeruch, Glühverlust bis etwa 20 Gew.-%			Mutterboden
				grob- bis gemischtkörnige Böden mit kalkigen, kieseligen Bildungen		OK	Beimengungen nicht pflanzlicher Art, meist helle Färbung, leichtes Gewicht, große Porosität			Kalksand Tuffsand
organische Böden			brenn- oder schwelbar	nicht bis mäßig zersetzte Torfe		HN	an Ort und Stelle aufgewachsene (sedentäre) Humusbildungen	Zersetzungsgrad 1 bis 5, faserig, holzreich, hellbraun bis braun		Niedermoortorf Hochmoortorf Bruchwaldtorf
				zersetzte Torfe		HZ		Zersetzungsgrad 6 bis 10 schwarzbraun bis schwarz		
				Mudden (Sammelbegriff für Faulschlamm, Gyttja, Dy, Sapropel)		F	unter Wasser abgesetzte (sedimentäre) Schlamme aus Pflanzenresten, Kot und Mikroorganismen, oft von Sand, Ton und Kalk durchsetzt, blauschwarz oder grünlich bis gelbbraun, gelegentlich dunkelgraubraun bis blauschwarz, federnd, weichschwammig			Mudde Faulschlamm
Auffüllung			Auffüllung aus natürlichen Böden; jeweiliges Gruppensymbol in eckigen Klammern			[ ]				
			Auffüllung aus Fremdstoffen			A				Müll Schlacke Bauschutt Industrieabfall

1) unter Mitwirkung von Organismen gebildete Böden

Table 37: continued

14.4 Soil Classification in the U.S.S.R.

The following classifications of soils are used in the U.S.S.R. Building Standards (SNIP 11-15-74).

14.4.1 Coarse-grained soils (on the basis of grain size)

			Content by weight
(a)	very coarse gravel, boulders		> 50 % of particles larger than 200 mm
	coarse gravel, cobbles		> 50 % of particles largen than 10 mm
	gravel		> 50 % of particles larger than 2 mm
(b)	gravelly	sand	> 25 % of particles larger than 2 mm
	coarse		> 50 % of particles larger than 0.50 mm
	medium		> 50 % of particles larger than 0.25 mm
	fine		> 75 % of particles larger than 0.1 mm
	silty		75 % of particles larger than 0.1 mm

If gravelly soils contain more than 40 % of sand, or more than 30 % of silty-clay soil, this should be designated as a supplement to the fundamental name (gravel with sand, or clay, etc.).

14.4.2 Fine-grained soils (on the basis of plasticity index, Ip)

Sandy silt, or silty fine sand	$0.01 \leq Ip \leq 0.07$
Silty clay (lean clay)	$0.07 \leq Ip \leq 0.17$
Clay (fat clay)	$Ip \geq 0.17$

The name is qualified as "with gravel", if the content of gravelly particles (> 2 mm) is 15—25 % (by weight); "gravelly", if the content of gravelly particles is 25—50 %. If the content of gravelly particles is more than 50 %, the soil is classified as a coarse-grained soil.