AS 1726—1993

Australian Standard®

Geotechnical site investigations

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PREFACE

This Standard was prepared by the Standards Australia Committee on Geotechnical Site Investigations, to supersede AS 1726—1981, *Geotechnical site investigations*. This edition was prepared in a form that will allow it to be called up in legislation, and the provisions are supported in a number of non-mandatory Appendices.

CONTENTS

FOREWORD

This Standard presents statements concerning the geotechnical investigation of sites as a preliminary to civil engineering and building construction.

The principle adopted in the preparation of this Standard is to specify concisely those considerations affecting the design and construction of works which must be made in a geotechnical site investigation. Assessment of these factors, in the manner described in this Standard, will then permit the identification of the field and laboratory work which must be implemented to provide the geotechnical data required to facilitate the engineering design and construction of the works.

Some methods suitable for the collection of data and the testing of geotechnical materials, and a system of material classification, are set out in the Appendices.

STANDARDS AUSTRALIA

Australian Standard

Geotechnical site investigations

1 SCOPE This Standard sets out minimum requirements for a geotechnical site investigation, as a component in the engineering design, construction, commissioning and operation of civil engineering and building works.

2 APPLICATION The applications of this Standard include assessment of natural or filled ground, new construction, maintenance of existing facilities, the evaluation of post construction performance and the assessment of failure.

3 REFERENCED AND RELATED DOCUMENTS

3.1 Referenced documents The following documents are referred to in this Standard:

AS
1289 Methods of testing soils for engineering purposes
1289.0 Part 0: General requirements and list of methods

3.2 Related documents Attention is drawn to the following documents:

Australasian Institute of Mining and Metallurgy
Monograph Series No. 9—Field geologists' manual 3rd edition, Melbourne 1989

Institution of Engineers, Australia
Guidelines for the provision of geotechnical information in construction contracts. (National Headquarters, Canberra 1987)

International Society for Rock Mechanics
Commission on standardisation of laboratory and field tests, 1978. *Suggested methods for the quantitative description of discontinuities in rock masses*, (Int. J. Rock Mech. Min. Sci. Vol. 15, 319-68)

4 DEFINITIONS For the purpose of this Standard, the definitions given below apply.

4.1 Client—the individual or organisation commissioning the geotechnical site investigation.

4.2 Classification—a system of identification and description of a material which places it in a limited number of groups on the basis of a defined group or characteristic. For example, a soil classification may be based on grading and plasticity of disturbed samples.

NOTE: A system of classification of soils and rocks suitable for geotechnical reports is given in Appendix A.

4.3 Data—information collected and assembled during the geotechnical site investigation.

4.4 Data, factual—materials, statistics and properties that can be seen, measured or identified by means of accepted or standardized criteria, classifications and tests.

4.5 Data, interpretative—information derived from factual data using accepted and proven techniques, or from reasonable judgment exercised in the assessment of geological conditions or processes evident at the site.

4.6 Geotechnical—pertaining to the nature, condition and physical properties of the earth's crust (whether soil or rock and including water and gases therein) which affect its performance in civil engineering and building works.

4.7 Geotechnical site investigations—the process of evaluating the geotechnical character of a site in the context of existing or proposed works or land usage. It may include one or more of the following:

(a) Evaluation of the geology and hydrogeology of the site.

(b) Examination of existing geotechnical information pertaining to the site.

(c) Excavating or boring in soil or rock.

(d) In situ assessment of geotechnical properties of materials.

(e) Recovery of samples of soil or rock for examination, identification, recording, testing or display.

(f) Testing of soil or rock samples to quantify properties relevant to the purpose of the investigation.

(g) Reporting of the results.

4.8 In situ—in its original place.

4.9 Investigator—the individual or organisation responsible for performing the geotechnical site investigation (including its reporting) or for that part of the geotechnical site investigation which is relevant in a particular context.

4.10 Monitoring—the activity of sensing, observing, measuring, and recording changes over a period of time.

4.11 Opinion—conclusions or recommendations derived by the investigator from consideration of factual and interpretative data, and from the exercise of judgment.

NOTE: A professional opinion is dependent on conclusions or recommendations derived from consideration of relevant available facts, interpretations and analysis and the exercise of judgment. Since the process involves interpretation and judgment, opinions of professionals may differ, although substantial agreement is expected. Examples where differences of opinion may occur are—

(a) ease of excavation, types of suitable plant to use, rippability;

(b) water inflow rates;

(c) excavation stability;

(d) settlements;

(e) bearing capacity; and

(f) pile types.

4.12 Serviceability—the ability of works to perform according to the design objectives.

4.13 Variability—the change in the properties or conditions of materials with time or location.

5 PLANNING AND DESIGN OF GEOTECHNICAL SITE INVESTIGATIONS

5.1 Nature and magnitude of proposed works The client shall provide the investigator with a written description of the proposed works in sufficient detail to permit definition of the objectives of the investigation.

5.2 Objectives of the investigation The investigator shall provide the client with a written statement of the objectives of the investigation. The statement of objectives shall define the level of detail required in the investigation.

5.3 Extent of investigation The investigation shall evaluate the material properties and the volume of ground which will significantly affect the performance of, or will be affected by, the proposed works.

6 METHODS OF INVESTIGATION

6.1 Investigations The site investigation methods used shall be chosen on the basis of a preliminary assessment of the relevant site conditions, and available geological information and history of the site.

6.2 Review of methods The methods used should be reviewed during the course of the site investigation and in the light of site conditions encountered.

6.3 Variability in nature of site conditions Account shall be taken of variations in material properties with time and location, in the area of the geotechnical site investigation.

NOTE: A selection of methods of investigation can be found in Appendices B and C, and a typical project brief is shown in Appendix D.

7 REPORTING

7.1 Data At the completion of a geotechnical site investigation, or at the completion of each phase of an extended investigation, a report shall be prepared by the investigator. As appropriate to the stated objectives and the phase of the investigation, this report shall contain—

(a) a description of proposed works;

(b) objectives of the investigation;

(c) identification of site;

(d) a description of methods of investigation and testing used;

(e) location and reduced levels of all boreholes, test sites and observations to a defined, consistent and recoverable reference grid and datum for the site;

(f) time observations made; and

(g) data obtained.

7.2 Opinion As appropriate to the stated objectives and the phase of the investigation, the report shall contain the investigator's opinion independently of the data.

8 CONSTRUCTION REVIEW AND PERFORMANCE MONITORING

8.1 Construction review If the review is not carried out as recommended, the investigator and the relevant regulatory authority shall be informed and reasons given for the non-compliance.

8.2 Performance monitoring If the monitoring is not carried out as recommended, the investigator and the relevant regulatory authority shall be informed and reasons given for the non-compliance.

NOTE: Some guidelines on construction review and monitoring are given in Appendix E.

APPENDIX A

DESCRIPTION AND CLASSIFICATION OF SOILS AND ROCKS FOR GEOTECHNICAL PURPOSES

(Informative)

A1 SCOPE This Appendix describes the preferred systems of description and classification of soils and rocks for use with this Standard. However, it does not preclude an investigator from using an alternative system, provided that the report clearly states that an alternative system has been used, and that a comprehensive description of the system used is included in the report.

Alternative systems may be useful, for example, for certain soil types such as calcareous soils, pedocretes and laterites, where the preferred system may not adequately describe characteristics peculiar to such materials.

A2 SOILS

A2.1 Description Soil description is based on an assessment of disturbed samples, as recovered from boreholes and excavations, and from undisturbed materials as seen in excavations and exposures or in undisturbed samples. Soils may be described in terms of ‘mass characteristics’ as assessed in the field and in terms of ‘material characteristics’ assessed from disturbed samples. The geological formation, age and type of deposit may also be identified where known, but these may not be readily assessable without an additional geological study of the area.

A soil classification places a soil in a limited number of groups on the basis of grading and plasticity of a disturbed sample. These characteristics are independent of the particular condition in which a soil occurs, and disregard the influence of the structure, including fabric, of the soil mass, but they can give a good guide to how the disturbed soil will behave when used as a construction material, under various conditions of moisture content.

In a soil description, the terms used should be presented in a logical, consistent order, which—

(a) distinguishes between *composition*, *condition* and *structure* of soil;

(b) describes firstly, the *information* which may be obtained from a disturbed soil sample; and

(c) secondly, describes the *additional condition and structure properties* which may only be observed in an undisturbed soil.

Table A1 is a guide to the naming and description of soils.

A2.2 Classification Any soil can be classified in one of a number of soil groups on the basis of the grading of the constituent particles, and the plasticity of the fraction of the material passing the 425 µm sieve. This may be done on the basis of estimation (field or rapid method) or from laboratory tests. The classification is carried out on material nominally finer than 63 mm. Coarse material, consisting of boulders and cobbles, is picked out and its proportion of the whole is estimated and recorded.

Group symbols for soil classifications are allocated as shown in Table A1.

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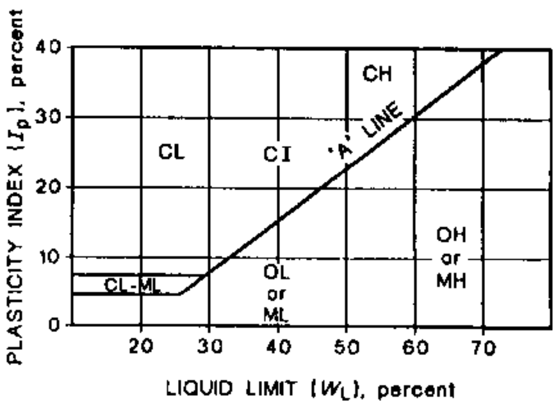
TABLE A1

GUIDE TO THE DESCRIPTION IDENTIFICATION AND CLASSIFICATION OF SOILS

Major divisions		Particle size, mm	Group symbol	Typical names	Field identification Sand and Gravels	Laboratory classification %(2) < 0.075mm	PLASTICITY OF FINE FRACTION	$C_u = \frac{D_{60}}{D_{10}}$	$C_c = \frac{(D_{30})^2}{D_{10}D_{60}}$	NOTES
COARSE GRAINED SOILS (more than half of material less than 63 mm is larger than 0.075 mm)	BOULDERS	200				Passing 63 mm for classification of fractions according to the criteria given in 'Major Divisions'				
	COBBLES	63								
	GRAVELS (more than half of coarse fraction is larger than 2.36 mm)	coarse 20	GW	Well-graded gravels, gravel-sand mixtures, little or no fines	Wide range in grain size and substantial amounts of all intermediate sizes, not enough fines to bind coarse grains, no dry strength	0-5	—	>4	between 1 and 3	1. Identify lines by the method given for fine-grained soils.
			GP	Poorly graded gravels and gravel-sand mixtures, little or no fines, uniform gravels	Predominantly one size or range of sizes with some intermediate sizes missing, not enough fines to bind coarse grains, no dry strength	0-5	—	Fails to comply with above		
		medium 6	GM	Silty gravels, gravel-sand-silt mixtures	'Dirty' materials with excess of non-plastic fines, zero to medium dry strength	12-50	Below 'A' line or $I_p<4$	—	—	2. Borderline classifications occur when the percentage of fines (fraction smaller than 0.075 mm size) is greater than 5% and less than 12%. Borderline classifications require the use of dual symbols e.g. SP-SM, GW-GC
		fine 2.36	GC	Clayey gravels, gravel-sand-clay mixtures	'Dirty' materials with excess of plastic fines, medium to high dry strength	12-50	Above 'A' line and $I_p>7$	—	—	
	SANDS (more than half of coarse fraction is smaller than 2.36 mm)	coarse 0.6	SW	Well graded sands, gravelly sands, little or no fines	Wide range in grain size and substantial amounts of all intermediate sizes, not enough fines to bind coarse grains, no dry strength	0-5	—	>6	between 1 and 3	
			SP	Poorly graded sands and gravelly sands; little or no fines, uniform sands	Predominantly one size or range of sizes with some intermediate sizes missing, not enough fines to bind coarse grains, no dry strength	0-5	—	Fails to comply with above		
		medium 0.2	SM	Silty sands, sand-silt mixtures	'Dirty' materials with excess of non-plastic fines, zero to medium dry strength	12-50	Below 'A' line or $I_p<4$	—	—	
		fine 0.075	SC	Clayey sands, sand-clay mixtures	'Dirty' materials with excess of plastic fines, medium to high dry strength	12-50	Above 'A' line and $I_p>7$	—	—	

FINE GRAINED SOILS (more than half of material less than 63 mm is smaller than 0.075 mm)	SILTS & CLAYS (liquid limit <50%)	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity	Dry* Strength	Dilatancy†	Toughness‡	Use the gradation curve of material		
				None to low	Quick to slow	None		More than 50% passing 0.06 mm	Below 'A' line
		CL, CI	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	Medium to high	None to very slow	Medium			Above 'A' line
		OL§	Organic silts and organic silty clays of low plasticity	Low to medium	Slow	Low			Below 'A' line
	SILTS & CLAYS (liquid limit >50%)	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	Low to medium	Slow to none	Low to medium			Below 'A' line
		CH	Inorganic clays of high plasticity, fat clays	High to very high	None	High			Above 'A' line
		OH§	Organic clays of medium to high plasticity, organic silts	Medium to high	None to very slow	Low to medium			Below 'A' line
	HIGHLY ORGANIC SOILS	Pt§	Peat and other highly organic soils	Identified by colour, odour, spongy feel and generally by fibrous texture			§Effervesces with H_2O_2		



Plasticity chart for classification of fine-grained soils

Field identification procedure for fine grained soils or fractions

These procedures are to be performed on the minus 0.2 mm size particles. For field classification purposes, screening is not intended, simply remove by hand the coarse particles that interfere with the tests.

*** Dry strength (Crushing characteristics)**

After removing particles larger than 0.2 mm size, mould a pat of soil to the consistency of putty, adding water if necessary. Allow the pat to dry completely by oven, sun or air drying, and then test its strength by breaking and crumbling between the fingers. This strength is a measure of the character and quantity of the colloidal fraction contained in the soil. The dry strength increases with increasing plasticity. High dry strength is characteristic for clays of the CH group.

A typical inorganic silt possesses only very slight dry strength.

Silty fine sands and silts have about the same slight dry strength, but can be distinguished by the feel when powdering the dried specimen. Fine sand feels gritty whereas a typical silt has the smooth feel of flour.

† Dilatancy (Reaction to shaking)

After removing particles larger than 0.2 mm size, prepare a pat of moist soil with a volume of 10 cm^3. Add enough water if necessary to make the soil soft but not sticky.

Place the pat in the open palm of one hand and shake horizontally, striking vigorously against the other hand several times. A positive reaction consists of the appearance of water on the surface of the pat which changes to a livery consistency and becomes glossy. When the sample is squeezed between the fingers, the water and gloss disappear from the surface, the pat stiffens, and finally it cracks or crumbles.

The rapidity of appearance of water during shaking and of its disappearance during squeezing assist in identifying the character of the fines in a soil.

Very fine clean sands give the quickest and most distinct reaction whereas a plastic clay has no reaction. Inorganic silts, such as a typical rock flour, shows a moderately quick reaction.

‡ Toughness (Consistency near plastic limit)

After removing particles larger than 0.2 mm size, a specimen of soil about 10 cm^3 in size is moulded to the consistency of putty. If too dry, water must be added and if sticky, the specimen should be spread out in a thin layer and allowed to lose some moisture by evaporation. The specimen is then rolled out by hand on a smooth surface or between the palms into a thread about 3 mm in diameter. The thread is then folded and rerolled repeatedly. During this manipulation the moisture content is gradually reduced and the specimen stiffens, finally loses its plasticity, and crumbles when the plastic limit is reached.

After the thread crumbles, the pieces should be lumped together with a slight kneading action continued until the lump crumbles. The tougher the thread near the plastic limit and the stiffer the lump when it finally crumbles, the more potent is the colloidal clay fraction in the soil.

Weakness of the thread at the plastic limit and quick loss of coherence of the lump below the plastic limit indicate either inorganic clay of low plasticity, or materials such as kaolin-type clays and organic clays which occur below the A-line. Highly organic clays have a very weak and spongy feel at the plastic limit.

A2.3 Order of description of a soil A systematic and standardized order of description is essential. The following order has been found to be suitable:

(a) *Composition of soil (disturbed or undisturbed state)* The description should include the following:

(i) Classification group symbol (use block letters) (see Table A1).

(ii) Soil name (use block letters).

NOTE: The presence of fill should be indicated at this stage.

(iii) Plasticity or particle characteristics of soil.

(iv) Colour of soil.

(v) Secondary soil components—name, estimated proportion, plasticity or particle characteristics, colour.

(vi) Other minor soil components—name, estimated proportion, *plasticity* or *particle characteristics, colour*.

NOTE: Precise description of properties shown in italics is frequently impracticable.

(b) *Conditions of soil* The following conditions are important:

(i) Moisture condition (disturbed or undisturbed state).

(ii) Consistency (undisturbed state only).

(c) *Structure of soil* In the undisturbed state, the following aspects of structure should be noted:

(i) Zoning.

(ii) Defects.

(iii) Cementing.

(d) *Additional observations* Certain additional observations may sometimes be required, such as the following:

(i) Soil origin, e.g. FILL, ALLUVIUM, COLLUVIUM, SLOPEWASH, RESIDUAL SOIL.

(ii) Other matters believed to be significant.

NOTES:

1 Soil origin cannot generally be deduced on the basis of material appearance and properties alone, but requires further geological evidence and field observation.

2 Soil origin, e.g. 'FILL' and 'TOPSOIL' is emphasised by use of BLOCK LETTERS.

A2.4 Composition of soil In describing the composition of a soil, the following aspects should be addressed:

(a) *Soil name* The soil name is based on particle size distribution and plasticity. These characteristics are used because they can be measured readily with reasonable precision and estimated with sufficient accuracy for descriptive purposes. They give a general indication of the probable engineering characteristics of the soil at any particular moisture content.

It will be seen from Table A1 that where a soil (any boulders or cobbles having been removed from the sample) contains 50 per cent or more of fine material, it is described as a clay or silt (fine-grained soil). With less than 50 per cent of fine-grained soil, it is described as sand or gravel (coarse-grained soil). In the field, these percentages can only be estimated. If accurate determination is required, laboratory tests are necessary.

The naming of soils on the basis of particle size distribution and plasticity is described in the following clauses. The basic soil types and their subdivisions are defined by the range of their particle sizes as shown in the third column of Table A1.

As most natural soils are part combinations of various constituents, the primary soil is described and modified by minor components, generally in accordance with the system outlined in Table A2.

NOTE: Organic and artificial materials cannot be adequately described using the terms in Table A2. For these materials descriptive terms should be specific as shown in Table A3.

TABLE A2

DESCRIPTIVE TERMS FOR MATERIAL PROPORTIONS

Coarse grained soils		**Fine grained soils**	
% Fines	**Modifier**	**% Coarse**	**Modifier**
≤ 5	Omit, or use ‘trace’	≤ 15	Omit, or use ‘trace’
> 5 ≤ 12	Describe as ‘with clay/silt’ as applicable	> 15 ≤ 30	Describe as ‘with sand/gravel’ as applicable
> 12	Prefix soil as ‘silty/clayey’ as applicable	> 30	Prefix soil as ‘sandy/gravelly’ as applicable

(b) *Plasticity* Clay and silt, both alone and in mixtures with coarser material, may be described according to their plasticity as follows.

Descriptive Term	**Range of liquid limit (per cent)**
Of low plasticity	≤ 35
Of medium plasticity	> 35 ≤ 50
Of high plasticity	> 50

(c) *Particle characteristics (coarse-grained soil)* The characteristics of the coarse grains forming the soil should be described in the following terms:

(i) Particle size. Report in millimetres or by use of subdivisions in Table A1. The spread of sizes represented is described using one of the following terms:

(A) ‘Well graded’—having good representation of all particle sizes from the largest to the smallest.

(B) ‘Poorly graded’—with one or more intermediate sizes poorly represented.

(C) ‘Gap graded’—with one or more intermediate sizes absent.

(D) ‘Uniform’—essentially of one size.

(ii) Particle shape. Report shape as follows:

(A) Equidimensional particles may be described as ‘rounded’, ‘sub-rounded’, ‘sub-angular’, or ‘angular’ as shown in Figure A1.

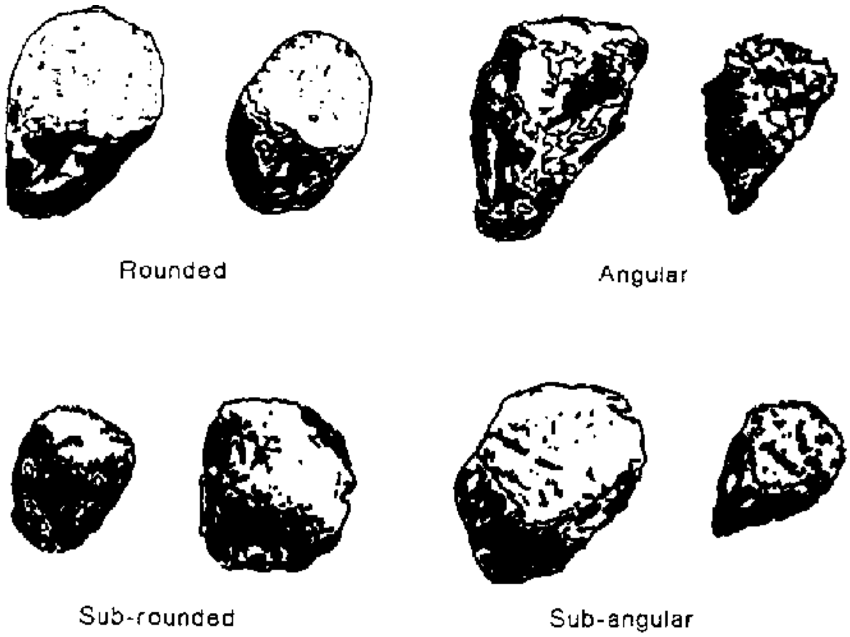


FIGURE A1 PARTICLE SHAPES

(B) Essentially two dimensional particles with the third dimension small by comparison may be described as ‘flaky’ or ‘platy’.

(C) Essentially one dimensional particles with the other two dimensions small by comparison may be described as ‘elongated’.

(iii) Particle composition using rock or mineral name.

(d) *Colour* The colour of a soil should be described in the ‘moist’ condition using simple terms, such as the following:

(i) black;

(ii) white;

(iii) grey;

(iv) red;

(v) brown;

(vi) orange;

(vii) yellow;

(viii) green; or

(ix) blue.

These may be modified as necessary by ‘pale’, ‘dark’, or ‘mottled’. Borderline colours may be described as a combination of these colours (e.g. red-brown).

Where a soil colour consists of a primary colour with a secondary mottling it should be described in the following fashion:

(Primary colour) mottled (secondary colour).

Example—grey mottled red-brown clay.

Where a soil consists of two colours present in roughly equal proportions the colour description should be as follows:

Mottled (first colour) and (second colour).

Example—mottled brown and red-brown clay.

A mixture of distinct colours may be described as, for example, mottled red/grey.

TABLE A3

DESCRIPTION OF ORGANIC OR ARTIFICIAL MATERIALS

Preferred terms	Secondary description
Organic matter	Fibrous peat Charcoal Wood fragments Roots (greater than 2 mm diameter) Root fibres (less than 2 mm diameter)
Waste fill	Domestic refuse Oil, bitumen Brickbats Concrete rubble Fibrous plaster Wood pieces, wood shavings, sawdust Iron filings, drums, steel bars, steel scrap Bottles, broken glass Leather

NOTE: For waste fill, the components should be described in detail.

A2.5 Condition of soil The condition of the soil may be described in the following terms:

(a) *Moisture condition* This is described by the appearance and feel of the soil using one of the following terms:

(i) 'Dry' (D) — Cohesive soils; hard and friable or powdery, well dry of plastic limit.
Granular soils; cohesionless and free-running.

(ii) 'Moist' (M) — Soil feels cool, darkened in colour.
Cohesive soils can be moulded.
Granular soils tend to cohere.

(iii) 'Wet' (W) — Soil feels cool, darkened in colour.
Cohesive soils usually weakened and free water forms on hands when handling.
Granular soils tend to cohere.

(b) *Consistency* There are two distinct methods of description of this parameter:

(i) Essentially cohesive soils. Consistency of essentially cohesive soils may be described in terms of a scale of strength (see Table A4). If a mineral cement appears to be present, it is also useful to note whether slaking occurs on immersing the air dry material in water.

In the field the undrained shear strength can also be assessed using a pocket penetrometer for firm to very stiff soils or a hand vane for very soft to firm soils. These devices must be used with calibration charts.

(ii) Essentially non-cohesive soils. The consistency of essentially non-cohesive soils is described in terms of the density index, as defined in AS 1289.0. It is not possible to make an assessment of the density index without some form of test on an undisturbed or in situ sample.

These soils are inherently difficult to assess, and normally a penetration test procedure (SPT, DCP or CPT) is used in conjunction with published correlation tables. Alternatively, in situ density tests can be conducted in association with minimum and maximum density tests performed in the laboratory. Table A5 lists terms applicable to these soils.

TABLE A4

CONSISTENCY TERMS—COHESIVE SOILS

Term	Undrained shear strength kPa	Field guide to consistency
Very soft	≤12	Exudes between the fingers when squeezed in hand
Soft	>12 ≤25	Can be moulded by light finger pressure
Firm	>25 ≤50	Can be moulded by strong finger pressure
Stiff	>50 ≤100	Cannot be moulded by fingers Can be indented by thumb
Very stiff	>100 ≤200	Can be indented by thumb nail
Hard	>200	Can be indented with difficulty by thumb nail

TABLE A5

CONSISTENCY TERMS—NON-COHESIVE SOILS

Term	Density index %
Very loose	≤15
Loose	>15 ≤35
Medium dense	>35 ≤65
Dense	>65 ≤85
Very dense	>85

A2.6 Structure of soil The structure of the soil may be described in the following terms:

(a) *Zoning* Soil in situ or in samples may consist of separate zones differing in colour, grain size or other properties. The patterns of these zones should be described using the following terms:

(i) ‘Layer’, i.e. zone is continuous across exposure or sample.

(ii) ‘Lens’, i.e. a discontinuous layer of different material, with lenticular shape.

(iii) ‘Pocket’, i.e. an irregular inclusion of different material.

The thickness, orientation and any distinguishing features of the zones should be described.

The boundaries between zones should be described as gradational or distinct.

(b) *Defects* The approximate dimensions, orientation and spacing of defects should be given. The surface of the defects should be described in terms of texture (rough, polished), and coating. Defects may include fissures, cracks, root-holes, and the like.

(c) *Cementing* Coarse grained soils or defects within soils may be cemented together by various agencies. If the cementing agent allows the particle aggregations to be easily fractured by hand when the soil is saturated it should be described as 'weakly cemented'.

If the cementing agent prevents fracturing by hand of the particle aggregations when saturated it should be described as 'strongly cemented'. In this case the soil has assumed rock properties which are described according to their saturated unconfined compressive strength using the system adopted for classification of rocks.

The nature of the cementing agent should be identified 'if possible' from its appearance, strength, reaction to acid, and the like.

(d) *Additional observations* Other pertinent aspects of the environment of the soil or the soil sample should be recorded, such as the following:

(i) Geological origin. If the origin of the soil can be deduced it should be noted (especially if FILL).

(ii) Any odour should be noted.

A3 ROCKS

A3.1 Introduction In most rocks the presence of defects and the effects of weathering are likely to have a great influence on engineering behaviour. Hence, the method of description given in this Standard pays particular attention to such features.

Rock descriptions can be made from disturbed samples or hand specimens as recovered from excavations or as received in the laboratory from bore cores or from in situ exposures as seen in outcrops and excavations. As with soils, rocks may be described in terms of 'material characteristics', assessed from disturbed samples and in terms of 'mass characteristics' as assessed in the field. The geological formation and age should be named where known.

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

(a) Terms describing the 'composition' and 'condition' of rock material and the rock mass properties, (including structure).

(b) Information which may be 'obtained from a hand specimen' followed by the additional condition and structure properties which may be 'observed in bore cores', and finally, rock mass properties which may only be 'observed in outcrop'.

A3.2 Order of description of properties of rocks The following order of description is recommended:

(a) *Composition of rock material*:

(i) Rock name.

(ii) Grain size.

(iii) Texture and fabric.

(iv) Colour.

(b) *Condition of rock material*:

(i) Strength.

(ii) Weathering.

(c) *Rock mass properties*:

(i) Structure of rock.

(ii) Defects—type, orientation, spacing, roughness, waviness, continuity.

(iii) Weathering (of the rock mass).

A3.3 Composition of rock material The following main features of composition should be mentioned:

(a) *Rock type* An aid to the identification of rock for engineering purposes is given in Table A6,(a) and (b). The Table follows general geological practice, but is intended as a guide only; geological experience is required for the satisfactory identification of rock. Engineering properties cannot be inferred from the rock names in the Table. The Table does not deal with pedocretes which require a special classification.

Suitable classification systems derived from CLARK and WALKER* have been developed with experience of Australian conditions and reported by POULOS†, and by JEWELL and KHORSHID‡.

(b) *Grain size* A descriptive classification scheme is built into Table A6. Grain size refers to the average dimension of the mineral or rock fragments comprising the rock. It is usually sufficient to estimate the size by eye, which may be aided by a hand lens in the assessment of fine-grained or amorphous rocks. The limit of unaided vision is approximately 0.06 mm.

(c) *Texture and fabric* The texture of a rock refers to individual grains. Terms frequently used include: porphyritic, crystalline, cryptocrystalline, granular, amorphous and glassy.

The arrangement of grains, referred to as the rock fabric, may show a preferred orientation (see Table A7).

(d) *Colour* The colour of a rock should be described in the 'moist' condition using simple terms such as—

(i) black;

(ii) white;

(iii) grey;

(iv) red;

(v) brown;

(vi) orange;

(vii) yellow;

(viii) green; or

(ix) blue.

These may be modified as necessary by 'pale', 'dark', or 'mottled'. Borderline colours may be described as a combination of these colours (e.g. 'red-brown', not 'reddish-brown').

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* CLARK, A. B. and WALKER, P. F. *A proposed scheme for classification and nomenclature for use in the engineering descriptions of Middle Eastern Sedimentary rocks*. Geotechnique, Vol.27, 1977 pp. 93-99.

† POULOS, H. G. *A review of the behaviour and engineering properties of carbonate soils*. Australian Geomechanics News, 6, Dec 1983, pp 17-27.

‡ JEWELL, R. J. and KHORSHID M. S. (editors). *Engineering for calcareous sediments*. Proc. Int. Conf. Calcareous Sediments, Vol. 2 Perth, W.A. 1988. Balkema, Rotterdam.

TABLE A6(a)

AN AID TO IDENTIFICATION OF ROCKS FOR ENGINEERING PURPOSES (SEDIMENTARY ROCKS)

Tables A6(a) and A6(b) follow general geological practice, but are intended as a guide only; geological training is required for the satisfactory identification of rocks. Engineering properties cannot be inferred from rock names in the Table.

Grain size mm	Bedded rocks (mostly sedimentary)				
More than 20	Grain size description		At least 50% of grains are of carbonate	At least 50% of grains are of fine-grained volcanic rock	
20 6 2	RUDACEOUS	**CONGLOMERATE** Rounded boulders, cobbles and gravel cemented in a finer matrix Breccia Irregular rock fragments in a finer matrix	**LIMESTONE** and **DOLOMITE** (undifferentiated) Calcirudite*	Fragments of volcanic ejecta in a finer matrix Rounded grains **AGGLOMERATE** Angular grains **VOLCANIC BRECCIA**	SALINE ROCKS Halite Anhydrite
2 0.6 0.2 0.06	ARENACEOUS (Coarse, Medium, Fine)	**SANDSTONE** Angular or rounded grains, commonly cemented by clay, calcitic or iron minerals Quartzite Quartz grains and siliceous cement Arkose Many feldspar grains Greywacke Many rock chips	**LIMESTONE** and **DOLOMITE** (undifferentiated) Calcarenite	Cemented volcanic ash **TUFF**	Gypsum
0.06 0.002	ARGILLACEOUS	**MUDSTONE** / **SILTSTONE** Mostly silt	**Calcareous mudstone**; **LIMESTONE** and **DOLOMITE** (undifferentiated); Calcisiltite; **CHALK**	Fine-grained **TUFF**	
Less than 0.002	ARGILLACEOUS	**SHALE** Fissile / **CLAYSTONE** Mostly clay	**Calcareous mudstone**; **LIMESTONE** and **DOLOMITE** (undifferentiated); Calcilutite; **CHALK**	Very fine-grained **TUFF**	
Amorphous or crypto-crystalline		Flint: occurs as bands of nodules in the chalk Chert: occurs as nodules and beds in limestone and calcareous sandstone			**COAL** **LIGNITE**
		Granular cemented—except amorphous rocks			
		SILICEOUS	CALCAREOUS	SILICEOUS	CARBON-ACEOUS

SEDIMENTARY ROCKS

Granular cemented rocks vary greatly in strength, some sandstones are stronger than many igneous rocks. Bedding may not show in hand specimens and is best seen in outcrop. Only sedimentary rocks, and some metamorphic rocks derived from them, contain fossils.

Calcareous rocks contain calcite (calcium carbonate) which effervesces with dilute hydrochloric acid.

* A more detailed classification is given in Clark, A.R. and Walker, B.F. *Geotechnique*, 1977, 27(1), 93-99.

TABLE A6(b)

AN AID TO IDENTIFICATION OF ROCKS FOR ENGINEERING PURPOSES (METAMORPHIC AND IGNEOUS ROCKS)

Obviously foliated rocks (mostly metamorphic)		**Rocks with massive structure and crystalline texture (mostly igneous)**						**Grain size mm**
Grain size description			**Grain size description**	Pegmatite			Pyroxenite	More than 20
COARSE	**GNEISS** Well developed but often widely spaced foliation sometimes with schistose bands Migmatite Irregularly foliated: mixed schists and gneisses	**MARBLE** **QUARTZITE** Granulite **HORNFELS**	COARSE	**GRANITE**[1] These rocks are sometimes porphyritic and are then described, for example, as porphyritic granite	Diorite[1,2]	**GABBRO**[3]	Peridotite	20 6 2
MEDIUM	**SCHIST** Well developed undulose foliation; generally much mica	Amphibolite Serpentine	MEDIUM	Microgranite[1] These rocks are sometimes porphyritic and are then described as porphyries	Microdiorite[1,2]	Dolerite[3,4]		0.6 0.2 0.06
FINE	**PHYLLITE** Slightly undulose foliation; sometimes 'spotted' **SLATE** Well developed plane cleavage (foliation)		FINE	**RHYOLITE**[4,5] These rocks are sometimes porphyritic and are then described as porphyries	**ANDESITE**[4,5]	**BASALT**[4,5]		0.002 Less than 0.002
	Mylonite Found in fault zones, mainly in igneous and metamorphic areas			Obsidian[5]	Volcanic glass			Amorphous or crypto-crystalline
CRYSTALLINE				Pale	colour <------------------------------------->		Dark	
SILICEOUS		Mainly SILICEOUS		ACID Much quartz	INTERMEDIATE Some quartz	BASIC Little or no quartz	ULTRA BASIC	
METAMORPHIC ROCKS Most metamorphic rocks are distinguished by foliation which may impart fissility. Foliation in gneisses is best observed in outcrop. Non-foliated metamorphics are difficult to recognise except by association. Any rock baked by contact metamorphism is described as a 'hornfels' and is generally somewhat stronger than the parent rock. Most fresh metamorphic rocks are strong although perhaps fissile.			IGNEOUS ROCKS Composed of closely interlocking mineral grains. Strong when fresh; not porous Mode of occurrence: 1 Batholiths; 2 Laccoliths; 3 Sills; 4 Dykes; 5 Lava flows; 6 Veins					

NOTES to Tables A6(a) and A6(b):

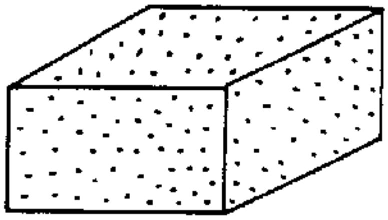
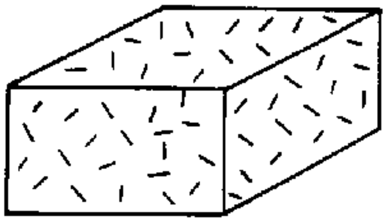
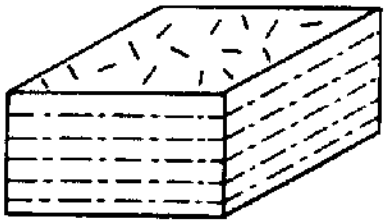
1 Principal rock types (generally common) are shown in bold type in capitals, e.g. **GRANITE**. Less common rock types are shown in medium type, e.g. Greywacke.

2 Granular rocks may be distinguished from crystalline rocks by scratching with a knife which should remove whole grains from cement matrix in the granular rocks. The separate grains may also sometimes be distinguished using a hand lens.

Siliceous rocks are generally harder and more resistant to scratching than calcareous rocks.

3 In the Table the boundaries of the heavy lined box describe the conditions to which the rock name applies.

TABLE A7
TEXTURE AND FABRIC OF ROCK

Geological description	Diagram	Fabric type
Massive		Effectively homogeneous and isotropic. Bulky or equidimensional grains uniformly distributed.
		Effectively homogeneous and isotropic. Elongated or tabular grains uniformly distributed, randomly orientated.
Layered (bedded foliate cleaved)		Effectively homogeneous with planar anisotropy. Elongated or tabular grains or pores in a layered arrangement.

NOTES:

1 The symbols in this Table are not standard symbols for any one soil or rock type; they represent diagrammatically the shape of mineral grains or pores.

2 ‘Effectively’ means that for practical engineering purposes tests give acceptable coefficients of variation.

A3.4 Condition of rock material

(a) *Strength of rock material* A scale of strength, based on point load index testing, is presented in Table A8.

Field guide assessments should be confirmed by point load strength testing when rock strength terms are used in earthworks and foundation investigation reports. Point load index testing should be performed in accordance with International Society for Rock Mechanics (ISRM) procedures as described in *Int. T. Rock Mech. Min. Sci. and Geomech. Abstr.* Suggested Method for Determining Point Load Strength, Vol.22 No.2 1985 pp.51-60.

TABLE A8

STRENGTH OF ROCK MATERIAL

Term	**Letter symbol**	**Point load index (MPa) I_s50**	**Field guide to strength**
Extremely low	EL	≤0.03	Easily remoulded by hand to a material with soil properties
Very low	VL	>0.03 ≤0.1	Material crumbles under firm blows with sharp end of pick; can be peeled with knife; too hard to cut a triaxial sample by hand. Pieces up to 3 cm thick can be broken by finger pressure
Low	L	>0.1 ≤0.3	Easily scored with a knife; indentations 1 mm to 3 mm show in the specimen with firm blows of the pick point; has dull sound under hammer. A piece of core 150 mm long 50 mm diameter may be broken by hand. Sharp edges of core may be friable and break during handling
Medium	M	>0.3 ≤1.0	Readily scored with a knife; a piece of core 150 mm long by 50 mm diameter can be broken by hand with difficulty
High	H	>1 ≤3	A piece of core 150 mm long by 50 mm diameter cannot be broken by hand but can be broken by a pick with a single firm blow; rock rings under hammer
Very high	VH	>3 ≤10	Hand specimen breaks with pick after more than one blow; rock rings under hammer
Extremely high	EH	>10	Specimen requires many blows with geological pick to break through intact material; rock rings under hammer

NOTES:

1 These terms refer to the strength of the rock material and not to the strength of the rock mass which may be considerably weaker due to the effect of rock defects.

2 The field guide visual assessment of rock strength may be used for preliminary assessment or when point load testing is not available.

3 Anisotropy of rock material samples may affect the field assessment of strength.

(b) *Weathering of rock material*

Table A9 presents a suitable classification system for rock material weathering.

TABLE A9

ROCK MATERIAL WEATHERING CLASSIFICATION

Term	Symbol	Definition
Residual soil	RS	Soil developed on extremely weathered rock; the mass structure and substance fabric are no longer evident; there is a large change in volume but the soil has not been significantly transported
Extremely weathered rock	XW	Rock is weathered to such an extent that it has 'soil' properties, i.e. it either disintegrates or can be remoulded, in water
Distinctly weathered rock	DW	Rock strength usually changed by weathering. The rock may be highly discoloured, usually be ironstaining. Porosity may be increased by leaching, or may be decreased due to deposition of weathering products in pores
Slightly weathered rock	SW	Rock is slightly discoloured but shows little or no change of strength from fresh rock
Fresh rock	FR	Rock shows no sign of decomposition or staining

A3.5 Rock mass properties The properties of the rock 'mass', as distinct from the rock 'material' should be described in the following terms:

(a) *Structure* The structure of the rock mass is concerned with the larger scale inter-relationship of textural features. Common terms should be used where possible, such as the following:

(i) Sedimentary rocks — bedded, laminated (laminae are less than 20 mm thick).

(ii) Metamorphic rocks — foliated, banded cleaved.

(iii) Igneous rocks — massive, flow banded.

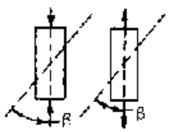
The spacing or thickness of these structural features should be given rather than unquantified descriptive terms.

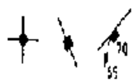
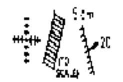
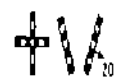
(b) *Defects* Defects are fractures in the rock mass and include joints, faults, sheared planes, cleavages and bedding partings. The details of all relevant defects should be given, whether defects are open or tight, healed, cemented or infilled, or incipient. The surfaces of defects may be plane, curved, irregular, slickensided, smooth or rough. It may often be necessary to describe large defects individually. When material infilling an open defect is observed, the material should be separately described, in accordance with this Appendix if it is a soil. See Table A10 for definitions and general notes on common defects.

TABLE A10

COMMON DEFECTS IN ROCK MASS

(Definitions and General Notes)

Term[1] General	Layering (Layer)[2]			Fractures and fractured zones		Weak seams or zones		
Specific	**Bedding**	**Foliation**	**Cleavage**	**Joint**	**Sheared zone**	**Crushed seam/zone**	**Decomposed seam/zone**	**Infilled seam/zone**
Physical description	Arrangement in layers, of mineral grains of similar sizes or composition, and/or arrangement of elongated or tabular minerals near parallel to one another, and/or to the layers Generally no microfractures	Discontinuous microfractures may be present, near parallel to the layering		A discontinuity or crack, planar, curved or irregular, across which the rock usually has little tensile strength. The joint may be open (filled with air or water) or filled by soil substances or by rock substance which acts as a cement, joint surfaces may be rough, smooth, or slickensided	Zone, with roughly parallel planar boundaries, of rock material intersected by closely spaced (generally < 50 mm) joints and/or microscopic fracture (cleavage) planes. The joints are at small angles to the zone boundaries; they are usually slightly curved and divide the mass into unit blocks of lenticular or wedge shape; their surfaces are smooth or slickensided TYPE 'R' ranging to TYPE 'S' Joints tightly closed cemented, but cements (usually chlorite or calcite) are weaker than the rock substance Joints not cemented but either coated with soil substances or are open, filled with air, water or both	Zone with roughly parallel planar boundaries, composed of disoriented, usually angular fragments of the host rock substance. The fragments may be of clay, silt, sand or gravel sizes, or mixtures of any of these. Some minerals may be altered or decomposed but this is not necessarily so. Boundaries commonly slickensided	Zone of any shape, but commonly with roughly parallel planar boundaries in which the rock material is discoloured and usually weakened. The boundaries with fresh rock are usually gradational. Geological structures in the fresh rock are usually preserved in the decomposed rock. 'Weathered' and 'altered' are more specific terms	Zone, of any shape, but commonly with roughly parallel planar boundaries composed of soil substance. May show layering roughly parallel to the zone boundaries. Geological structures in the adjacent rock do not continue into the infill substance
Engineering[3] [4] properties	• Where uniformly developed in a rock substance any of these types of structure render that rock substance anisotropic in its behaviour under stress • Compressive Strengths min. when $\beta = 30°$ to $45°$ Initial shear usually max. when $\beta = 0°$ and $90°$ Tensile strength usually max. when $\beta = 0°$ min. when $\beta = 90°$ Deformation modulus usually higher for $\beta = 0°$ than for $\beta = 90°$ Where *not* uniformly developed, these structures represent defects in the rock mass, i.e. as individual layers or layered zones 			• Tensile strength low/zero • Sliding resistance depends upon properties of coatings or cement and condition of surfaces PARAMETERS *c* cohesion of coating/cement/wall-rock ϕ friction angle of coating/cement/wall-rock / angle of roughness of surface k_n normal stiffness k_s tangential stiffness	• Rock properties, very fissile rock mass • When excavated forms GRAVEL (generally GP) SOIL properties, GRAVEL (GP, GM or GC) Both types show extreme planar anisotropy. Lowest shear strength in direction of slickensides, in plane parallel to boundaries	• SOIL properties either cohesive or non-cohesive • Usually shows planar anisotropy; lowest shear strength in direction of slickensides in plane parallel to boundaries	• Extremely decomposed (XD) seam has SOIL properties usually cohesive but may be non-cohesive • Mostly very compact except when soluble minerals removed • Slightly to highly decomposed substances ROCK properties but usually lower strengths than the fresh rock substance	• SOIL properties, usually cohesive (CL or CH) but may be non-cohesive
				Engineering properties commonly different from place to place especially where the defect passes through several different rock substance types				
Extent	Usually governed by the thickness and lateral extent of the rock substance or mass containing the defect	May occur in a zone continuous through several different rock substance types		From 10 mm to 50 m or more, depends on origin	Generally large (50 m to many km)		Weathered zones related to present or past land surface limited extent. Altered zones occur at any depth	Usually small limited to mechanically weathered zone. Can be great in rocks subject to solution

<table>
<tr><td rowspan="2">Origin
(usually controls extent)</td><td rowspan="2">Deposition in layers</td><td rowspan="2">• Viscous flow
• Crystal growth at high pressures and temperatures
• Shearing under high confining pressure</td><td rowspan="2">• Shearing during folding or faulting
• Consolidation, compaction</td><td rowspan="2">• Shearing, extension or torsion failure, arising from faulting, folding, relief of pressure, shrinkage due to cooling or loss of fluid</td><td colspan="2">Faulting</td><td rowspan="2">• Decomposition of minerals, removal or rupture of cement, due to circulation of mineralized waters usually along joints sheared zones or crushed zones</td><td rowspan="2">• Cohesive soil carried into open joint or cavity as a suspension in water
• Non-cohesive soil falls or washes in</td></tr>
<tr><td>Shear failure by small displacements along a large number of near-parallel intersecting planes. The different strengths of Types R and S are usually due to (a) different depths of rock cover at the time of faulting or (b) Later cementation or (c) Later mechanical weathering</td><td>• Failure by large movement within narrow zone
• Generally formed at shallow depth (< 3000 m)</td></tr>
<tr><td rowspan="3">Description required</td><td>Bed thickness, grain types and sizes</td><td colspan="2">Fabric description, and spacing and extent of microfractures</td><td rowspan="3">Shape, aperture, surface condition, coating, filling, extent</td><td colspan="4">Zone width, shape and extent</td></tr>
<tr><td colspan="3" rowspan="2">Ease of splitting and nature of fracture faces</td><td rowspan="2">Pattern of joints or micro-fractures and resulting shape and size of unit blocks. Standard description of joints</td><td></td><td>Degree of decomposition</td><td></td></tr>
<tr><td colspan="3">Standard description of soil or rock substance</td></tr>
<tr><td rowspan="2">Associated description etc</td><td rowspan="2">Graded-, discord- and, slump-bedding; other primary structures: Facing Attitudes Lineations</td><td colspan="2">Attitude of planes and of any linear structure, extent</td><td>Spacing, attitude of joint and of slickensides</td><td colspan="2" rowspan="2">Attitude of zone. Direction of slickensides and amount, direction, and sense of displacement. Type of fault. History of past movements. Any modern activity. Likelihood of future movements. The terms ‘major’ and ‘minor’ fault are defined whenever used. The definitions are made on the basis of (a) width and nature of the fault materials, (b) significance to the project</td><td rowspan="2">Attitude of zone. Classify as weathered or altered if possible and determine origin, and defect or defects influencing decomposition</td><td rowspan="2">Attitude of zone. Type of defect which is infilled, origin of infill substance</td></tr>
<tr><td colspan="3">Allocate to set, determine origin type</td></tr>
<tr><td>Terms not[5] used
(for these defects)</td><td colspan="3">Strata, stratification, schistosity, gneissocity, micro-fissuring</td><td>Fissure, crack, slip, shear, break, fracture (except in general sense for joints, faults cleavage planes)</td><td colspan="2">Shear-, shatter-, shattered-, crush-, broken-, blocky-, zone; slip, shear, mylonite, gouge breccia, fault-breccia, crush breccia, pug.
The terms ‘fault’ or ‘fault-zone’ are only used in a genetic or general sense and must be qualified by the use of the defined terms given above. ‘Mylonite’ is rock substance with intense planar foliation, developed due to shearing at great depth beneath the earth’s crust.</td><td>Rotten, disintegrated, softened, soft (unless in defined sense for clay)</td><td>Vein, fissure, pug, gouge</td></tr>
<tr><td>Map symbols[6]
(horiz., vert., dipping)</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

NOTES to Table A10:

1 The actual defect is described, not the process which formed or may have formed it, e.g., 'sheared zone', not 'zone of shearing': the latter suggests a currently active process.

2 The terms 'layering', 'bedding', etc are used as the main headings on this portion of the Table allowing them to refer to both rock substances and masses.

3 These notes refer to the engineering properties of the defect type, not those of the rock mass containing the defect.

4 In general, each rock defect is more permeable than the material in which it occurs, and the defect strength becomes lower with increase in water content/pressure.

5 Such terms as 'strong', 'strongly' or 'weakly', are never used to indicate the degree of development of a defect or group of defects.

6 Geological map symbols conform where possible to *Standard Geological Symbols 1963*, Bureau of Mineral Resources, Canberra.

7 Thickness, openness—measured in millimetres normal to plane of the discontinuity.

8 Roughness—a measure of the inherent surface unevenness and waviness of the discontinuity relative to its mean plane, as follows:

Roughness class	*Description (see Figure A2)*
I	Rough or irregular, stepped
II	Smooth, stepped
III	Slickensided, stepped
IV	Rough or irregular, undulating
V	Smooth, undulating
VI	Slickensided, undulating
VII	Rough or irregular, planar
VIII	Smooth, planar
IX	Slickensided, planar

9 Coating or infilling:

Clean — no visible coating or infilling.
Stain — no visible coating or infilling but surfaces are discoloured by mineral staining.
Veneer — a visible coating or infilling of soil or mineral substance but usually unable to be measured (less than 1 mm). If discontinuous over the plane, patchy veneer.
Coating — a visible coating or infilling of soil or mineral substance, greater than 1 mm thick. Describe composition and thickness.

10 Persistence—the areal extent of defect. Give trace lengths, in metres.

11 Spacing—measure of the spacing of defects. Measure mean and range of spacings for each set where possible (do not use descriptive terms).

Alternative criteria may be used for quantitative description of the fracture state of rock cores such as the solid core recovery, fracture log, and rock quality designation (*RQD*). The simplest measure is the solid core recovery ratio, particularly when contrasted with the total core recovery (which includes fragmented cores). A fracture log is a count of the number of natural fractures present over an arbitrary length. *RQD* is often used as a quantitative measure of the rock recovered as lengths of 100 mm or more. Only core lengths determined by geological fractures should be measured. If the core is broken by handling or by the drilling process (i.e. the fracture surfaces are fresh, irregular breaks rather than natural joint surfaces) the fresh broken pieces are fitted together and counted as one piece.

The terms used in this Note are defined as follows:

(a) *Fracture log or frequency (F)* is the number of natural fractures present in a unit length of core (usually 1 m).

(b) *Recovery ratio or total core recovery (R)* is the ratio of total length of core recovered to length of core run drilled (usually 1.5 m or 3.0 m), expressed as a percentage.

(c) *Rock quality designation (RQD)* is the ratio of length of rock core recovered in pieces of 100 mm or longer to length of core run drilled (usually 1.5 m or 3.0 m) expressed as a percentage.

12 Defect spacing in three dimensions. The spacing of defects may be described with reference to the size and shape of rock blocks bounded by defects, as follows:

Term	*Description*
Blocky	Equidimensional
Tabular	Thickness much less than length or width
Columnar	Height much greater than cross section

@Seismicisolation

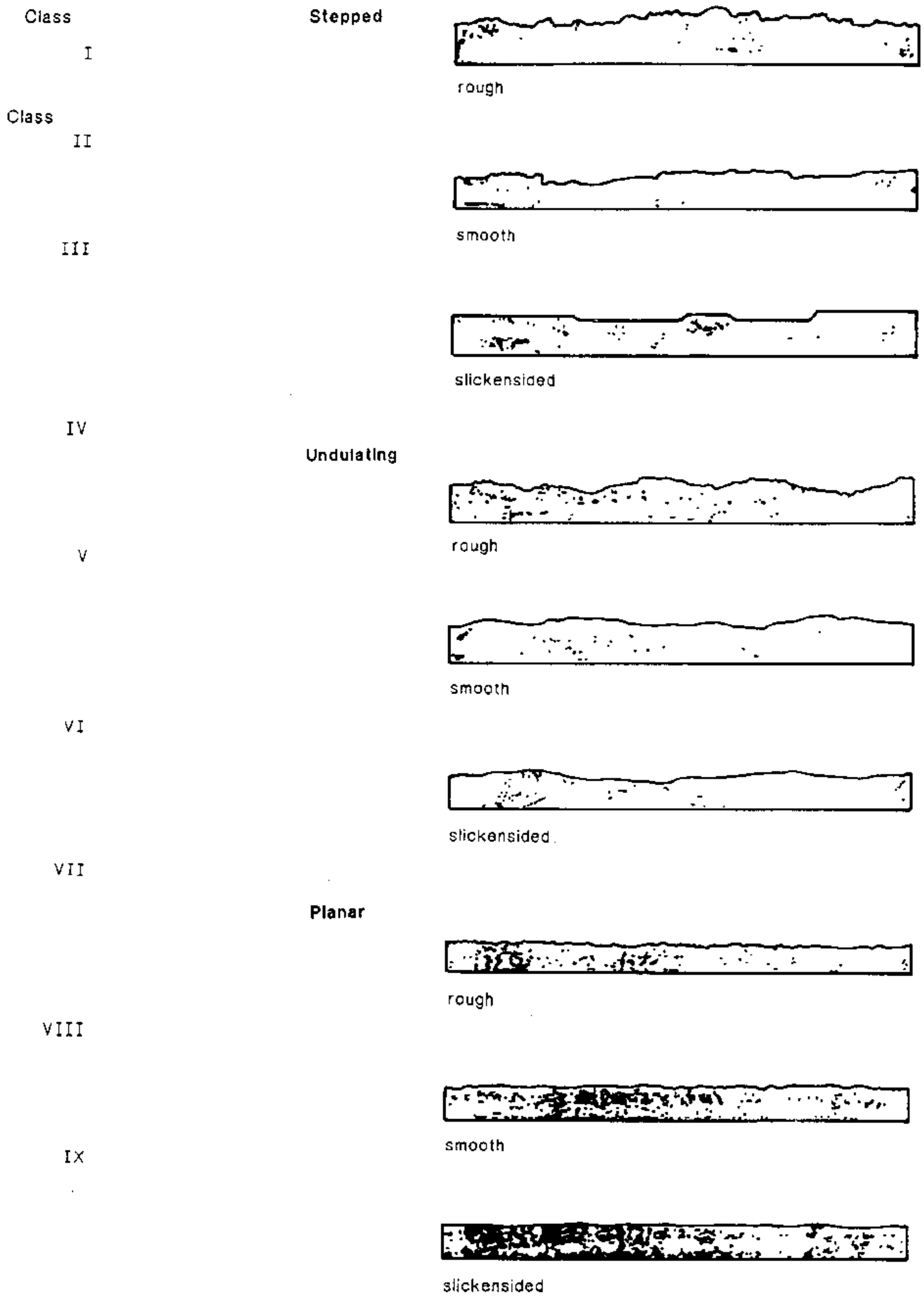


FIGURE A2 TYPICAL ROUGHNESS PROFILES
(after ISRM Commission 1978)

Defects usually occur in more than one direction in a rock mass, and may be present as distinct sets. Borehole cores provide essentially one dimensional data on defect spacing; exposures are usually needed for full evaluation of the defect pattern.

(c) *Weathering of the rock mass* The weathering of the rock mass may be described in relation to the distribution of the variously weathered materials within it and the effect on discontinuities. See Table A11.

It is recommended that the descriptive terms in Table A11 be used as a general basis for the design of site specific weathered rock mass classifications. The grade number is not to be used for detailed logging of boreholes but may be used for large scale excavations such as dam abutments and cut rock slopes.

TABLE A11

ROCK MASS WEATHERING GRADES

Grade	Descriptive terms
IA	Fresh; no visible sign of rock material weathering
IB	Fresh except for limonite staining on major defect surfaces
II	Some to all of the rock material is discoloured by slight weathering
III	Less than half of the rock material is moderately to extremely weathered. Fresh or slightly weathered rock is present either as a discontinuous framework or as corestones
IV	More than half of the rock material is moderately to extremely weathered. Fresh or slightly weathered rock is present either as a discontinuous framework or as corestones
V	The rock material is extremely weathered with the original mass structure still largely intact
VI	Refer to soil classification system

NOTE: If a rock mass classification is to be devised, it should take strength and defect variations into account.

APPENDIX B
FIELD TEST METHODS
(Informative)

A wide variety of techniques and tests are available for on-site geotechnical investigations. Listed are a range of techniques that are commonly considered. Other more specialized techniques and tests are available and can also be considered when circumstances dictate.

(a) Geological studies:

(i) Regional geological mapping.

(ii) Detailed geological mapping of excavations and outcrops.

(iii) Borehole logging.

(b) Geophysical methods:

(i) Seismic refraction.

(ii) Resistivity and conductivity.

(iii) Magnetics.

(iv) Geophysical borehole logging.

(v) Subsurface radar.

(c) Drilling and sampling:

(i) Rotary core drilling.

(ii) Auger boring and coring.

(iii) Percussion drilling.

(iv) Undisturbed sampling.

(v) Disturbed sampling.

(d) In situ subsurface testing:

(i) Standard penetration tests.

(ii) Dynamic cone penetrometer.

(iii) Static cone penetrometer.

(iv) Vane shear test.

(v) Pressuremeter.

(vi) Impression packer.

(vii) Core orientation device.

(viii) Borehole periscope TV and photography.

(e) In situ rock testing in excavations and galleries:

(i) Direct shear tests.

(ii) Plate bearing tests.

(iii) In situ stress measurement.

(f) In situ soil testing in excavations:

  (i) Plate bearing test.

  (ii) Density measurement.

  (iii) California bearing ratio.

(g) Slope and excavation stability monitoring:

  (i) Inclinometer.

  (ii) Extensometer.

(h) Blasting tests and blast vibration monitoring.

(i) Topographic studies:

  (i) Topographic mapping.

  (ii) Terrain evaluation.

  (iii) Photogrammetry and photo interpretation.

  (iv) Remote sensing.

(j) Groundwater studies:

  (i) Packer tests.

  (ii) Rising head, constant head and falling head tests.

  (iii) Pumping tests.

  (iv) Groundwater level measurement.

  (v) Chemical and microbiological water quality.

(k) Seismicity studies.

(l) Exploratory pits, trenches, shafts, tunnels and galleries.

APPENDIX C

LABORATORY EXAMINATION AND TESTING

(Informative)

For civil engineering purposes laboratory testing provides the means of identifying and classifying soil and rock properties. Listed are some of the commonly considered laboratory tests. Reference should be made to the relevant Australian Standard or appropriate test method for such requirements as sample condition and size.

(a) Sample disturbance:

 (i) Both disturbed and undisturbed samples may be obtained for laboratory testing. Generally the laboratory test method will indicate the type of test sample required.

(b) Visual examination:

 (i) Consistency, structure, and particle size.

 (ii) Colour, inclusions and accessory materials.

 (iii) Geological type.

 (iv) Rock defects and weathering.

 (v) Similar characteristics and pertinent information.

(c) Classification—soil/water properties:

 (i) In situ/natural moisture content.

 (ii) Liquid, plastic and shrinkage limits.

 (iii) Plasticity and liquidity indices.

 (iv) Linear shrinkage.

 (v) Dispersion tests.

 (vi) Permeability tests.

(d) Material density tests:

 (i) In situ/natural density.

 (ii) Particle density.

 (iii) Dry density/moisture content relation of a soil.

 (iv) Aggregate bulk density and unit mass.

 (v) Maximum and minimum density of sands.

(e) Particle size and shape tests:

 (i) Sieve and hydrometer analysis.

 (ii) Aggregate shape, flakiness index and angularity.

(f) Soil deformation characteristics:

 (i) Consolidation/oedometer tests.

 (ii) Soil-water suction.

 (iii) Free swell.

(g) Soil strength tests:

 (i) Unconfined compression test.

 (ii) Triaxial compression tests.

(iii) Direct shear tests.

(iv) California bearing ratio.

(h) Aggregate strength and durability tests:

(i) Crushing tests.

(ii) Soundness.

(iii) Point load strength test.

(iv) Los Angeles value.

(v) Deval attrition.

(vi) Polishing of aggregates.

(i) Chemical tests:

(i) pH.

(ii) Cation exchange capacity.

(iii) Individual exchangeable cations.

(iv) Soluble salts content.

(v) Sulfate content.

(vi) Organic matter content.

(vii) Potential reactivity of aggregates.

(viii) Resistivity tests.

(j) Mineralogical tests:

(i) Petrographic examination.

(ii) X-ray diffraction.

(k) Miscellaneous tests.

The tests listed above are either standard or well established investigation methods. The list is not intended to be exhaustive, and in any site investigation consideration should be given to the design or use of special tests suited to the problems of the site or relevant to other requirements such as road or rail engineering.

APPENDIX D

TYPICAL PROJECT BRIEF FOR A GEOTECHNICAL SITE INVESTIGATION

(Informative)

D1 THE PROJECT

D1.1 Name and address of commissioning agency (Reports, correspondence and accounts will be sent to this address.)

Attention Title

Telephone No.

Telex No.

Fax No.

D1.2 Project description (This name and identity number, if any, will appear on all reports, correspondence and accounts.)

(a) Name of project.

(b) Project number.

(c) Brief description of project.

D1.3 Owner of project

D1.4 Government and Regulatory Authorities having an interest in the project

(If appropriate.)

D1.5 Miscellaneous notes concerning project (If appropriate.)

D2 THE SITE

D2.1 Address and description

D2.2 Locality plan (Attached.)

D2.3 Plan of survey (Attached.)

D2.4 Owner of site

D2.5 Title details of site

D2.6 Access to site

D2.7 Available services, and where available

D2.8 Reports, maps and other documents of previous site investigations

D2.9 Owners of adjoining properties

D2.10 Location and type of existing underground services and constructions

D2.11 Other data concerning site (If applicable.)

(a) Topographic maps.

(b) Mining maps.

(c) Boreholes.

(d) Environmental reports.

(e) Flood levels.

(f) Geological reports, maps and sections.

(g) Rainfall and hydrologic data.

(h) Hydrogeology.

(i) Aerial photographs (particularly stereo pairs).

(j) Areas of waterlogged ground, active/potential slips, old fills, sinkholes, other geological/terrain features, old foundations.

D3 SITE INVESTIGATION PARAMETERS

D3.1 Approximate layout of development

D3.2 Budgeted cost of development

D3.3 Approximate overall size, orientation, reduced level and purpose of principal structural units

D3.4 Estimated maximum footing loads

D3.5 Sensitivity of structures etc. to differential settlement/movement of footings

D4 OBJECTIVES OF INVESTIGATION

APPENDIX E

COMMENTARY

(Informative)

E1 SCOPE AND APPLICATION This Appendix sets out guidelines on construction assessment, maintenance and evaluation of failures.

E2 APPLICATION Works in this context may include new construction, assessment of natural ground or maintenance of existing facilities, and the evaluation of failures or post-construction assessments.

E3 REFERENCED AND RELATED DOCUMENTS No commentary.

E4 DEFINITIONS If any of the terms defined in this Standard are used with any other sense or meaning than that herein defined, then in a site investigation purporting to comply with this Standard, the meaning used should be clearly specified in each document in which the alternative usage occurs.

E5 PLANNING AND DESIGN OF GEOTECHNICAL SITE INVESTIGATIONS

E5.1 General A potential hazard classification should be assigned to the works by selecting one of the classifications, 'Severe', 'Significant' or 'Minor', using the criteria set out in Table E1. If appropriate, a distinction should be made between different parts of the works, by assigning to them different potential hazard classifications. The scope and intensity of the investigation should take account of the result of the assessment.

TABLE E1

CLASSIFICATION OF POTENTIAL HAZARD

Aspect of classification	Assessment		
	Class A Severe	Class B Significant	Class C Minor
1 Risk to human life	Reasonable to anticipate loss of life, directly attributable to failure	Possibility of loss of life recognized but not expected; however significant risk of serious injury to persons is appreciated	Neither loss of life nor serious injury expected
2 Economic loss			
2.1 Property damage	Expect extensive damage to structures and facilities	Expect appreciable damage to structures, and to public and private facilities	Minor damage expected
2.2 Indirect loss, e.g. by short term disruption to communities or to facilities	Serious	Appreciable	Negligible
3 Ease of restoration	Project provides an essential service, restitution not practicable; no short to medium term alternatives available	Project provides an essential or important service but restitution is practicable or alternatives are available in short to medium term	Restitution is practicable, indirect losses due to failure can be tolerated until restitution is complete

This assessment and the assignment of the potential hazard classification should be done by the client with the advice of the investigator as to the geotechnical implications of the situation.

E5.2 Objectives It is recommended that the objectives of the investigation should be identified by the investigator and agreed to by the client before significant work begins.

For a particular site, for example, the objectives might include the identification, measurement and assessment of any of the following:

(a) Subsurface conditions.

(b) Strength of foundation strata.

(c) Estimates of deformation and settlement.

(d) Level, quantity and quality of groundwater.

(e) The effect of the works on the adjoining land, for example in the case of a building site excavation of a basement adjacent to the site's boundaries.

(f) Recommendations for suitable footing systems.

(g) Excavation conditions, ground support or underpinning requirements.

(h) Properties of borrow materials.

(i) Failure mechanisms.

No site should be considered in isolation but rather in the larger context of which it forms a part. Thus, the relationship of the site to the general area topography, geology and drainage should be established before examining the site in detail.

The techniques by which the objectives are intended to be achieved may need to be redefined during the course of the work.

E6 METHODS OF INVESTIGATION There may be additional unpublished information which may be accessible, and this should be reviewed.

The appropriateness of the techniques to the conditions actually encountered should be reviewed during the investigations and the techniques should be modified where necessary to meet the objectives of the investigation.

There are many methods of site investigation; a selection of suitable methods is set out in Appendices B and C.

E7 REPORTING Identification aspects of the report should extend to at least the following:

(a) *Location* To enable the site to be identified without the need to refer to maps or plans not generally available to the public, the location of the site should be clearly defined within the investigation report by description or plans.

The datum of levels referred to in the report should be clearly stated, and preferably should be Australian height datum, (AHD). Mixing of datum specifications in the report should be avoided, e.g. both AHD and a local datum should not be used together in the same report.

(b) *Location of investigations* Components of the investigation process should be clearly located, preferably on plans showing existing features, site boundaries, or other appropriate fixed reference points which will remain identifiable at the conclusion of the project. If a coordinate grid is used, its orientation and origin should be defined, preferably to Australian map grid (AMG).

Ground levels at the time of investigation should be clearly stated, preferably on the investigation logs, and the datum of levels should be defined.

Where appropriate, locations on adjacent or nearby sites of major structures or features which could significantly affect, or be significantly affected by, geotechnical aspects of development on the site under investigation should be identified.

The report should state the proposed potential hazard classification (see Table E1).

E8 CONSTRUCTION REVIEW AND PERFORMANCE MONITORING

E8.1 General Observations and measurements should be made during construction.

Such observations may include—

(a) pore water pressures;

(b) extent, location and origin of groundwater seepage;

(c) earth pressures and changes in earth pressure;

(d) settlements; and

(e) lateral movements of ground or structures.

The ground conditions encountered on the site and the ground behaviour on and adjacent to the site should be reviewed during construction.

The procedures, arrangements and reporting of the construction review should be established prior to the commencement of the works, so that the frequency of review, the persons responsible for carrying out the reviews and the recording systems are defined.

The results of the review should be compared with design assumptions and interpretations, and any differences identified. Reports should be issued which draw attention to significant differences from earlier reports and, if necessary, amended recommendations should be made.

The period of construction provides the best opportunity to assess natural ground conditions. The purpose of this review is to determine whether site conditions and behaviour observed are as assumed in the design of the works, and if not, whether they differ sufficiently to warrant a change in the design assumptions, the design itself, or in construction technique to ensure safety or integrity of the site or adjacent land.

E8.2 Continuing monitoring Observations and measurements should be made after completion of construction, to record the in-service performance for as long as the nature of the project and the consequences of failure may require. Arrangements should be made at the outset to permit such extended monitoring to take place.

Such continuing monitoring may be considered essential in the case of earth embankments for dams, and some landslip repair works where safety and stability must be maintained under varying operating conditions. Furthermore, it is often opportune to obtain performance data to enhance and develop foundation design technology and economy, to the benefit of future projects.

Continuing monitoring can also be beneficial to the owner as assurance that the works are performing as intended, and in the early detection of unexpected conditions or developments.

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