Appendix A1

Guidelines for engineering geological descriptions

A1 Guidelines for engineering geological descriptions

A1.1 Introduction

In describing rocks and soils (unconsolidated sediments) it is particularly important for present purposes that the mass characteristics are described rather than just the material characteristics *i.e.* that the description takes account of such mass characteristics as fabric, discontinuities and weathered state in addition to lithology, grain size and consistency. Some features may appear to have little or no engineering significance but, for example in the case of the colour of the soil or rock, may provide a useful way of communicating especially with non-technical staff. It is not necessary to discuss these features at length, suffice to say that such descriptions should be kept clear and concise since although 'bluish grey' provides a useful tool for communication 'bluish brownish yellow-grey mottled greenish blue' does not.

A1.2 Description of rocks

Where possible the methods used follow those suggested by the International Society for Rock Mechanics (ISRM, 1981). Where this does not apply, the descriptions revert to those described in the British Standard Code of Practice for Site Investigations (BSI, 1999).

The weathering state and type and frequency of discontinuities are especially important to the mechanical properties of the rock and these will be discussed in some detail here. Lithology is perhaps only important as a general guide to properties such as grain size and texture, which may affect friction angle, and whether the rock mass is bedded, foliated or cleaved, or massive. General geological principles apply and geological training is required for the satisfactory identification of rocks. Table A1, provides general guidelines.

Table A1: Aid to identification of rocks for engineering purposes (from BS 5930:1999; BSI, 1999).

Grain size mm	Bedded rocks (mostly sedimentary)					
Grain size boundaries approximate	Grain size description			At least 50% of grains are of carbonate (LIMESTONE and DOLOMITE (undifferentiated))	At least 50% of grains are of 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		Calcirudite	Fragments of volcanic ejecta in a finer matrix. Rounded grains AGGLOMERATE Angular grains VOLCANIC BRECCIA	SALINE ROCKS HALITE ANHYDRITE
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		Calcarenite	Cemented volcanic ash TUFF	GYPSUM
0.002	ARGILLACEOUS	MUD-STONE	SILTSTONE Mostly silt	Calcareous mudstone; Calcisil-tite; Calcilu-tite; CHALK	Fine-grained TUFF 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.

Table A1: Aid to identification of rocks for engineering purposes (*continued*).

Grain size description	Igneous rocks: generally massive structure and crystalline texture				Metamorphic rocks: Foliated	Metamorphic rocks: Massive
COARSE	GRANITE[1]	DIORITE[1,2]	GABBRO[1,2]	Pyroxe-nite Perido-tite	GNEISS Well developed but often widely spaced foliation sometimes with schistose bands Migmatite Irregularly foliated; mixed schists and gneisses	MARBLE QUARTZITE GRANULITE HORNFELS AMPHIBOLITE SERPENTINE
	These rocks are sometimes porphyritic and are then described, for example, as porphyritic granite					
MEDIUM	MICROGRANITE[1]	MICRODIORITE[1,2]	DOLERITE[3,4]		SCHIST Well developed undulose foliation; generally much mica	
	These rocks are sometimes porphyritic and are then described as porphyries					
FINE	RHYOLITE[4,5]	ANDESITE[4,5]	BASALT[5]		PHYLLITE Slightly undulose foliation; sometimes spotted SLATE Well developed plane cleavage (foliation) MYLONITE Found in fault zones, mainly in igneous and metamorphic areas	
	These rocks are sometimes porphyritic and are then described as porphyries					
Amorphous Crypto-crystalline	OBSIDIAN	VOLCANIC GLASS				
	Colour: Pale <—> Dark				CRYSTALLINE	
	ACID Mutch quartz	INTERMEDIATE Some quartz	BASIC Little or no quartz	ULTRA BASIC	SILICEOUS	Mainly SILICEOUS

(Increasing grain size →)

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.

METAMORPHIC ROCKS

Generally classified according to fabric and mineralogy rather than grain size.

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.

Most fresh metamorphic rocks are strong although perhaps fissile.

The material strength of rocks can be obtained from laboratory tests such as uniaxial compression tests or point load tests and it is not out of the question that point load apparatus could be carried into the field. However, given the remoteness of many of these situations and the fact that material characteristics are considered less important than mass characteristics, it is more likely that assessments of strength will be based upon simple tests such as the Schmidt hammer or field estimation. Table A2 provides definitions of strength applicable to both sophisticated laboratory tests and simple field methods.

Table A2: Scale of rock strength, based on the uniaxial compressive test (from BS 5930:1999; BSI, 1999).

Term	Field definition	Unconfined compressive strength (MN/m^2)
Very weak	Gravel size lumps can be crushed between finger and thumb	< 1.25
Weak	Gravel size lumps can be broken in half by heavy hand pressure	1.25 to 5
Moderately weak	Only thin slabs, corners or edges can be broken off with heavy hand pressure	5 to 12.5
Moderately strong	When held in the hand, rock can be broken by hammer blows	12.5 to 50
Strong	When resting on a solid surface, rock can be broken by hammer blows	50 to 100
Very strong	Rock chipped by heavy hammer blows	100 to 200
Extremely strong	Rock rings on hammer blows. Only broken by sledgehammer.	> 200

The structure of a rock formation can be important and commonly used terms may be ‘bedded’ or ‘laminated’ for sedimentary rocks, ‘banded’, ‘foliated’ or ‘cleaved’ for metamorphic rocks and ‘massive’ or ‘flow banded’ for igneous rocks. It is important to include an estimate of spacing of the structure as defined in Table A3.

The weathering classification adopted is a simplification of that included in BS 5930 as follows:

Fresh -	Unchanged from original state
Slightly weathered-	Discoloured and weakened only along discontinuities
Moderately weathered-	< 50% of rock mass is discoloured and weakened. Rock framework still locked.
Highly weathered-	> 50% of rock mass is discoloured and weakened. Rock framework not locked.
Completely weathered-	Whole of rock mass is discoloured and weakened but the original fabric remains.
Residual soil-	Soil derived by *in situ* weathering but retaining none of the original texture and fabric.

Table A3: Terms for the description of structure thickness in rocks (from BS 5930:1999; BSI, 1999).

Term	Thickness
Very thick	> 2 m
Thick	600 mm to 2 m
Medium	200 mm to 600 mm
Thin	60 mm to 200 mm
Very thin	20 mm to 60 mm
Thickly laminated (Sedimentary) Narrow (Metamorphic and Igneous)	6 mm to 20 mm
Thinly laminated (Sedimentary) Very narrow (Metamorphic and Igneous)	< 6 mm

The method for description of discontinuities follows the ISRM suggested methods. The following characteristics are considered important and their definitions are after ISRM:

Orientation- Attitude of discontinuity in space. Described by the dip direction (azimuth) and dip of the steepest declination in the plane of the discontinuity. Example: dip/dip direction (35º/015º).

Spacing- Perpendicular distance between adjacent discontinuities. Normally refers to the mean or modal spacing of a set of joints.

Persistence- Discontinuity trace length as observed in an exposure. May give a crude measure of the extent or penetration length of a discontinuity. Termination in solid rock or against other discontinuities indicates the persistence.

Roughness- Inherent surface roughness and waviness relative to the mean plane of the discontinuity. Both roughness and waviness contribute to the shear strength. Large scale waviness may also alter the dip locally.

Wall strength- Compressive strength of the adjacent rock walls of a discontinuity. May be less than rock block strength due to weathering or alteration of the walls. An important component of shear strength if rock walls are in contact.

Aperture- Perpendicular distance between adjacent rock walls of a discontinuity, in which the intervening space is air or water filled.

Filling- Material that separates the adjacent rock walls of a discontinuity and that is usually weaker than the parent rock. Typical filling materials are sand, silt, clay, breccia, gouge, mylonite. Also includes thin mineral coatings and healed discontinuities e.g. quartz and calcite veins.

Seepage- Water flow and free moisture visible in individual discontinuities or in the rock mass as a whole.

Number of sets- The number of joint sets comprising the intersecting joint system. The rock mass may be further divided by individual discontinuities.

Block size- Rock block dimensions resulting from the mutual orientation of intersecting joint sets, and resulting from the spacing of the individual sets. Individual discontinuities may further influence the block size and shape.

In practice a number of these may be difficult to ascertain on the scale of a Himalayan or Andean valley, for example, wall strength and filling. They have been included because the occasion may arise when mapping at such a detailed level is appropriate. More detailed advice on preferred methods of ascertaining and describing each of these characteristics may be obtained from the ISRM document.

A1.3 Description of soils

Soils have been described according to methods recommended in the British Standard Code of Practice for Site investigations (BSI 1999). This is summarised in Table A4. Although this was developed for British conditions, it is considered that the principles are broad and generally suitable internationally. As in all cases, it may be necessary to develop local rules where particular special conditions prevail but these should be kept to a minimum and any terms and variations used should be defined clearly. A difficulty is likely to arise in estimation of relative density or compactness, since it is unlikely that *in situ* tests, such as the Standard

Penetration Test, will be carried out. In such a case, where possible, an estimate may be made from inspection of the material, voids and particle packing, and its behaviour when dug by a pick. Useful information may be obtained from observation of the angles, measured using a compass clinometer and/or a hand level, achieved by existing unsupported slopes.

Table A4: Identification and description of soils (from BS 5930:1999; BSI, 1999).

Density/compactness/strength:

Soil group	Term	Field test
Very coarse soils	Loose	By inspection of voids and particle packing
Very coarse soils	Dense	
Coarse soils (over about 65% sand and gravel sizes)	Borehole with SPT N-value	
	Very loose	0 - 4
	Loose	4 -10
	Medium dense	10 - 30
	Dense	30 - 50
	Very dense	> 50
	Slightly cemented	Visual examination: pick removes soil in lumps which can be abraded
Fine soils (over about 35% silt and clay sizes)	Un-compact	Easily moulded or crushed between fingers
	Compact	Can be moulded or crushed by strong pressure in the fingers
	Very soft 0 - 20	Finger easily pushed in up to 25 mm
	Soft 20 - 40	Finger pushed in up to 10 mm
	Firm 40 - 75	Thumb makes impression easily
	Stiff 75 - 150	Can be indented slightly by thumb
	Very stiff 150 - 300	Can be indented by thumb nail
	Hard (or very weak mudstone) Cu > 300 kPa	Can be scratched by thumbnail

Discontinuities (Scale of spacing of discontinuities):

Term	Mean spacing mm
Very widely	Over 2 000
Widely	2 000 to 600
Medium	600 to 200
Closely	200 to 60
Very closely	60 to 20
Extremely closely	Under 20
Fissured	Breaks into blocks along unpolished discontinuities
Sheared	Breaks into blocks along polished discontinuities
Spacing terms also used for distance between partings, isolated beds or laminae, desiccation cracks, rootlets, *etc.*	

Bedding (Scale of bedding thickness):

Term	Mean thickness mm
Very thickly bedded	Over 2 000
Thickly bedded	2 000 to 600
Medium bedded	600 to 200
Thinly bedded	200 to 60
Very thinly bedded	60 to 20
Thickly laminated	20 to 6
Thinly laminated	Under 6
Inter-bedded	Alternating layers of different types Prequalified by thickness term if in equal proportions. Otherwise thickness of and spacing between subordinate layers defined.
Inter-laminated	

Colour: Red, Orange, Yellow, Brown, Green, Blue, White, Cream, Grey, Black, *etc*; Light, Dark, Mottled.

Composite soil types (mixtures of basic soil types):

Term	Approx. %[c] secondary
Slightly (sandy[d])	< 5
(sandy[d])	5 to 20[b]
Very (sandy[d])	> 20[b]
SAND AND GRAVEL	about 50[b]
Term	**Approx %[c] secondary**
Slightly (sandy[e])	< 35
(sandy[e])	35 to 65[a]
Very (sandy[f])	> 65[a]

Particle shape: Angular, Sub angular, Sub rounded, Rounded, Flat, Tabular, Elongated.

Minor constituent: Calcareous, shelly, glauconitic, micaceous, *etc.* using terms such as Slightly calcareous, calcareous, very calcareous; % defined on a site or material specific basis or subjective

Particle size and PRINCIPAL SOIL TYPE:

Particle size	PRINCIPAL SOIL TYPE
— 200	BOULDERS / COBBLES
— 60 Coarse — 20 Medium — 6 Fine — 2	GRAVEL
Coarse — 0.6 Medium — 0.2 Fine — 0.06	SAND
Coarse — 0.02 Medium — 0.006	SILT
Fine	CLAY / SILT
— 0.002	CLAY

Organic soils:

Term	Field test	Term	Description	Transported mixtures	Colour	
Firm	Fibres already compressed together	Fibrous	Plant remains recognisable and retains some strength	Slightly organic clay or silt Slightly organic sand	Grey as mineral	Contains finely divided or discrete particles of organic matter, often with distinctive smell, may oxidise rapidly. Describe as for inorganic soils using terminology above.
				Organic clay or silt Organic sand	Dark grey Dark grey	
Spongy	Very compressible and open structure	Pseudo-fibrous	Plant remains recognisable, strength lost	Very organic clay or silt Very organic sand	Black Black	
				Accumulated in situ	Predominantly plant remains, usually dark brown or black in colour, distinctive smell, low bulk density. Can contain disseminated or discrete mineral soils.	
Plastic	Can be moulded in hand and smears fingers	Amorphous	Recognisable plant remains absent	Peat		

NOTES

[a] Or described as coarse soil depending on mass behaviour
[b] Or described as fine soil depending on mass behaviour
[c] % coarse or fine soil type assessed excluding cobles and boulders
[d] Gravelly or sandy and/or silty or clayey
[e] Gravelly and/or sandy
[f] Gravelly or sandy

References

BSI. 1999. *BS 5930, Code of practice for site investigations*. British Standards Institution.
ISRM. 1981. *Rock characterization testing and monitoring, ISRM suggested methods.* Pergamon Press.