SOIL ENGINEERING

SUPPORTING FACTUAL DATA

APPENDIX 1

Explanatory Notes on Fieldwork, Logging and Laboratory Testing

FIELDWORK PROCEDURES

1.0 CABLE PERCUSSION BORING TECHNIQUES

Unless otherwise stated the light cable percussion technique of 'soft ground' boring has been employed in the formation of boreholes for this contract. In cohesive soils a clay cutter has been used to advance the boreholes whilst in granular deposits a shell has been employed. The combination of clay cutter and shell bring up disturbed material which is generally sufficiently representative to permit identification of the strata. Whilst these particular techniques allow the maximum data to be obtained on strata conditions, a degree of mixing of some layered soils (e.g. thin layers of coarse and fine granular material) is inevitable.

2.0 DYNAMIC SAMPLING

As an alternative to cable percussion boring, Soil Engineering employs a number of techniques for the sampling of soils. The most common alternative techniques comprise some form of dynamic sampling system which involves sampling tubes being driven into the ground by means of a sliding weight.

'Window sampling' techniques form the most common type of dynamic sampling and typically comprise 1.0m long steel cylinders with elongated windows. These are driven to the required depth by the use of a percussive hammer. In the 'windowless' mode a plastic liner can be placed in the steel cylinders such that effectively continuous sampling can be undertaken. This method of sampling only produces Quality Class 3 or 4 samples which are not suitable for any form of laboratory machine testing.

3.0 ROUTINE SAMPLING

In the UK "undisturbed" samples of predominantly cohesive soils have historically generally been obtained in a 102mm diameter open drive sampler as described in the British Standard Code of Practice BS 5930: 1999 (ref 01). These samplers are known as U100 and historically are of two types; a metal tube or a plastic liner. BS EN ISO 22475-1: 2006 (ref 03) however makes it clear that such samplers will not produce a quality class 1 sample. It is this class of sample that is required for laboratory machine testing.

Alternative methods of sampling which will produce a class 1 sample are available and these include piston samplers, Shelby tubes and the UT100. The latter is a modification of the U100 and classifies as a thin wall sampler and as such is capable of obtaining class 1 samples. It should be noted however that this type of sampler is only suitable for certain ground conditions and cannot be used in very stiff to hard cohesive soils or in very granular cohesive soils. Equally other thin walled samplers such as the piston sampler are more appropriate for very soft and soft cohesive soils.

Soil Engineering recognise that in certain soil types, there will not be a single solution to sampling and it will be necessary to utilise a variety of sampling techniques in order to obtain the best quality samples possible. Such techniques may include rotary coring and this is described in section 4.0. For some 'difficult' soil types it may not be possible to obtain truly undisturbed samples, and engineering judgement will be required if such samples are to be used for geotechnical laboratory testing. Where such challenging soil types have been encountered and alternative sampling techniques used, this is discussed in the report text.

In granular deposits and mixed cohesive granular deposits where it is not possible to recover undisturbed samples, either large or small disturbed samples are normally obtained. The size of these samples are in accordance with the requirements of BS 5930: 1999 whilst the frequency of sampling is unique to this contract.

It is important to note that the number of blows taken to drive any kind of sampling tube is not necessarily indicative of the strength of the material being sampled. For this reason Soil Engineering recommends that no attempt is made to correlate such blows with the strength of cohesive strata.

4.0 ROTARY DRILLING

Where rotary open hole drilling techniques have been employed it is important to note that descriptions of the strata encountered are generally solely based on the lead drillers observations of cuttings and drill flush returns. Whilst such techniques can provide useful information in certain ground conditions it should be recognised that an accurate determination of subsurface rock strata can only be obtained by rotary coring techniques.

An examination of rock cores obtained by rotary drilling generally enables bedding planes, fissuring and consistency to be observed but does not necessarily reveal the presence of vertical fissures or joints. Where an appropriate core diameter and flushing medium have been used, sub-sampling of the core immediately following removal from the core barrel can produce quality Class 1 samples. Such samples require to be sealed and waxed in order to prevent moisture loss.

Details of the strata encountered are given on the borehole log along with the geologist's assessment of Total Core Recovery (TCR), Solid Core Recovery (SCR) and Rock Quality Designation (RQD) each expressed as a percentage of the individual core runs. When appropriate the Fracture Index (FI) or Fracture Spacing (If) is also given on the logs and represents respectively the number of natural fractures per metre run of core for core that has a similar intensity of fracturing, or the minimum, average and maximum spacing of such natural fractures over an arbitrary length of core of similar intensity of fracturing.

The symbols and abbreviations used on the rotary borehole logs are explained on the exploratory hole legend and notation sheet that precedes the exploratory hole records. It is considered however that the meaning of the abbreviations NI and NA needs further clarification. NI denotes material recovered non intact and applies to material that has numerous fractures or incipient fractures and which is either naturally broken up or which becomes broken up by drilling activities. The result in both cases is that the core is recovered in a highly fragmented state, generally as a gravel. The term NA is the abbreviation for not applicable and refers to any materials to which determination of a fracture index would be inappropriate, i.e. for clay bands.

Where significant core loss (>300mm) has occurred, it is Soil Engineering general policy to insert a separate 'stratum' on the log to coincide with the inferred zone of core loss. Unless there is good evidence as to the rock (or soil) type that has been lost, the legend column is left blank. For zones of inferred mine workings, an appropriate legend is used and this together with all the legends used on the logs is shown on the log notation sheet that precedes the exploratory logs in the report.

A summary of logging methodology for rock strata and core measurements is given in Appendix 1: Terminology used in the Description and Classification of Rocks.

5.0 IN SITU DYNAMIC PENETRATION TESTS

The Standard Penetration Test using either a split spoon (SPT) or a solid cone (SPT(C)), is generally employed where undisturbed samples cannot be obtained e.g. in granular soils, fill and rock etc, in order to obtain an indication of the in situ density, compaction or hardness. It can also be used as an alternative to undisturbed sampling in cohesive deposits. Inherent difficulties are present in obtaining true SPT or SPT(C) "N" values in water bearing fine grained granular deposits and careful consideration of the test technique and groundwater conditions are necessary before test results are used for design purposes.

The full procedure for carrying out the Standard Penetration Test (SPT) is given in BS EN ISO 22476-3: 2005 (ref 02). For fine to medium granular deposits and in clays the test consists of driving a 50mm external diameter split barrel sampler into the soil using a 63.5kg hammer dropping 760mm. In coarse granular soils or in rock, the split barrel may be replaced by a solid cone. The penetration resistance is expressed as the number of blows required to obtain 300mm penetration below an initial seating drive of 150mm through any disturbed ground at the bottom of the borehole. The number of blows for the 300mm test drive penetration is recorded on the borehole logs as the "N" value. A full record of the number of blows required to drive the sampler at 75mm intervals throughout the total 450mm drive is also tabulated along with the groundwater level at the time of test. Where full 450mm penetration is not achieved, it is important to distinguish how the blow count relates to the penetration of the sampler and this may be achieved in the following manner:

(i) Where the test drive is terminated before full (300mm) penetration the number of blows for the partial test drive (usually 50) and the penetration of the sampler within the test drive are recorded. An approximate "N" value may be obtained by linear extrapolation of the number of blows recorded for the partial test drive.

(ii) If the total seating drive penetration is equal to or less than 150mm then the number of blows (usually 25) and the depth of penetration within the initial seating penetration are recorded on the borehole logs.

The "N" value obtained from the Standard Penetration Test may be used to assess the relative density of sands and gravels in accordance with Clause 41.3.2 of BS 5930: 1999 (ref 01), as shown in table 1.

It should be noted that the "N" values reported on the logs are uncorrected, as specified in section 7.1.2 of BS EN ISO 22476-3:2005.

SPT's performed by Soil Engineering are carried out using automatic trip hammers that have been calibrated in accordance with BS EN ISO 22476-3:2005. The hammer ID and energy ratio are recorded on the 'header page' of each log and calibration certificates for the hammers used on the project are contained in the Appendix Section of the report, as required by BS EN ISO 22476-3:2005.

TABLE 1: DETERMINATION OF RELATIVE DENSITY FROM PENETRATION TESTS (from BS 5930)

Term	SPT N-Value: Blows/300mm Penetration
Very Loose	0-4
Loose	4-10
Medium Dense	10-30
Dense	30-50
Very Dense	Over 50

It should be noted that it is a requirement of BS EN ISO 22476-3: 2005 that all test hammers are calibrated. Soil Engineering routinely calibrate all their test hammers and the results of the calibration are expressed as an Energy Ratio (Er) on the exploratory hole logs. The Er value is required for design purposes and should be applied to the recorded test N value in the manner described in BS EN ISO 22476-3: 2005.

Standard Penetration Testing may also be performed in very stiff/hard clays in which it would be difficult to obtain undisturbed samples. In such cases the SPT "N" values may be used for design purposes based on correlations between "N" value and various soil parameters such as those proposed by Stroud and Butler (1975) (ref 04) and by Stroud (1989) (ref 05).

6.0 GROUNDWATER

The groundwater conditions entered on the exploratory hole records are those encountered at the time of the investigation. These however, may not represent the actual conditions or those which may apply in large excavations. The normal rate of boring does not always permit the recording of an equilibrium water level for any one water strike, particularly because the entry of water into a borehole may be reduced or even eliminated due to casing off a water bearing layer or due to a skin being formed on the borehole wall by the drilling tools. It should also be noted that groundwater conditions may vary seasonally and/or tidally and that the water levels as shown at the time of investigation should not necessarily be taken as being constant because they may be subject to such fluctuations.

More accurate information on groundwater conditions can be obtained from exploratory hole installations such as piezometers and standpipes. Normally a minimum of three or four monitoring visits are required at the site to provide this information.

References

01) BS 5930: 1999: Code of Practice for Site Investigation. British Standards Institution.

02) BS EN ISO 22476-3: 2005: Geotechnical Investigation and Testing - Field Testing - Part 3: Standard Penetration Test.

03) BS EN ISO 22475-1: 2006: Geotechnical Investigation and Testing - Sampling Methods and Groundwater measurements - Part 1: Technical Principles for Execution.

04) Stroud, M.A, Butler, F.G April 1975: ‘The Standard Penetration Test and the Engineering Properties of Glacial Materials’. The Engineering Behaviour of Glacial Materials Proc. of Symp.

05) Stroud, M.A. 1989: 'The Standard Penetration Test - Its Application and Interpretation. Thomas Telford, London.

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TERMINOLOGY USED IN SOIL DESCRIPTIONS

1.0 GENERAL PROCEDURES

Soil descriptions contained in this report have been produced in accordance with the procedures and principles given in BS EN ISO 14688-1: 2002 (ref 01), BS EN ISO 14688-2: 2004 (ref 02) and also where there is no conflict with the European standards, in accordance with BS 5930: 1999 (ref 03).

For a soil description the main soil characteristics should be given in a standard word order although the word order can be adjusted to enhance and clarify if appropriate. The main soil characteristics can be divided as follows:-

1 **Mass Characteristics**
comprising state and structure
1a Density and Field Strength
1b Discontinuities
1c Bedding

2 **Material Characteristics**
comprising nature and state
2a Colour
2b Composite Soil Types: particle grading and composition, shape and size
2c Principal Soil Type, name in capitals eg CLAY

3 **Stratum Name (optional)**
3a Geological group or Formation

The basic soil categories may be broadly summarised as follows, with categories i to iii covered by these notes and categories iv and v by separate notes.

(i) Very coarse soils: greater than 63mm in diameter, ie cobbles and boulders.
(ii) Coarse soils: 0.063mm to 63mm in diameter, ie sands and gravels.
(iii) Fine soils: less than 0.063mm in diameter, ie clays and silts.
(iv) Organic soils.
(v) Man made "soils".

2.0 MASS CHARACTERISTICS OF SOILS

2.1 Cohesive Soils

For cohesive material determination of consistency is made in accordance with Table 1. The undrained shear strength of clays is determined by laboratory or field testing and is made in accordance with the terms given in Table 2.

TABLE 1: CONSISTENCY GUIDE FOR COHESIVE MATERIAL (from BS EN ISO 14688-1: 2002)

Term	Field Identification
Very Soft	Exudes between fingers when squeezed in the hand
Soft	Can be moulded by light finger pressure
Firm	Cannot be moulded, but can be rolled into 3mm thick thread
Stiff	Crumbles when rolled into 3mm thick thread
Very Stiff	Cannot be moulded and crumbles under pressure. Indented by thumbnail

APPENDIX 1: TERMINOLOGY USED IN SOIL DESCRIPTIONS

TABLE 2: STRENGTH TERMS OF FINE SOILS (from BS EN ISO 14688-2: 2004)

Strength Term	Undrained shear strength (Cu) kPa
Extremely Low	<10
Very Low	10 to 20
Low	20 to 40
Medium	40 to 75
High	75 to 150
Very High	150 to 300
Extremely High[1]	>300

1 Materials with shear strengths greater than 300kPa may behave as weak rocks and should be described in accordance with BS EN ISO 14689-1

2.2 Granular Soils

For granular deposits relative density may only be determined by the Standard Penetration Test (SPT). The following table provides a scale of terms related to SPT 'N' values from BS 5930: 1999 (ref 03).

TABLE 3: ASSESSMENT OF RELATIVE DENSITY FOR GRANULAR SOILS (from BS 5930: 1999)

Term	Field Identification (generally in trial pits)	SPT 'N' Values (blows for 300mm penetration)
Very loose	Can be excavated with a spade	0-4
Loose	and 50mm wooden peg can be easily driven	4-10
Medium dense	-	10-30
Dense	Requires pick for excavation	30-50
Very dense	and 50mm wooden peg is hard to drive	over 50

N.B: The field identification terms for very loose/loose material and dense/very dense material are very subjective and should be treated with caution.

2.3 Discontinuities

The type of discontinuity should be described eg fissures, faults and shear planes together with their spacing as given in Table 4. Discontinuity openness, and surface texture eg rough, smooth, polished and striated are recorded although these may not always be added to the borehole log if the required level of detail is low.

2.4 Bedding

Bedding spacing is assessed using the thickness terms given in Table 4.

TABLE 4: DESCRIPTIONS FOR DISCONTINUITIES AND BEDDING (from BS 5930: 1999)

DISCONTINUITIES		BEDDING	
Scale of SpacingTerm	Mean Spacing mm	Scale of BeddingTerm	Mean Thickness mm
Very widely	>2000	Very thickly bedded	>2000
Widely	2000-600	Thickly bedded	2000-600
Medium	600-200	Medium bedded	600-200
Closely	200-60	Thinly bedded	200-60
Very closely	60-20	Very thinly bedded	60-20
Extremely closely	<20	Thickly laminated	20-6
		Thinly laminated	<6

N.B: Spacing terms are also used for describing the distance between partings, isolated beds, laminae or roots etc.
Interbedded/interlaminated: alternating layers of different material type. These terms are given a thickness if material is present in equal proportions. Otherwise the thickness of and spacing between subordinate layers are defined.

3.0 MATERIAL CHARACTERISTICS OF SOIL

An examination of insitu soil deposits, disturbed or undisturbed samples allows the material characteristics to be recorded. These characteristics include colour, particle shape, particle grading and particle composition.

3.1 Colour

The recorded colour is based on the logger's general impression of the overall colour. For material with more than three colours the term multicoloured may be used. The term mottled is applied to soils which exhibit two colours, one of which is subordinate to the other.

White, cream, grey, black, yellow, orange, red, brown, green and blue etc may be used but supplemented as necessary with: light, dark, mottled and reddish brownish etc. All colouration associated with chemical changes is noted ie grey gleying on fissures.

3.2 Soil Types (Including Composite Soils)

3.2.1 Very Coarse Soils (Boulders and Cobbles)

Where the soil sample is considered large enough to be representative, material is described as shown in Table 5.

TABLE 5: DESCRIPTORS FOR VERY COARSE SOILS (from BS 5930: 1999)

Main Name	Estimated Boulder/Cobble Content of Very Coarse Fraction
BOULDERS	Over 50% is of boulder size (>200mm)
COBBLES	Over 50% is of cobble size (200mm to 63mm)

Mixtures of very coarse and finer materials are described by combining terms for the very coarse constituents with those for the finer constituents as shown in Table 6.

APPENDIX 1: TERMINOLOGY USED IN SOIL DESCRIPTIONS

TABLE 6: DESCRIPTORS FOR MIXTURES OF VERY COARSE AND FINER SOILS (from BS 5930: 1999)

Term	Composition (Approx %)
BOULDERS (or COBBLES) with a little finer material [1]	Up to 5% finer material
BOULDERS (or COBBLES) with some finer material [1]	5% to 20% finer material
BOULDERS (or COBBLES) with much finer material [1]	20% to 50% finer material
FINER MATERIAL with low boulder content	<5% boulders
FINER MATERIAL with low cobble content	<10% cobbles
FINER MATERIAL with medium boulder content	5% to 20% boulders
FINER MATERIAL with medium cobble content	10% to 20% cobbles
FINER MATERIAL with high boulder content (or cobbles)	>20% boulders or cobbles

(1) The description of "finer material" is made in accordance with BS 5930: 1999 ignoring the very coarse fraction; the principal soil type name of the finer material may also be given in capital letters, e.g. sandy GRAVEL with low boulder content; COBBLES with some sandy CLAY.

3.2.2 Coarse Soils (Gravel and Sand)

A coarse soil (omitting any cobbles and boulders) contains 65% or more of SAND or GRAVEL. The terms given in Table 7 are used to describe the coarse fraction.

TABLE 7: DESCRIPTORS FOR MIXTURES OF COARSE SOILS (from BS 5930: 1999)

Term	Principal Soil Type	Approximate Proportion of Secondary Constituent
Slightly sandy or gravelly	SAND	<5%
Sandy or gravelly	or	5% to 20%
Very sandy or gravelly	GRAVEL	>20%
-	SAND and GRAVEL	About equal proportions

3.2.3 Fine Soils and Mixtures of Fine and Coarse Soils

Fine soil should be described as either a SILT or a CLAY. The use of silty CLAY or clayey SILT is however permitted, where the presence of the secondary constituent is considered important.

For deposits that contain a mixture of soil types the descriptors given in Table 8 are used. The dominant secondary fraction is placed immediately before the principal soil type. It should also be noted that the terms silty and clayey are mutually exclusive in a coarse soil. The use of the terms sandy and gravelly are however permitted.

TABLE 8: DESCRIPTORS FOR FINE SOILS AND COMPOSITE SOIL TYPES (from BS 5930: 1999)

Term	Principal Soil Type	Approximate Proportion of Secondary Constituent	
		Coarse Soil	Coarse and/or Fine Soil
Slightly clayey or silty and/or sandy or gravelly	SAND and/or		<5%
Clayey or silty and/or sandy or gravelly	GRAVEL		5% - 20% *
Very clayey or silty and/ or sandy or gravelly			>20% *
Very sandy or gravelly	SILT or	>65% +	
Sandy and/or gravelly	CLAY	35% - 65%	
Slightly sandy and/or gravelly		<35%	

* or described as fine soil depending on assessed engineering behaviour
+ or described as coarse soil depending on assessed engineering behaviour

3.3 **Particle Shape and Grading**

For coarser granular deposits (gravel and cobbles) the particle shape is described as shown in Table 9. A schematic of angularity and form terms is given in Figure 1.

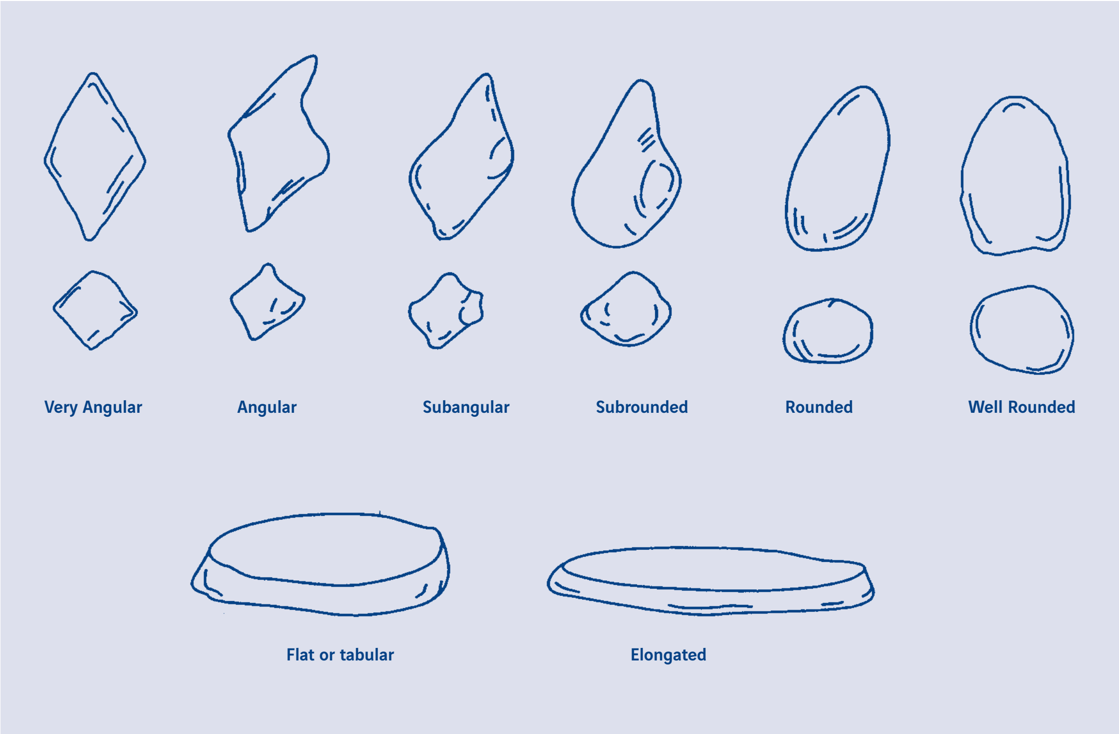
TABLE 9: DESCRIPTORS FOR PARTICLE SHAPE (from BS EN ISO 14688-1: 2002)

Angularity	Form	Surface Texture
Very Angular	Cubic	
Angular	Flat	Rough
Subangular	Elongated	Smooth
Subrounded		
Rounded		
Well Rounded		

The distribution of particle sizes within sands and gravels is described stating the predominant size fraction present eg fine to medium SAND.

APPENDIX 1: TERMINOLOGY USED IN SOIL DESCRIPTIONS

FIGURE 1: PARTICLE ANGULARITY AND FORM TERMS (from BS 5930: 1999 and Soil Engineering)



References

01) BS EN ISO 14688-1: 2002: Geotechnical Investigation and Testing - Identification and Classification of Soil Part 1: Identification and Description.

02) BS EN ISO 14688-2: 2004: Geotechnical Investigation and Testing - Identification and Classification of Soil Part 2: Principles for a Classification.

03) BS 5930: 1999: Code of Practice for Site Investigation. British Standards Institution.

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TERMINOLOGY USED IN THE DESCRIPTION OF MADE GROUND

APPENDIX 1: TERMINOLOGY USED IN THE DESCRIPTION OF MADE GROUND

1.0 GENERAL DEFINITIONS

Man made soils may be defined as those materials that have not been laid down by geomorphological processes. Under the heading of 'man made soils' two distinct material types can be identified as follows:-

TABLE 1: DEFINITIONS FOR MAN MADE SOILS

Term	Description
NATURAL SOILS (Reworked)	Use terminology outlined for soils in BS EN ISO 14688-1: 2002 (ref 01), BS EN ISO 14688-2: 2004 (ref 02) and BS 5930: 1999 (ref 03). Can be described using normal approach for soils. Can be tested in accordance with BS1377: 1990.
MAN MADE MATERIALS	Can also frequently be described using normal approach and terminology as above, and tested geotechnically. Includes materials that defy description in any standard manner and includes a range of exotic materials and artifacts. Often not testable in the field or in the laboratory. For example it is not possible to measure strength of a bicycle frame or liquid limit of plastic.

There is also a distinction between the terms "Fill" and "Made Ground" as follows:

FILL = Material placed under engineering control
MADE GROUND = Material placed without any kind of control, ie non engineered

2.0 IDENTIFICATION OF MAN MADE SOILS

Some common examples of man made soils are given in Table 2 on page 2. The table illustrates that the heading of 'man made' soils can cover a wide variety of materials, some of which may not readily appear to be anything other than natural.

Natural soils re-laid by man may be difficult to identify as such and so it is necessary to look for evidence in the form of artifacts or relic structure in the material.

For example as few as one or two artifacts may be diagnostic (rare brick fragments or car body at base of trial pit). Lenses or pockets of clay that are laminated etc help to indicate natural material that has been relaid. However be aware of the following:

Contamination by driller (Clinker from around rig, green grass from 15m...).
Contamination during trial pitting (brick rubble can fall from the upper layers in a pit and then get pushed in to natural deposits by the action of the excavator bucket).

APPENDIX 1: TERMINOLOGY USED IN THE DESCRIPTION OF MADE GROUND

TABLE 2: DEFINITIONS FOR MAN MADE SOILS

CATEGORY	EXAMPLE
Natural Soils re-laid by man	Embankment Fill Colliery Spoil (Coarse Discard) Drainage Layer e.g Gravel
Man Made Materials that can be described and which are testable geotechnically	Abutment backfill e.g Crushed rock Colliery Spoil (Fine Discard) Mine Tailings from non-coal mines Crushed Concrete Pulverised Fuel Ash (PFA) Chalk whiting (slurry from cement manufacture)
Man Made Materials that are NOT readily describable and which are not testable geotechnically	Landfill Demolition rubble (including frames, slates etc) Fly tipped materials Burgy (glass work waste)

3.0 DESCRIPTION OF MAN MADE SOILS

Information that is be reported to define the material includes the following:-

Origin of materials, if known from desk study.
Layers and their inclination to inform on mode of tipping, whether ponded, end tipped, spread or stockpiled.
Large objects, obstructions such as concrete, masonry walls, old cars.
Presence of hollow objects, compressible/collapsible objects or voids such as oil drums, cellars, tanks.
Chemical wastes and dangerous or hazardous substances such as creosote, hospital wastes, unlabelled drums, asbestos.
Decomposable materials with note on degree of decomposition such as garden waste, paper.
Smell such as organic, phenolic, sulphurous, petrol.
Striking colours
Any dating possible such as type of bottles, newspapers, papers.
Signs of heat or combustion such as steam, smoke, burnt shale.

NOTES

Because of the variability of the constituents of man made soils, strength or in situ density descriptors are not generally assigned to made ground. Where describing fill as opposed to made ground it may be possible to use the descriptors that are used for natural soils.
Large or hollow objects cannot be sampled so the description is the sole information on condition and character of the features.
The constituents of made ground are grouped together under the above categories and it is usual to give volumetric percentages where possible.

Granular made ground may be given a particle size, although the following description methodology is employed.
MADE GROUND: Grey fine to coarse gravel sized fragments of brick and concrete.

OR

MADE GROUND: Grey gravelly clay with occasional subangular cobble sized fragments of brick. Gravel sized fragments are angular to subangular, fine, medium and coarse of brick.

In these two examples, note the use of term 'sized fragments' to describe the granular content. Because the material is man made we do not use the terms sand, gravel or cobbles etc in the same context as for natural soils. In other words it would be incorrect to use the following:

MADE GROUND: Grey gravelly clay with occasional cobbles. Gravel is angular coarse of brick, cobbles are rounded of brick.

The use of sand, gravel or cobble prior to 'sized fragments' is only intended to define a size range to the granular made ground material.

Similar grain size indicators are also used to describe the size of other man made materials such as concrete, bituminous road surfacing etc. In addition the terms can also be used to describe natural material that has been modified by man, such as wood that may be present in the form of railway sleepers etc. Where whole man made items are identified they should be described as follows:

'with numerous wooden railway sleepers'

For such materials it is necessary to add size measurements, since no other quantifying terms are used.

4.0 DEFINITIONS OF SOME MAN MADE SOILS

There is generally a lack of national guidance on the meaning of common terms used in made ground. This applies particularly to man made materials. For this reason descriptions of man made soils within this report aim to provide as much information as possible on the material being logged, whilst staying within the guidance provided in these notes.

For some sites a set of definitions for the likely range of made ground to be encountered may have been determined and where this is the case it is identified within the report text.

Some terms for one group of commonly encountered made ground are given below.

COMBUSTION PRODUCTS, often physically unstable and usually containing concentrations of metals and poly-aromatic hydrocarbons. The definitions below are workable compromises.

ASH: Sand or silt size by definition, so do not need but can use "ash sand", and cannot have "gravel size ash" although cinders can be gravel size but readily crush down. Can include unburnt coal.

CLINKER: Gravel size or larger by definition so do not need but can use "clinker gravel", and cannot have "sand size clinker".

SLAG: Materials fused or poured as liquid or scum or froth, of any size or shape, and will be at least strong. If in blocks or layers, can present difficulties for borehole or trial pit penetration. Slag is often pelletised, expanded or crushed for reuse in construction.

References

01) BS EN ISO 14688-1: 2002: Geotechnical Investigation and Testing - Identification and Classification of Soil Part 1: Identification and Description.

02) BS EN ISO 14688-2: 2004: Geotechnical Investigation and Testing - Identification and Classification of Soil Part 2: Principles for a Classification.

03) BS 5930: 1999: Code of Practice for Site Investigation. British Standards Institution.

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TERMINOLOGY USED IN PEAT AND ORGANIC SOIL DESCRIPTIONS

APPENDIX 1: TERMINOLOGY USED IN PEAT AND ORGANIC SOIL DESCRIPTIONS

The basic designation for soils consisting principally of organic matter is summarised in Table 1.

TABLE 1: IDENTIFICATION AND DESCRIPTION OF ORGANIC SOIL

Term	Description
Fibrous Peat	Fibrous structure, easily recognisable plant structure, retains some strength
Pseudo-fibrous Peat	Recognisable plant structure, no strength of apparent plant material
Amorphous Peat	No visible plant structure, mushy consistency
Gyttja	Decomposed plant and animal remains, may contain inorganic constituents
Humus	Plant remains, living organisms and their excretions together with inorganic constituents, from the topsoil

If a soil contains organic material in identifiable fragments these are individually described using the "occasional, some and much" terms as appropriate. Any smells or odours should be noted. Where the organic materials are disseminated throughout the soil the term "organic" should be given prior to the soil type.

eg: Soft grey organic CLAY

Where the soil is composed of natural organic material a peat description may be more appropriate. Peats are normally described after BS EN ISO 14688-1: 2002 (ref 01), although as the descriptive scheme in that standard is very limited, the additional terms summarised by Hobbs (ref 02) may be used if required.

Peats can be identified as shown in Table 2. The word order is as for other natural soils, however different terms are used to describe the consistency of the peat and the soil type is preceded by an additional term (Fibrous or Amorphous).

No guidance is given in either BS EN ISO 14688-1: 2002 or 14688-2: 2004 or BS 5930: 1999 as to how to deal (in terms of description) with peat soils that contain other materials such as clay or gravel. If the peat has a coarse soil fraction the proportions given in Terminology Used in Soil Descriptions, Table 6 (Descriptors for Mixtures of Very Coarse and Finer Soils) are used. It is difficult to assess visually what proportion of the fine soil is mineral and what proportion is organic therefore the terms "clayey" or "silty" are used with caution if at all.

eg: Firm black fibrous PEAT (H3)
Plastic brown amorphous PEAT (H8)
Spongy black slightly sandy fibrous PEAT (H4)

References

01) BS EN ISO 14688-1: 2002: Geotechnical Investigation and Testing - Identification and Classification of Soil Part 1: Identification and Description.

02) Hobbs, N.B. 1986: 'Mire morphology and the properties and behaviour of some British and foreign peats.' Q.J. Engng Geol. 19, No 1, 7-80.

03) BS 5930: 1999: Code of Practice for Site Investigation. British Standards Institution.

04) BS EN ISO 14688-2: 2004 Geotechnical Investigation and Testing - Identification and Classification of Soil Part 2: Principles for a Classification.

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TABLE 2: GUIDANCE ON THE IDENTIFICATION AND DESCRIPTION OF PEAT (AFTER BS 5930 AND HOBBS)

CONSISTENCY	SOIL TYPE	DEGREE OF HUMIFICATION	DECOMPOSITION	DESCRIPTION	MATERIAL EXTRUDED BETWEEN FINGERS	RESIDUE IN HAND
Firm or Spongy	Fibrous PEAT	H1	None	Entirely unconverted mud-free peat	Clear, colourless water	Not pasty
		H2	Insignificant	Almost entirely unconverted mud-free peat	Yellowish water	
		H3	Very slight	Very slightly converted or very slightly muddy peat	Brown, muddy water, no peat	
		H4	Slight	Slightly converted or somewhat muddy peat	Dark brown muddy water, no peat	Somewhat pasty
		H5	Moderate	Fairly converted or rather muddy peat, plant structure still quite evident	Muddy water and some peat	
		H6	Moderately strong	Fairly converted or rather muddy peat, plant structure indistinct but more obvious after squeezing	Above one third of peat squeezed out; water dark brown	Thick, pasty
		H7	Strong	Fairly well converted or markedly muddy peat; plant extract still discernible	About one half of peat squeezed out, consistency like porridge; any water is very dark brown	Very thick paste
Plastic	Amorphous PEAT	H8	Very strong	Well converted or very muddy peat, very indistinct plant structure	About two thirds of peat squeezed out, also some pasty water	Plant roots and fibre which resist decomposition
		H9	Nearly complete	Almost completely converted or mud-like peat, plant structure almost not recognisable	Nearly all the peat squeezed out as a fairly uniform paste	
		H10	Complete	Completely converted or entirely muddy peat, no plant structure visible	All the peat passes between the fingers, no free water visible	

SOIL ENGINEERING

SUPPORTING FACTUAL DATA

APPENDIX 1

Explanatory Notes on Fieldwork, Logging and Laboratory Testing

ASSESSMENT OF AGGRESSIVE GROUND AND GROUNDWATER CONDITIONS

APPENDIX 1: ASSESSMENT OF AGGRESSIVE GROUND AND GROUNDWATER CONDITIONS

Certain ground and groundwater conditions may be described as aggressive depending on their chemical composition which is related to previous industrial use. Where foundations are proposed to be constructed on industrial sites or on landfill sites in which the ground or groundwater may be contaminated with chemical waste, detailed consideration needs to be given to both the method of investigation and the severity of ground and groundwater conditions with respect to construction materials. For such sites it will usually be necessary to undertake a full chemical analysis in order to identify the potentially aggressive compounds.

On sites where new concrete foundations are to be constructed in natural ground it is usually only necessary to examine the sulfate content and pH level of the ground. The sulfate content of soils varies widely and can range from being virtually absent to extremely high concentrations in crystals such as gypsum. In between these two extremes sulfate may be disseminated throughout a soil or may be present in discrete bands or lenses. Because of this wide variation in the sulfate content of soils, the most reliable indication of possible aggressive conditions can be obtained by testing representative samples of groundwater. In order to take account of natural variations in the distribution of sulfates in the ground, samples should be taken at a number of locations that are well spaced across the site and at different depths.

The methods for the determination of total sulfate of soil and the sulfate content of groundwater and 2:1 aqueous soil extracts are given in various specifications including BS 1377 1990: Part 3: Section 5 (ref 01). The results of tests performed in accordance with BS 1377 yield results which are expressed as percentage of dry weight retained or grammes/litre SO_3. Tests performed in accordance with other specifications however, tend to express results as SO_4.

The classification of natural sulfate conditions is based on BRE Special Digest 1 2005 (ref 02). This digest makes most use of sulfate values expressed as milligrammes/litre SO_4. In order to convert the results expressed as SO_3 (BS 1377) to SO_4 (BRE Special Digest 1) it is necessary to apply a multiplication factor of 1.2. In the following discussion of sulfate conditions values given in the tables are expressed in terms of SO_4. The current approach to the classification of aggressive ground conditions given in BRE Special Digest 1 is based on the Aggressive Chemical Environment for Concrete (ACEC). This takes into account the type of site, sulfate concentration and groundwater acidity and mobility. Different site assessment procedures are used for natural ground, for brownfield sites that contain industrial waste and pyritic ground. The reactions of sulfates in the presence of other ions, notably carbonate and magnesium are also taken into account.

In general when the results of sulfate determinations are assessed, emphasis must be given to the samples which fall in the higher classes. Therefore if eight out of ten samples are found to be non aggressive and fall within Class DS1 and the remainder fall within Class DS2 it will be necessary to adopt the precautions appropriate to Class DS2 conditions for the whole site. The current digest differentiates between 'natural ground locations' and 'brownfield locations'.

Table 1 on page 2 is reproduced from the digest and deals with natural ground locations.

APPENDIX 1: ASSESSMENT OF AGGRESSIVE GROUND AND GROUNDWATER CONDITIONS

TABLE 1: AGGRESSIVE CHEMICAL ENVIRONMENT FOR CONCRETE (ACEC) CLASSIFICATION FOR NATURAL GROUND LOCATIONS (a) (From BRE Special Digest 1)

SULFATE				GROUNDWATER		
DESIGN SULFATE CLASS FOR LOCATION	2:1 WATER/SOIL EXTRACT (b)	GROUNDWATER	TOTAL POTENTIAL SULFATE (c)	STATIC WATER	MOBILE WATER	ACEC CLASS FOR LOCATION
1	2 (SO_4 mg/l)	3 (SO_4 mg/l)	4 (SO_4 %)	5 (pH)	6 (pH)	7
DS-1	<500	<400	<0.24	>2.5		AC-1s
					>5.5 (d)	AC-1 (d)
					2.5-5.5	AC-2z
DS-2	500-1500	400-1400	0.24-0.6	>3.5		AC-1s
					>5.5	AC-2
				2.5-3.5		AC-2s
					2.5-5.5	AC-3z
DS-3	1600-3000	1500-3000	0.7-1.2	>3.5		AC-2s
					>5.5	AC-3
				2.5-3.5		AC-3s
					2.5-5.5	AC-4
DS-4	3100-6000	3100-6000	1.3-2.4	>3.5		AC-3s
					>5.5	AC-4
				2.5-3.5		AC-4s
					2.5-5.5	AC-5
DS-5	>6000	>6000	>2.4	>3.5		AC-4s
				2.5-3.5	>2.5	AC-5

NOTES

a) Applies to locations on sites that comprise either undisturbed ground that is in its natural state or clean fill derived from such ground.

b) The limits of Design Sulfate Classes based on 2:1 water/soil extracts have been lowered relative to previous digests.

c) Applies only to locations where concrete will be exposed to sulphate ions (SO_4) which may result from the oxidation of sulfides (eg pyrite) following ground disturbance.

d) For flowing water that is potentially aggressive to concrete owing to high purity or an aggressive carbon dioxide level greater than 15mg/l, increase the ACEC Class to AC-2z.

Explanation of suffix symbols to ACEC Class

Suffix ‘s’ indicates that the water has been classified as static

Concrete placed in a ACEC Class that includes the suffix ‘z’ primarily have to resist acid conditions and may be made with any of the cements listed in Table D2 in the Digest.

Additional testing is required for those natural sites that contain pryrite. In particular it is essential to take account of the total potential sulfate content which might result from oxidation following ground disturbance. On such sites it is necessary to determine total sulfate content (AS% $S0_4$), total sulfur (TS%S). The total potential sulfate is then determined from TPS%SO_4=3.0 x TS%S. Finally the amount of oxidisable sulfides (OS as %SO_4) is determined by subtracting the acid soluble sulfates (AS%$S0_4$) from the total potential sulfate content: OS%SO_4 = TPS%SO_4 – AS%$S0_4$. It is important to note that this testing is in addition to and not instead of the standard sulfate determination testing.

Unless the site can be demonstrated to comprise natural ground, Table 2 for brownfield locations must be used in all assessments for the design of concrete. It should be noted that the effects of the magnesium ion become relevant to concrete design for certain Design Sulfate Classes.

TABLE 2: AGGRESSIVE CHEMICAL ENVIRONMENT FOR CONCRETE (ACEC) CLASSIFICATION FOR BROWNFIELD LOCATIONS (a) (From BRE Special Digest 1)

SULFATE AND MAGNESIUM						GROUNDWATER		
DESIGN SULFATE CLASS FOR LOCATION	2:1 WATER/SOIL EXTRACT (b)		GROUNDWATER		TOTAL STATIC POTENTIAL SULFATE (c)	MOBILE WATER	ACEC WATER	CLASS FOR LOCATION
1	2 (SO_4 mg/l)	3 (Mg mg/l)	4 (SO_4 mg/l)	5 (Mg mg/l)	6 (SO_4 %)	7 (pH) (d)	8 (pH) (d)	9
DS-1	<500	-	<400	-	<0.24	>2.5		AC-1s
							>6.5 (d)	AC-1
							5.5-6.5	AC-2z
							4.5-5.5	AC-3z
							2.5-4.5	AC-4z
DS-2	500-1500	-	400-1400	-	0.24-0.6	>5.5		AC-1s
							>6.5	AC-2
						2.5-3.5		AC-2s
							5.5-6.5	AC-3z
							4.5-5.5	AC-4z
							2.5-4.5	AC-5z
DS-3	1600-3000	-	1500-3000	-	0.7-1.2	>5.5		AC-2s
							>6.5	AC-3
						2.5-5.5		AC-3s
							5.5-6.5	AC-4
							2.5-5.5	AC-5
DS-4	3100-6000	<1200	3100-6000	<1000	1.3-2.4	>5.5		AC-3s
							>6.5	AC-4
						2.5-3.5		AC-4s
							2.5-6.5	AC-5
DS-4m	3100-6000	>1200 (e)	3100-6000	>1000 (e)	1.3-2.4	>5.5		AC-3s
							>6.5	AC-4m
						2.5-5.5		AC-4ms
							2.5-6.5	AC-5m
DS-5	>6000	<1200	>6000	<1000	>2.4	>5.5		AC-4s
						2.5-3.5	>2.5	AC-5
DS-5m	>6000	>1200 (e)	>6000	>1000 (e)	>2.4	>5.5		AC-4ms
						2.5-5.5	>2.5	AC-5m

NOTES

a) Brownfield locations are those sites or parts of sites that might contain chemical residues produced by industrial processes.

b) The limits of Design Sulfate Classes based on 2:1 water/soil extracts have been lowered relative to previous digests.

c) Applies only to locations where concrete will be exposed to sulfate ions (SO_4) which may result from the oxidation of sulfides (eg pyrite) following ground disturbance.

d) An additional account is taken of hydrochloric and nitric acids by adjustment to sulfate content

e) The limit on water soluble magnesium does not apply to brackish groundwater (chloride content between 12000mg/l and 17000mg/l). This allows 'm' to be omitted from the relevant ACEC classification. Sea water (chloride about 18000mg/l) and stronger brines are not covered by this table.

Explanation of suffix symbols to ACEC Class

Suffix 's' indicates that the water has been classified as static

Concrete placed in ACEC Classes that include the suffix 'z' primarily have to resist acid conditions cements listed in Table D2 in the Digest.

Suffix 'm' relates to the higher levels of magnesium in Design Sulfate Classes 4 and 5.

The pH value of groundwater provides a crude measure of the potential aggressiveness due to the presence of organic acids. The standard procedure for measuring the acidity of soils and groundwater is the electrometric method using a pH meter and is described in BS 1377: 1990: Part 3: Section 5. The pH value of pure water is 7.0 and the presence of acid substances will yield results with values less than 7. It should be noted however that the pH of most natural waters depends mainly on the dissolved carbon dioxide content and therefore lies between pH values of 6.5 and 8.5. It is generally accepted that soils or groundwater with pH values in the range 6 to 9 may be classified as near neutral. It should be noted that the pH value of soil and groundwater can change with time and it is therefore necessary to carry out testing on fresh samples of soil or water.

The pH value of the soil or groundwater also needs to be taken into consideration when the recorded sulfate content is borderline between two classes or approaches the upper limit of a given class. In these circumstances both the pH value and the mobility of the groundwater needs to be assessed and where doubt exists, the sample should be placed in the more severe class of the sulfate classification. This general approach may be justified on the grounds that the acids present will tend to break down the concrete surface and therefore make it more susceptible to sulfate attack. This will be especially so if the sample contains large amounts of sulfides since these can be converted to sulfuric acid.

Organic acids are often found in peaty or marshy soils in which the pH value is below 6.0. In such soils it will be necessary to take specific precautions to protect any concrete which would be exposed to organic acids. The recommended precautionary measures outlined in Tomlinson 2001 (ref 03) could be followed. In all cases where mineral acids are present the groundwater is likely to be aggressive with regard to foundation concrete and in these circumstances the recommendations given in BRE Special Digest 1 Part C will need to be followed.

Apart from acid groundwater, the effects of static and mobile groundwater tables are taken into account in BRE Special Digest 1 in 'Box C9' and the incremental rules in this table need to be viewed in relation to Tables C1 and C2 in the Digest.

Alkaline groundwater is not generally considered aggressive to concrete unless present in high concentrations. Unless the aggregate used in foundation concrete is of a reactive type, pH values of groundwater up to pH = 14 need not be considered as problematic.

References

01) BS 1377: 1990: Methods of Test for Soils for Civil Engineering Purposes. Part 3: Chemical Electrochemical Tests, British Standards Institution.

02) Building Research Establishment 2005: Concrete in Aggressive Ground. BRE Special Digest 1. Building Research Station, Garston

03) Tomlinson M.J 2001: Foundation Design and Construction. 7th Edition, Pearson, Prentice Hall.

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