SPECIFICATION FOR SUBSURFACE INVESTIGATION

1.0 GENERAL REQUIREMENTS

1.1 Definitions

These definitions refer to the Specification, Drawings, Condition of Contract and Bill of Quantities of this Soil Investigation Contract only.

"Ancillary Works" means all appliances or things of whatsoever nature required to be installed or constructed on, under, in or through the Site and which are to remain on Site and become the property of the Employer in accordance with the Contract upon the issuance of a Certificate of Completion in respect of the Site operations or section or part thereof as the case may be.

"Equipment" means any appliances or things of whatsoever nature required temporarily for carrying out the Site Operations but does not include anything which forms part of the Ancillary Works.

"Exploratory Hole" means any kind of hole made to explore ground conditions.

"Laboratory Testing" means the testing operations and processes necessary for the preparation of the Report to be carried out in accordance with the Contract at a laboratory approved by the Employer on samples and cores obtained during the Site Operations.

"Report" means the report to be prepared and submitted in accordance with the Contract.

"Appendix" means the lists of Site Operations, Laboratory Testing and other requirements referred to in the Specification.

"Site Operations" means all the works of every kind including Ancillary Works required to be carried out on, under, in or through the Site in accordance with the Contract.

1.2 Information

Information particular to the Contract is provided by the Employer in Annexure 1 to Annexure 4 as follows:

Annexure 1 - Scope and Object of the Contract.
Annexure 2 - Description of the development
Annexure 3 - List of Contract Drawings
Annexure 4 - General description of the Site Operations including Ancillary Works

Appendices referred to by the Specification are as follows :

Appendix 1 - List of Substitute, Additional or Cancelled Clauses
Appendix 2 - Exploratory Hole Locations and Probable Depths for Ground investigation
Appendix 3 - List of Ancillary Works
Appendix 4 - Methods for Field And Laboratory Testing
Appendix 5 - Requirements of Reports
Appendix 6 - Level of Professional Attendance
Appendix 7 - S.O.'s Office, Equipment And Transportation
Appendix 8 - Particular Requirement of The Contract

1.3 Programme to be Furnished

Within five (5) days after the acceptance of his Tender the contractor shall submit to the SO for his approval a programme showing the order of procedure and method in which he proposes to carry out the Works and particulars of Equipment which the Contractor intends to supply, use or

construct as the case may be. The submission and approval by the SO of such programme or particulars shall not relieve the Contractor of any of his duties or responsibilities under the Contract.

If at anytime it should appear to the SO that the actual progress of Works does not conform to the approved programme, the Contractor shall produce at the request of the SO a revised programme showing the modifications to the approved programme necessary to ensure completion of the whole works within the time for completion provided for in the Contract.

1.4 Setting Out and Taking Levels

The Employer will provide the Contractor with adequate bench marks, permanent ground markers and/or other information sufficient for the Contractor to set out the whole of the Site Operation in accordance with the Conditions of Contract.

The Contractor shall establish the position of each Exploratory Hole, and shall confirm the position of each Exploratory Hole with the SO prior to commencing any Site Operations at that location.

Reduced levels shall be measured by the Contractor for all locations of Exploratory Holes. The temporary bench marks used shall follow those given in the original site plan if the bench marks are given. Otherwise they shall be based on permanent features on site. Under no circumstances shall reduced levels be given by interpolating contour lines on the site plan.

1.5 Supply of Equipment, Materials and Labour

The Contractor shall supply and provide all the Equipment, labour and materials necessary for execution of the works and Ancillary Works including the supervision thereof, transport to or from the Site and in and about the Works and other things of every kind required for the construction, completion and maintenance of the Works.

1.6 Watching and Lighting

The Contractor shall in connection with the works provide and maintain all lights, guards, fencing and watching when and where necessary as required by the SO or by any competent statutory bodies or other authority for the protection of the Works or for the safety and convenience of the public or others.

1.7 Interference with Traffic

All operations necessary for the execution of the Works shall so far as in compliance with the requirements of the Contract permits be carried on so as not to interfere unnecessarily or improperly with the public convenience or the access to use and occupation of public or private roads, footpaths and waterways.

1.8 Facilities for Other Contractors

All Contractors shall in accordance with the requirements of the SO afford all reasonable facilities for any other contractors employed by the Employer and their workmen and for the workmen of the Employer and of any other properly authorised authorities or statutory bodies who may be employed in the execution on or near the site of any work not included in the Contract or of any contract which the Employer may enter in connection with or ancillary to the Works.

1.9 Temporary Access

The Contractor shall provide temporary accesses required for the execution of the Works. He shall provide at all times during the progress of the works proper means of access and the necessary attendance for inspection of the Works by the Employer or his Representative as directed.

1.10 Workmen's Accommodation

The Contractor shall be responsible for the proper housing at site of his labour force to the satisfaction of the relevant Health Authorities. Alternatively, the Contractor may provide housing in hotels.

1.11 Water Supply

The Contractor shall provide water required in connection with the Works, including the supply and fixing of **all** fittings, maintenance of the supply, payment of all fees, removal of all fittings and making good all disturbances after completion of the Works.

1.12 Electrical Power Supply

Should the Contractor require any electricity supply he shall make his own arrangements with the authority concerned, comply with **all** safety regulations and pay all fees in connection with the installation and supply.

1.13 Storage Facilities

The Contractor shall provide proper facilities for the storage and protection of soil, rock and water samples. These facilities shall provide protection at all times from temperatures in excess of 35 degrees Celsius and from wetting or drying out due to weather exposure.

1.14 Removal of Improper Plant, Etc.

The Employer shall during the course of the Works have the power to order in writing from time to time :

a) the removal from the site of any plant not conforming to the requirements of the Specification, and the replacement of such plant at the Contractor's own cost.

b) the dismissal from the site of any technician, supervisor, plant operator, or any workmen of the Contractor found incapable or refusing to follow the proper procedure of work as specified, and replacement of such workmen at the Contractor's own cost.

1.15 Damage to Overhead and Underground Mains and Services

Particular care should be taken to avoid damages to electricity mains, water mains, telephone lines, sewerage mains, gas mains and the like.

The Contractor is fully responsible to ascertain the positions of all mains or services in the vicinity of the Exploratory Hole. He shall be fully responsible for any damage and for claims for consequential damages.

The SO shall be immediately informed if any of the original locations of the Exploratory Holes coincide with the positions of the mains or services. It will be the SO's responsibility to change the locations of the affected boreholes or other tests.

1.16 Clearance of Site on Completion

As soon as the investigation works is completed, all Exploratory Holes shall be properly backfilled to the satisfaction of the SO. On completion, the Contractor shall remove from site all plants, surplus materials, condemned equipment, temporary works and rubbish of any kind, and leave the Site clean and tidy to the satisfaction of the SO.

1.17 Care of Works

From the commencement to the completion of the Works, the Contractor shall take full responsibility for the care thereof and in case any damage, loss or injury shall happen to the Works from any causes whatsoever shall at his own cost repair and make good the same so that at completion the Works shall be in good order and condition and in conformity in every respect with the requirements of the Contract and the SO's instructions.

1.18 Laboratory Testing Facilities

The Contractor shall carry out the laboratory testing at his own testing laboratories. If the testing facilities of other laboratories are to be made use of, the Contractor shall submit in writing the names of the proposed laboratories to the SO for approval as required by Clause 27 of the Conditions of Contract.

1.19 Independent Testing by Employer

Independent laboratory testing may be carried out by the Employer and for this purpose the SO reserves the right to instruct the Contractor to send samples to an Independent laboratory for testing.

1.20 Exploratory Hole Markers

The positions of Exploratory Holes as shown in Appendix 2 or as instructed by the SO carried out on land shall be permanently marked by markers immediately after their completion. Each marker shall comprise a 610mm long steel rod of 20mm diameter which shall be cast into not less than 0.03 cubic metres of concrete at surface level with their tops carefully squared. The Exploratory Hole number shall be clearly inscribed in the fresh concrete. The steel rod shall be painted white.

1.21 Photographs

The Contractor shall supply colour photographs as described in Appendix 6 of rock cores, trial pits or such portion of the Works in progress as may be directed by the SO from time to time. The camera used shall be of a 35mm single lens reflex type. Proofs shall be supplied to the SO within seven (7) days of the photographs being taken and the required sets of prints shall be supplied within seven (7) days of the selected proofs being returned to the Contractor. The negatives of the photographs shall remain the property of the Employer and no print from these negatives may be supplied to any person or persons except with the Authority of the SO.

A suitable typed caption shall be affixed to the reverse side of each photograph describing detail and date taken. One set of the photographs shall be signed by the Contractor and the SO.

1.22 SO's Transport

The Contractor shall provide plain coloured transport as described in Appendix 7 for the exclusive use of the SO for any purposes in connection with the Site Operations. The vehicles shall be delivered and maintained in good roadworthy condition. They shall be licensed and insured for use on the public highway and shall have comprehensive insurance cover for any qualified driver authorised by the SO together with any authorised passengers and the carriage of goods or samples. The Contractor shall provide fuel, oil and maintenance in conformity with the vehicle manufacturer's recommendation and shall clean the vehicles inside and outside as required. A suitable replacement shall be provided for any vehicle out of service for more than 24 hours. When drivers are to be provided with the vehicles they shall be duly licensed.

1.23 SO's Office

The Contractor shall supply and maintain accommodation, furnishings, services, and equipment for the sole use of the SO all in accordance with Appendix 7. All accommodation, furnishings, services, office and survey equipment and vehicles shall be ready for occupation and use by the SO on the Date for Commencement of the Site Operations unless otherwise directed by the SO.

1.24 Contractor's Professional Attendance on Site

The Contractor shall provide engineers or engineering geologists of experience as described in Appendix 6 full time on site during the Site Operations who shall be approved by the SO, whose approval may be withdrawn at any time, and who shall be responsible for the technical direction and output of the whole of the investigation. The Contractor's engineers or engineering geologists are required to ensure quality work, compliance with Specification and taking site instructions from the SO, and are also required to ensure consistent and correct logging according to specified standards.

1.25 Particular Contract Requirements

The works shall be carried out following the particular Contract requirements as described in Appendix 8.

1.26 Submission of Reports

On completion of the Works, the Contractor shall submit a Report as specified in Appendix 5 and Section 8 for this Specification.

1.27 References Used in the Specification

The following references are used in Specifications:-

BS 5930 Code of Practice for Site Investigations
BS 1377 Methods of Test for Soils for Civil Engineering Purposes.

Head, K.H., Manual of Soil Laboratory Testing
Vol. 1 - Soil Classification and Compaction Test (1980)
Vol. 2 - Permeability, Shear Strength and Compressibility Tests (1982)
Vol. 3 - Effective stress testing (1986)

Brown E.T. (Editor) — Rock Characterisation Testing and Monitoring, Part 2, International Society for Rock Mechanics. Suggested Methods: 1981

Broch E and Franklin H.A., — The point load strength test, International Journal of Rock Mechanics and Mining Sciences; Vol. 8, 1972.

ASTM D 2113-83,	Diamond Core Drilling for Site Investigation
ASTM D 1587-83,	Thin-walled tube sampling of soils.
ASTM D 3441-79,	Deep, quasi-static, cone and friction-cone penetration test of soil.
ASTM D 1452-80,	Soil investigation and sampling by auger borings.
ASTM D 4220-83,	Preserving and Transporting Soil Samples.

The above references are included for guidance and are indicative of good engineering standards. The Contractor may follow other international standards with the prior approval of the SO.

Particular test specifications required by the SO must be followed precisely by the Contractor, unless a revised test specification has been discussed and agreed with the SO.

All references referred to are assumed superseded by the latest revisions if available.

1.28 System of Units

All records and results of the site work and laboratory testing shall be reported using International System (SI) units in accordance with BS 3763.

2.0 BOREHOLES

2.1 Percussion Boring

2.1.1 Scope

Percussion boring shall be carried out at locations shown on the Drawings or Appendix 2 or as instructed by the SO and shall comprise the formation of a borehole using a cable percussion rig and attachments such as shell, clay cutter, chisel and sinker bar.

The Percussion boring method shall not be used in soft cohesive soil where undisturbed samples are required.

2.1.2 Borehole and Casing Diameter

The minimum diameter of borings or internal diameter of casing shall be 150mm. Where borings are of such depth that the advancement of a casing becomes impracticable or where hard strata and obstructions are likely to be met, the Contractor shall bore or provide casings of sufficient diameter to complete the work.

2.1.3 Use of Clay Cutters

Clay cutters shall not be used for advancing the boring in soils where they will cause excessive disturbance in soils to be sampled. Where clay cutters are permitted they shall be of a pattern approved by the SO, and the combined weight of clay cutter and any sinker bar shall not exceed 150kg.

2.1.4 Use of Shell and Casing

Care shall be taken at all times to avoid disturbing or loosening of the soil or loss of ground. When using a shell and casing in order to keep disturbance of the ground to a minimum, the Contractor shall operate the equipment in such a way as to allow the shell to proceed before the casing only the minimum distance necessary to advance the boring. When using a shell in granular soils beneath the water table the diameter of the shell shall be 25mm less than the diameter of the casing.

2.1.5 Addition of Water to Borings

The Contractor shall not add water during boring unless boring in dry granular soils or in very stiff clays. For conditions where the addition of water is permitted, the Contractor shall use the minimum amount of water necessary for advancing the boring. When water is added to assist with the works, the Contractor shall record the depths through which water was added. Where borings reveal saturated soft soils or artesian or sub-artesian ground water in granular soils, the Contractor shall immediately add and maintain a head of water during boring and sampling in order to counteract the disturbance caused by the removal of overburden or inflow of groundwater.

2.1.6 Hard Strata and Obstruction

In borings where hard strata or obstructions are encountered, the Contractor shall continue boring using a chisel or similar approved tool for a minimum time of 1 hour in an attempt to penetrate the hard strata or obstructions. Upon completion of the above requirement, the Contractor shall consult with the SO who shall instruct the Contractor either to continue chiselling or to change to a different method of boring or to terminate the borehole.

2.1.7 Groundwater Observations

The observation of groundwater shall be in accordance with Clause 3.1. The groundwater levels shall be reported in the borehole logs.

2.1.8 Weather Record

The Contractor shall keep a weather record of the site for the whole duration of the field works.

2.2 Rotary Wash Boring

2.2.1 Scope

Rotary wash boring shall be carried out at locations shown on the Drawings or Appendix 2 or as instructed by the SO and shall comprise the formation of a borehole by the rotary action of a drill bit, with cuttings washed to the ground surface by drilling fluid pumped down the drilling rod.

2.2.2 Borehole and Casing Diameter

The diameter of boreholes and casing shall be such that the requirements of sampling and field testing are satisfied.

2.2.3 Casing and Support of Borehole Sides

Casing shall be used to the full depth of the boreholes at all times unless otherwise permitted by the SO. Other methods of stabilization of the borehole may be carried out subject to the prior approval of the SO on the procedure used. Nevertheless, casing shall be used when there is doubt as to the effectiveness of the method of stabilization proposed or practised.

Methods of stabilisation involving the use of bentonite or other drilling fluids shall not be used when permeability tests are to be carried out or piezometers are to be installed.

2.2.4 Heaving of the Bottom of the Borehole

To prevent heave and disturbance of the soil at the bottom of the borehole, the level of drilling fluid in the borehole must at all times be equal to or higher than the elevation of the groundwater. This condition shall be strictly observed in formations of sand or coarse silt, or in operations involving undisturbed sampling and insitu testing.

In very soft ground or when instructed by the SO, the Contractor shall use heavy drilling fluid in addition to full depth casing to stabilize the borehole. However, such fluids shall not be used when permeability tests are to be carried out or piezometers are to be installed.

2.3 Rotary Core Drilling

2.3.1 Scope

Rotary core drilling shall be carried out at locations shown on the Drawings or Appendix 2, or as directed by the SO. Drilling shall be carried out in accordance with good practice as detailed in ASTM D 211.3 or similar approved standard. Drilling shall consist of obtaining core samples of the full depth of the strata being penetrated.

Should the Contractor fail to ensure that drilling and sampling is undertaken as specified or instructed then he may be liable to redrill all or part of a borehole at his own expense should the SO direct.

2.3.2 Core Barrels Types

In residual soils and highly weathered rock, rotary drilling shall be carried out using Mazier type triple tube retractable core barrels producing a core diameter of not less than 76mm diameter (H size). The detachable inner liner shall be used to transport and store the sample.

When drilling competent and relatively un-weathered rock conventional triple and double tube barrels shall be used. The latter type shall be confined to good rock without a significant presence of fractures and only swivel-type design shall be accepted. The triple tube system is preferred. When using these non-retractable core barrels the minimum core diameter shall be 50mm (N size).

2.3.3 Drilling Method

The method and equipment used shall be such that :

a) The soils encountered and the levels of strata boundaries can be accurately identified.

b) Truly representative disturbed and undisturbed samples can be recovered from any depth in the borehole, and

c) All in-situ tests referred to in the Specification can be undertaken and field installations incorporated at any depth in the borehole.

Drilling shall be carried out in such a manner and using such sizes of bits including any required modification to the drill bit, such that the maximum amount of core is recovered. This requires close surveillance of drilling fluid, drilling pressures, lengths of runs and all other factors relevant to the nature of the material being drilled.

The core barrel shall be withdrawn and the core removed as often as may be necessary to secure the maximum possible amount of core.

Coring runs shall be limited to a maximum length of 1.5m. When less than 95% of the core is recovered from a run the length of the following run shall be reduced by 50% unless otherwise directed by the SO. If less than 50% recovery is achieved the following run shall not exceed 0.5m until full recovery is achieved from two consecutive runs.

The core barrel shall be removed from the borehole immediately if blocking of the bit or grinding of the core is apparent regardless of the length of run which has been made.

The Contractor shall in general use no drilling lubricants in the borehole other than clean water, air or air with an approved drilling foam additive. Additives shall only be used in the flushing medium upon approval by the SO.

2.3.4 Core Barrels, Casing and Drill Rods

Details of the manufacturers and the specifications of all core barrels and of proposed tungsten carbide and diamond core bits shall be given.

The Contractor shall supply section drawings of the barrels and bits he proposes to use. He shall submit also manufacturer's brochures illustrating the type of equipment he proposes to use. The use of equipment without such information shall not be allowed.

The core barrels shall be of approved manufacture and, unless otherwise approved by the SO, all accessories and spare parts shall be as supplied or recommended by the Manufacturer.

The Contractor shall provide sufficient numbers of core barrels and accessories in order to carry out the scheduled work.

Each core barrel shall be provided with the full range of bit types to cope with the various ground conditions encountered at the site. Spares for each bit type shall be available for use on site without causing any delay to drilling operations. An adequate supply of short, medium and long plain retractor shoes shall be available for use with Mazier type triple tube retractable core barrels.

All core barrels shall be equipped with sediment catcher tubes. The tube shall have the same external diameter as the core barrel, and its length shall be approximately 0.75m.

The upper end shall be tapered with the upper edge curved slightly inwards to prevent fouling the side of the borehole on withdrawal of the core barrel.

Triple tube core barrels shall be equipped with built in ball check pistons to ensure that the core is not subjected to water flushing when extracting the inner barrel containing the core.

Casing shall be used to prevent collapse of the sides of the hole. The size of casing and drill rods shall be appropriate for the size of core barrel in use.

All casing and drill rods shall be flush jointed and each length shall be straight and in good condition, and shall be cleaned thoroughly before use to ensure that the scale, dirt, and other loose material are removed. All drill rods shall be of standard lengths (eg. 3.0, 1.5, 0.75m)

Short lengths of drill rod and casing shall be available to enable continuous coring to be carried out.

2.3.5 Drilling Rigs and Ancillary Equipment

Drilling rigs shall be of the hydraulic feed type with sufficient horsepower and capacity to drive a rotary tool tipped with diamonds or tungsten carbide in the sizes and to the depths specified. The rigs shall be such that they are capable of applying to the drilling bit a working hydraulic thrust of the order of 10kN to 15kN.

The weight of the drilling rig shall be compatible with the maximum hydraulic thrust required without movement of the rig. If the weight of the rig is insufficient to prevent movement, the base of the rig shall be securely anchored down or loaded.

The rigs shall also be fitted with a tachometer and a hydraulic feed pressure gauge, both of appropriate scales. A rigid rod, clearly graduated in 10mm increments shall be permanently attached to and parallel with the hydraulic feed rams, to provide a means of measuring penetration and estimating penetration rates.

Where the flushing medium is water, a centrifugal or reciprocating pump shall be provided equipped with a gear box and capable of delivering up to 2 l/s. The pump all incorporate a 'surge' bottle to reduce fluctuations in water pressure and the suction hose shall be fitted with a suitable filter at all times. A full by-pass system shall be provided and attached to the drilling rig allowing the operator full control of water flow from zero to maximum pump delivery rate.

A pressure gauge capable of operating in the range 0kN/m2 to 2000kN/m2 shall be directly fitted into the water supply line on the 'downstream' side of the by-pass valve. Where the flushing medium in use is air with foam additive an air compressor capable of producing 2m3/min to 5m3/min with a working pressure up to 700kN/m2 shall be provided. A by-pass system similar to that required for water flush and a pressure gauge of appropriate scale shall also be provided.

To inject liquid foam mixture into the flushing airstream an air-driven drum pump or other approved system shall be provided. The pump shall be equipped with a pressure balancer, a pressure limiting valve, an on/off control valve with the facility for regulating the flow of liquid foam mixture up to a maximum of 0.1 l/s.

Details of the proposed foam additive and mixes shall be submitted to the SO for approval and the use of a foam stabiliser shall not be permitted unless this has been agreed with the SO. The Contractor shall ensure that the proposed foam is either fully biodegradable or water soluble and make arrangements for the collection and removal or disp0ersal of the foam returns when required.

The Contractor shall provide recent certified calibration for all gauges and measuring equipment used. Certification shall have taken place within one year of intended use.

2.3.6 Record of Drilling Equipment

On the daily record sheet the driller shall record the type of core barrel used and the type of coring bit used. This information shall be recorded of each core run.

2.3.7 Extraction of Cores

Core shall be extracted from double tube barrels using a hydraulic or similar approved extruder. The extruder shall apply a continuous pressure to one end of the core whilst the barrel is in a horizontal position.

Drilling shall not be allowed to commence unless a suitable approved extruder is available on site. No standing time shall be approved by the SO in respect of delays resulting from this equipment.

Cores from triple tube barrels with continuous inner liners shall be carefully removed from the core barrel, sealed and labelled as specified.

Cores from split-tube triple tube core barrels shall be carefully removed from the core barrels using hydraulic pressure and be carefully transferred into split plastic tubes of the same internal diameter as the split inner tubes.

The SO may instruct certain core lengths to be sealed in aluminium foil and waxed before sealing inside the plastic tube.

Where air/foam is used as the flushing medium water supply with complete by-pass shall also be available and used for the extrusion of the split inner tubes from the core barrel. Under no circumstances shall air pressure be used for the extrusion of cores.

The Contractor shall submit a detailed method statement explaining how the core shall be extracted from the core barrel. The Works shall not proceed until this method statement has been agreed with the SO.

2.3.8 Core Boxes, Packing and Labelling of Cores

Core boxes shall be constructed of sound materials such as timber, galvanised steel or reinforced plastic with a lid having secure fastenings. Handles shall be attached to the core box for lifting. Core boxes shall not contain more than 50kg of core. The height of the core boxes shall be compatible with the diameter of the core to be stored in them.

As the core is extruded it shall be arranged in the box in proper sequence starting with the shallowest core on the left side nearest the hinge and then working along the slat and subsequently outwards towards the clasp. Slat shall be positioned and secured such that the core is restrained from movement.

Wooden partition blocks not less than 25mm in thickness shall be placed at the beginning and end of each box and at the end of each core run. These blocks shall be marked with the depth below ground level in waterproof marking ink numbers at least 20mm high and facing the box lid. Each locality, borehole number, core box number, depths and date.

Core losses shall be shown by wooden blocks or polystyrene of a square cross section to fill the core space and of a length equal to the core lost.

Until the boxes containing the cores are transported from the site they shall be neatly stored at the borehole locations in such a manner that inspection of the cores can easily be made. The boxes shall be stored under cover and protected from the weather. All core boxes shall be carefully transported to avoid damage and disturbance to the contents.

Unexamined core samples contained within plastic lining tubes and waxed samples retained for testing shall be stiffened with laths of wood and wrapped carefully with foam sheeting to minimise disturbance during transportation.

All core boxes and samples shall be delivered to Contractor's store and shall remain the property of the Employer.

2.3.9 Core Recovery Ratio (CRR), Rock Quality Designation (RQD) and Fracture Index (FI)

The Core Recovery Ratio (CRR), Rock Quality Designation (RQD) and the Fracture Index (FI) as described below shall be reported for each core run. Good quality core is defined as intact core having a fully circular circumference. The CRR shall mean the ratio of the total length of the good quality core over the drilling run expressed to the nearest 5%. The RQD is the percentage of the total length of good quality cores each exceeding 100mm in length over the drilling run, expressed to the nearest 5%. Any length of core containing breaks caused during drilling or handling shall be considered as solid when computing the RQD. The FI shall mean the number of naturally occurring fractures per metre run of core. Care shall be exercised to ensure that fractures caused during drilling or extraction of the core from the core barrel or liner are not included in the assessment of FI.

2.3.10 Rock Core Photographs

Colour photographs of rock cores shall be taken by the Contractor as described in Clause 1.21.

2.4 Hand Auger Borings

2.4.1 Scope

Hand auger boring shall be carried out at locations shown on the Drawings or as instructed by the SO in accordance with ASTM D 1452 or similar approved standard and shall consist of the formation of a borehole by hand auguring techniques.

2.4.2 Equipment and Diameter of Boreholes

The auger stem shall be of a design such that an open-tube or thin-walled sampler can be fitted at the auger end and undisturbed samples may be taken. The minimum diameter of hand auger borings shall be 100mm and casing shall not be required.

2.4.3 Depth of Hand Auger Borings

The hand auger holes shall be stopped when the sides of the hole starts to collapse or when the resistance to auguring is so great that the auger cannot be advanced with the

force of two healthy workers of average Malaysian physique. It is not expected to auger more than 7.5m.

2.5 Backfilling of Boreholes

Exploratory holes shall be backfilled as soon as practicable after the hole is completed, unless otherwise directed by the SO. The Contractor shall backfill and compact all exploratory holes in such manner and using such materials that no subsequent depression is formed at the ground surface due to settlement of the backfill.

Should any special backfilling procedures or materials be required, these shall be given in Appendix 2.

3.0 GROUND WATER

3.1 Ground Water Observations

3.1.1 Measurement Accuracy

The observation of ground water level for all types of boreholes shall be made with a tape, rod, rule or diameter that permits measurements with an accuracy of plus or minus 25mm.

3.1.2 First Encounter

For boreholes advanced without use of drilling fluid and when water is first encountered, the depth from ground level to point of entry shall be recorded and exploratory hole operations stopped. The depth from ground to water shall then be recorded at 5 minute intervals until no further rise is observed. However, if at the end of the period of 20 minutes the water level is still rising, unless otherwise instructed by the SO, this shall be recorded together with the depth to water below ground level and the exploratory hole shall be continued.

If casing is used and this forms a seal against the entry of groundwater, the Contractor shall record the depth at which no further entry or only insignificant infiltration of water occurred. Where applicable every effort shall be made to seal off each water strike.

Where ground water occurs as a slow seepage into the exploratory hole, the point of entry of the seepage shall be recorded and water levels monitored as specified above.

3.1.3 Subsequent Encounter

When further changes in water levels occur such as when lower water tables are found after upper water tables have been sealed off by the casing, they shall be recorded as in 3.1.2 above.

3.1.4 Beginning and End of Shift

For all types of cased boreholes, before a day's work is completed the casing shall be pulled up by about 0.3m and left in such a position overnight. The groundwater level shall be recorded as the last operation of the day and the first operation on the following day's boring. The duration of rainfall for the last 12 hours should be recorded. The recordings shall be repeated daily while boring for that particular borehole is in

progress. The casing shall be capped and protected overnight by the Contractor in such a way as to prevent the entry of rainwater and surface water but allow a free passage of air into the casing.

In a hand auger hole the groundwater level shall be recorded immediately the hole is completed and early in the following morning. For the purpose of such groundwater level observations, holes shall be suitably covered and protected from the entry of rainwater and surface water once they are completed. If the sides of the hole have collapsed over night, the "apparent" depth of the hole shall be recorded. At least one observation of the groundwater level and the "apparent" depth of auger hole, if applicable, is necessary for all hand auger holes.

3.2 Standpipe Piezometer

3.2.1 Scope

Standpipe piezometer shall be installed in boreholes at locations shown on the Drawings or Appendix 2 or as instructed by the SO. The final details of any piezometer installation will be decided by the SO and will be dependent upon the actual subsoil and ground water conditions found.

3.2.2 Piezometer Tip and Tubing

The piezometer tip shall consist of a porous ceramic element or other element not less than 150mm long with a diameter not less than 40mm, and shall be protected at each end by unplasticised polyvinylchoride (UPVC) fittings. The porous element shall be a pore diameter of the order of 60 microns and permeability of the order of 3 x 10^{-4}m/s.

The tubes shall be jointed together and to the porous element with approved couplings and glue in such a manner that the joints remain leak-proof under the anticipated head of water.

3.2.3 Grouting

A grout of cement and bentonite shall be used. If water in the exploratory hole is contaminated by grout it shall be replaced by clean water, the method being to the approval of the SO. Unless otherwise approved by the SO, the grout shall consist of 4 parts of bentonite mixed with 10 parts of water to which is then added 1 part of Ordinary Portland Cement.

3.2.4 Sand Filter

The sand filter surround to the porous element shall be clean and fall wholly between the limits of grading 1200 and 210 microns and the volume of the sand filter placed shall be recorded. The Contractor's arrangements shall ensure that no sand adheres to the soil in the sides of the unlined borehole. Where there is water in the borehole the Contractor shall allow sufficient time for all the sand to settle. The final elevation of the top of this sand shall be recorded. The porous element shall be placed in the hole and the remaining sand filter shall then be added as described above.

3.2.5 Surface Installation

The top of the UPVC tubing shall be covered by a plastic cap or similar as approved by the SO. An air vent shall also be provided. Arrangement to protect the top of the UPVC tubing shall consist of a steel water barrel of 75mm diameter which shall be set in concrete.

3.2.6 Water Levels Monitoring

The ground water level shall be recorded immediately before and after installation of the piezometer. Before readings are commenced the piezometer shall be filled with water and its correct functioning demonstrated to the SO. Each piezometer shall be clearly and permanently labelled with a metal stamp or tag giving the exploratory hole number. During the site operations the Contractor shall record the ground water level in standpipe piezometer at least one everyday or as instructed by the SO.

3.2.7 Checking of Piezometer Installation

The correct installation and functioning of all piezometer installations shall be confirmed immediately following their completion.

(a) The Contractor shall ensure that there are no obstructions in the riser tube.

(b) The Contractor shall ensure that the piezometer tip is located to within 0.lm of the instructed depth and that the piezometer tip has not been displaced as a result of removing the borehole casing.

(c) The Contractor shall flush the system and top up the riser tube with clean water and measure and record the fall in the head of water for a period not exceeding 30 minutes.

3.2.8 Piezometer Bucket

The observation of peak groundwater response in open-hydraulic piezometers or standpipes shall be measured using string of piezometer "buckets". The buckets are filled progressively as water rises in the piezometer and will retain their water even if the piezometer pressure subsequently falls. By using a series of closely-spaced piezometer buckets, the peak transient response during or after a rainstorm can be recorded at a convenient time later on. The buckets are tied to a weighted nylon string at selected depth intervals above the normal base water level and can be pulled to the surface for readings. They shall typically be placed at 1.0m intervals within the range of 4m both above and below the critical groundwater level assumed in the design or determined during the measurement readings. Care should be taken when handling the string to ensure that it does not drop into the borehole (thus rendering the piezometer useless), or that it does not tangle and reduce the spacing between the buckets.

3.3 Standpipes

3.3.1 Scope

Standpipes shall be installed in boreholes at locations shown on the Drawings or Appendix 2 or as instructed by the SO. The final details of any installation will be decided by the SO and will be dependent upon the actual subsoil and groundwater conditions found. The Contractor shall be responsible for the correct installation, and proper functioning and maintenance of all standpipes installation throughout the duration of the works. The Contractor shall submit to the SO all measurements and

records of the works, for the acceptance or otherwise of the installed standpipes by the SO. Any installation which is deemed by the SO to be malfunctioning or damaged shall be replaced or repaired by the Contractor at his own expense.

3.3.2 Equipment and Installation

Standpipes shall consist of a minimum 25mm internal diameter UPVC tube with minimum thickness of 2mm with an end cap and slotted or perforated over its lower end. The slots or perforations shall be at least 1.5mm wide, and evely distributed over the slotted or perforated part of the tube to provide a minimum open area of 30% of the total circumferential surface by the SO. The slotted part of the tube shall be wrapped with filter fabric as approved by the SO. The length of the slotted portion shall be 3m minimum.

The standpipe shall be placed in the borehole, backfilled with graded filter sand (600 to 2000 micron) up to 1.0m below ground level or as specified by the SO. The top 0.5m (min.) of the borehole shall be sealed with a concrete plug and subsequent 0.5m (min.) depth sealed with bentonite pellets or with an approved bentonite cement grout. The top of the standpipe shall be covered by a plastic cap or similar as approved by the SO.

Piezometer buckets as approved by the SO shall be installed in the standpipe as shown on the Drawings or Appendix 2 or as instructed by the SO. The buckets are to be tied to a non-extendable nylon string at selected depth intervals and weighted at the bottom as directed by the SO, and shall be installed such that the buckets can be pulled to the surface for readings.

3.3.3 Commissioning

Before taking initial readings the Contractor shall stabilise the standpipe by alternately baling and filling at least five (5) times unless otherwise directed by the SO. The Contractor shall then carry out a simple falling head test by topping up the riser tube with clean water and measure and record the fall in the head of water for a period not exceeding 30 minutes.

3.3.4 Method of Monitoring

Depth from the top of the riser tube to water in the standpipe shall be measured using a dipmeter. The dipmeter shall be of the electric type of the approval of the SO, but simple metal probes attached to nylon cord may be used with the approval of the SO for shallow depths. Where piezometer buckets are installed, water levels in the piezometer buckets shall also be recorded.

3.3.5 Frequency of Monitoring

The Contractor shall monitor the water levels in the installed standpipes at least once daily.

4.0 SAMPLING

4.1 Extent and Frequency of Sampling

4.1.1 General Requirements

Method and frequency of sampling shall depend on the purpose or nature of structure for which the borehole is required. The purpose of each borehole is given in Appendix 4 and shall fall into the following main categories:

- Cuttings
- Embankments and shallow structural foundations on residual soils
- Embankments on soft ground
- Major Structures
- Cut/fill interface

The requirements given below are general guidelines which may be altered by the SO. Special requirements for sampling are given in Appendix 2.

Sampling frequencies are given in Table 4.1 and shall be used within each principal soil type encountered in a borehole. In addition, at any major change of soil type or consistency a small disturbed sample shall be taken followed immediately by an undisturbed, bulk disturbed or split spoon sample as appropriate.

Methods of forming boreholes shall be suitable for the types and sizes of sample required.

4.1.2 Cuttings

Sampling within areas of cutting shall be carried out to depths as follows:

- to a depth of 1.5m below the proposed carriageway
- to a depth of 5.0m below the proposed cutting slope.

4.1.3 Embankments and Shallow Structural Foundations on Residual Soils

Maximum depth of sampling shall be as given in Appendix 2.

4.1.4 Major Structures

Sampling shall be continued until the Standard Penetration Test "N" exceeds a value of 50 for a depth of 9.0m, when piled foundations are proposed. For cases where shallow foundations may be suitable, the requirements of Clause 4.1.3 shall be followed.

4.1.5 Cut/Fill Interface

Maximum depth of sampling shall be as given in Appendix 2.

4.2 Disturbed Sampling

4.2.1 Small Disturbed Samples

Small disturbed samples may be obtained by any means provided that the soil sample obtained is representative and unchanged in its constituent components. Samplers with flap retainer or basket retainer or other attachment may be necessary for cohesionless soils.

Small disturbed samples shall be not less than 1.0kg. They shall be placed immediately in a wide-mouth, air-tight screw-top clear plastic jar which they should sensibly fill and sealed with a masking tape and non-shrink wax.

4.2.2 Bulk Disturbed Samples

Bulk disturbed samples shall be obtained from the cutting tools during percussion boring. The samples shall be collected over a depth interval of 1.0m or less and shall weigh not less than 30kg.

4.3 Undisturbed Sampling

4.3.1 Preparation for Sampling

Before taking an "undisturbed" sample the bottom of the exploratory hole shall be carefully cleared of loose material and where a casing is being used the sample shall be taken below the bottom of this casing. The depth to the bottom of the casing shall be recorded on the borehole logs. When an uncompleted hole is left overnight or for any other substantial period of time, no samples shall be taken until the hole has been advanced by a minimum of 300mm from the previous depth.

In soft soils a head of water shall be maintained in the casing to minimise heave of the borehole.

4.3.2 Sampling Tubes

All tubes used for undisturbed sampling shall be of light alloy, stainless steel or with an equivalent surface plating for corrosion protection and shall be clear and free of all surface irregularities including projecting weldseams, dents, and rust and should be properly greased. Sample tubes that are corroded or susceptible to corrosion shall not be used. The cutting edges, area ratios and inside clearances shall be as specified in the following clauses.

4.3.3 Open-Tube Sampling

Open-tube drive samples shall generally be taken in stiff to hard cohesive soils in cable percussion borings using open-tube sampler and equipment as described in BS 5930. The sampler shall be suitable to obtain samples having minimum diameter of 70mm and a minimum length of 450mm. The cutting shoes shall be clean, sharp and without burred edges. The cutting edge taper shall not exceed 20°. Area ratio shall be less than 25% with an inside clearance of 1% to 2%. The number of blows, weight of drop hammer, height of drop and length driven shall be recorded when cable percussion boring is used.

4.3.4 Thin-walled Sampling

Thin-walled samples shall generally be taken in soft to firm soils using equipment and procedures as described in ASTM D 1587. The tube shall be suitable to obtain samples minimum diameter of 70mm and nominal length of the tube shall be 1000mm. Wall thickness shall be between 1.5mm and 2.0mm with an inside clearance of 0.5% to 1.0%. The area ratio shall be not greater than 10%.

The tube shall be pushed into the base of the borehole by a continuous and steady motion without driving, impact or twisting. The drilling rig or boring plant used shall be capable of exerting a static thrust of 10kN on the sampler.

4.3.5 Piston Sampling

For detailed investigation of soft cohesive soils stationary piston sampling equipment shall be used. The minimum inside diameter of the tube shall be 70mm and the nominal length of the tube shall be 1000mm. Wall thickness shall be between 1.5mm and 2.0mm.

The sampling tube shall be stainless steel and shall have a rust free smooth surfaces. The area ratio shall be not greater than 10%.

The edge taper angle shall be between 6° and 10° and the inside clearance ratio shall be 0% to 0.5%.

When drilling has advanced to the required sampling depth the base of the borehole shall be cleaned thoroughly to ensure there is no debris at the bottom of the borehole.

The assembled piston sampler shall be lowered down the borehole taking great care that the sampler does not come into contact with the borehole casing.

Once the piston sampler reaches the base of the borehole the depth of the sampler must be checked against the prior measured depth of the borehole. If these measurements are not exactly the same it is likely that debris has accumulated at the base of the borehole. If such a condition exists the sampler shall be removed and the borehole shall be cleared out again.

Provided the sampler has reached the clean base of the borehole the sampler shall be held tight by the drilling rods to ensure that the weight of the sampler together with the drill string does not rest on the soil to be sampled.

The piston shall then be unlocked from the sampler body by twisting the central piston rod. The piston rod shall then be attached to the tower, mast, or tripod of the drilling machine.

A considerable tensile force can develop in the piston rod. The swivel, adjustable turnbuckle and chain shall be chosen to withstand a force equivalent to the jacking load capability of the drilling equipment.

The turnbuckle shall be adjusted to ensure that all play and backlash has been taken up. The piston rod shall be marked in a convenient manner to measure any settlement of the piston during sampling.

Prior to advancing the sampler the length of advance shall be determined and the drill rods marked accordingly. The advance length shall be approximately 90% of the effective internal length of the sampling tube.

The advance of the sampler shall be made in one fast continuous movement. The rate of penetration of the sampler shall be of the order of 200mm/s.

The actual advance length of the sampler shall be measured in a conventional way and the amount of advance shall be recorded on the drilling logs. The settlement, if any, of the fixed piston shall be measured and recorded on the drilling logs.

A waiting period of at least 5 minutes shall elapse before the complete sampler is removed from the borehole. The sampler shall be lifted without rotation.

After withdrawal of the sampler from the borehole the sample and tube shall be removed from the sampler. The air vent screws shall be removed to ensure that there is not any vacuum created as the sampler head and sample tube are separated.

Prior to the execution of piston sampling on site the Contractor shall submit details of the equipment he proposes to use and he shall submit a copy of the instruction on piston sampling that shall be given to the drillers.

4.3.6 Recovery and Preservation of Undisturbed Samples

a) Following undisturbed sampling, a rubber cap shall be placed on the lower end of the sampling tube containing the cutting edge. This will prevent damage to the cutting edge itself.

b) From the other end of the sampling tube about 40mm of material shall be carefully removed. The material shall be retained in a screw top clear plastic container and sealed.

c) The inside of the tube from its open end to the surface of the undisturbed sample shall be cleared of all soil debris using special cleaning tools and lightly greased.

d) A circular piece of paper having the same diameter as the inside of the sampling tube shall be placed on top of the sample. This paper is to minimise wax impregnation.

e) The inside of the tube to be covered with wax shall be thoroughly degreased and melted non-shrinking microcrystalline wax shall be poured onto the paper disc to a thickness of about 10mm.

f) Once the wax is nearly solid a neoprene disc having the same diameter as the inside of the tube shall be gently pressed into the wax to ensure the wax makes a good seal with the wall of the sampler.

g) Another 10mm thickness of wax shall be poured onto the neoprene disc, once hardened a final 30mm thickness of wax shall be poured onto the sample.

h) Once the wax has hardened moist sand, saw dust, or soil shall be placed on the waxed sample to fill completely the sampling tube.

i) A rubber cap shall then be placed on the end of the sample tube and its edge sealed against the outside of the sample tube with adhesive vinyl tape and wax.

j) The tube shall be inverted carefully and steps (2) to (9) repeated for the cutting shoe end of the tube.

k) The sample tube shall be labelled in accordance with Clause 4.6.

l) Until the samples are removed from the site they shall be placed in protective boxes in a dry place and under cover to the requirements of Clause 1.13.

4.3.7 Unsuccessful Sampling

Where an attempt to take an undisturbed sample fails, the boring shall be cleaned out for the full depth to which the sampling tube has been driven and the recovered soil saved as a disturbed sample. A fresh attempt shall then be made from the level of the base of the failed attempt. Should this second attempt prove unsuccessful the Contractor shall adopt means of sampling as agreed with the SO.

4.4 Ground Water Sampling

Ground water samples shall be taken in accordance with BS 5930 on each occasion that ground water is encountered during boring. In percussion borings where water has not been added and in hand auger borings ground water samples shall be taken as soon as practicable after ground water is encountered. In all types of boring where water is added, ground water samples should be collected when directed by the SO, by first removing all water from the borehole by pumping or bailing, then taking a ground water sample from the water which collects by seepage.

Approximately 1.0 litre of water should be collected and stored in a clear inert plastic bottle, rinsing the bottle three times with the water being sampled before filling. The ground water sample shall sensibly fill the bottle which shall be sealed with a watertight screw cap.

4.5 Surface Water Sampling

Water samples shall be taken from streams, ditches or standing water as directed by the SO. The samples taken shall be representative of the water in the source. Collection and storage of the water samples shall be as for ground water samples as described in Clause 4.4.

4.6 Labelling of Samples

All samples shall be labelled immediately after being taken from the Exploratory Hole or surface water. The label shall be clearly and indelibly marked and shall show all the necessary information about the sample, including the following:

- Contract title and reference number
- Date of sampling
- Exploratory Hole reference number (for surface water, give relevant details)
- Sample reference number
- Depth of sample (including top and bottom of sample)

The following legend shall be used for the Exploratory Hole and sample reference numbers :

Rotary wash or percussion borings	BH
Auger borings	HA
Trial pits	TP
Mazier core sample	IS
Rotary core sample	RS
Stationary piston undisturbed sample	UP
Thin-walled tube undisturbed sample	UT
Open-tube undisturbed sample	UD
Small disturbed sample	DS
Bulk disturbed sample	DB
Ground water sample	WG
Surface water sample	WS

The label shall be securely fixed onto the outside of the sample tube, jar or bag. The outside of the sample tube, jar or bag shall also be clearly and indelibly marked with the same information as the label.

4.7 Storage, Protection and Transportation of Samples

The Contractor shall store all samples in an orderly fashion at site in protective boxes in a dry place and under cover to the requirements of Clause 1.13 until they are despatched to the designated laboratories or as directed by the SO.

The thin-walled, stationary piston and Mazier type undisturbed samples shall be stored, protected and transported with utmost care to avoid disturbance to the samples. They shall be placed and transported in approved shipping containers.

The shipping container shall be constructed such that they are padded throughout with rubber foam and contain partitions to stop the sampler tubes from moving in any direction during transporting to the laboratory. The rubber foam lining shall have a minimum uncompressed thickness of 100mm.

The container shall be capable of accommodating a minimum of three undisturbed samples and shall be of strong construction with carrying handles. Prior to the commencement of site work the Contractor shall submit a sample of the shipping container for approval.

During transportation all undisturbed samples shall be protected in the same manner as during storage on site.

4.8 Provision of Record Samples

The Contractor shall take 150gm of representative soil sample from each undisturbed, bulk disturbed and split spoon sample collected and seal it inside a wide-mouth, screw-top, air-tight clear plastic jar which it sensibly fills. These samples shall be known as "record samples" and shall be delivered as directed by the SO. The Contract Title and reference number, borehole number, sample reference number and the depth of sample shall be marked on a card fixed to the outside of the jar. The "record samples" from a project shall be stored in a crate with the Contract Title and reference and the year and month of investigation clearly and indelibly marked on the crate. These samples shall be delivered at the same time as submission of the preliminary records.

4.9 Retention and Disposal of Samples

All samples shall be kept for a period of not less than three months after submission of the approved report and shall be discarded after that time only on the instructions of the SO. The SO may request that certain samples be retained either by the Contractor or sent elsewhere.

Purpose of Borehole	Location	Boring Method	Method of Sampling	Frequency of Sampling
Cutting	Within material to be excavated and subgrade	Percussion (1)	Alternate bulk disturbed(2) and undisturbed	2.0m
	Below cutting slope to be formed	Percussion (1) or rotary core drilling	Undisturbed	1.0m
Embankments and shallow structural foundations on residual soils	From ground level to 5m below foundation level	Percussion (1) or rotary core drilling	Split spoon (SPT) with some undisturbed	1.0m
	After greater depths than above.	Percussion (1) or rotary core drilling	Split spoon (SPT) with some undisturbed	1.5m
Embankment on soft ground	Within soft compressible	Rotary wash boring, Trial Pit	Undisturbed stationary piston	Continuous (3)

	deposit Below soft compressible deposit	Rotary wash boring	Split spoon (SPT)	1.5m
Major Structures		Percussion (1) or ratory core drilling	Split spoon (SPT) with some undisturbed	1.5m
Cut/fill interface		Percussion or trial pit	Bulk disturbed or undisturbed	1.0m

Table 4.1 - Sampling Requirements

Notes: (1) To be used to the maximum depths possible for open tube sampling then continued y rotary core drilling using triple tube retractable core barrel.

(2) SPT to be done before taking bulk sample (bulk sample to include material penetrated by split spoon)

(3) Approximately 200 mm between base of sample and top of next sample.

(4) If soft ground is present then investigate as for "embankment of soft ground".

5.0 INSPECTION PITS AND TRIAL PITS

5.1 Inspection Pits and Precautions for Underground Services

The Contractor shall start all Exploratory Holes located within the boundaries of public highways and elsewhere where the presence of underground services is expected by means of a hand excavated inspection pit not less than 0.5sq.m in plan and not more than 1.5m deep. Hand operated power tools may be used to assist excavation where hard strata such as road pavements cannot be broken out without the use of such tools. Exploratory Holes shall not begin until the present or otherwise of all such services has been established. The positions depths and dimensions of all services encountered shall be measured and recorded in the daily Journal, and strata recorded.

5.2 Trial Pits for Examining and Sampling Soils

5.2.1 Scope

Trial pits shall be excavated at locations shown on the Drawings or Appendix 2 or as instructed by the SO.

5.2.2 Excavation Methods

The Contractor shall excavate trial pits by hand or machine to permit insitu examination of soil, soil sampling and insitu testing as required. The plan area of any trial pits shall not be less than 1.0sq.m.

5.2.3 Support to Pit Sides and Safety

The Contractor shall adequately support the sides of pits and trenches at all times to protect anyone entering and working in the hole. The supports shall be placed so as to minimise interference with the taking of samples or inspection of the faces. The Contractor shall take all necessary safety checks, including checking for noxious or toxic gases or materials, or radioactive materials.

Unsupported trial pits shall be excavated by machine to depths as stated in the Contract. The purpose of these pits is for visual examination from ground level only, and access is not required.

5.2.4 Ground Water

The Contractor shall keep inspection pits and trial pits free of surface run-off water. Ground water shall be controlled by pumping or other means to permit continuous exploration in-so-far as the rate of inflow of water does not make control difficult.

5.3 Sampling from Trial Pits

5.3.1 Small Disturbed Samples

Small disturbed samples of not less than 1kg shall be taken at each change in soil type, change in consistency or as instructed by the SO. They shall be placed immediately in air-tight containers which they should sensibly fill.

5.3.2 Tube Sampling in Trial Pits

As directed by the SO, tube undisturbed samples shall be taken in trial pits using open-tube drive samples or approved thin-walled sample tubes as described in BS 5930.
Prior to sampling in trial pits, the area over-lying file soil to be sampled shall be cleared by the Contractor of all material which has altered from its natural condition in order to expose soil in its natural condition.

Horizontal and vertical samples shall be taken by jacking in the sampler with a hydraulic jack. On completion of jacking the sampling tube shall be rotated one half turn before withdrawal.

5.3.3 Bulk Disturbed Samples

Bulk disturbed samples of not less than 30kg shall be collected over a depth interval of 0.5m at specified depths or as instructed by the Employer. The samples collected shall be representative of the zone from which they have been taken.

In association with the bulk sampling, two separate samples of not less than 0.2kg each shall be taken for natural moisture content determination and shall be collected, preserved and stored as disturbed samples in accordance with Clause 4.2.1.

5.4 Backfilling

The inspection pits and trial pits shall be backfilled as soon as practicable after they have been completed. The Contractor shall backfill and compact the pits with the excavated materials in such a manner that no subsequent depression is formed at the ground surface due to settlement of the backfill.

6.0 FIELD TESTING

6.1 Standard Penetration Test (SPT)

6.1.1 Scope

The Standard Penetration Test (SPT) shall be carried out in boreholes at intervals given in the Specification or where indicated by the SO in accordance with BS 1377. The SPT shall consist of driving a split spoon sampler in a standard manner and obtaining a disturbed sample of the soil penetrated.

6.1.2 Equipment and Sample Recovery

Equipment and procedures shall follow the requirements of BS 1377. The driving assembly used shall be a self-tripping hammer of an approved design which permits a free drop of the hammer. All threaded connections between the split spoon sampler and the anvil shall be tightened using pipe wrenches. The recovered sample shall be preserved, labelled and stored as required for "small disturbed samples" in Clause 4.2.1. If no sample is recorded in the split spoon sampler a small disturbed sample shall be recovered from the position of the test.

6.1.3 Procedure

All SPT's shall consist of both a seating drive followed by a test drive, including cases where high penetration resistances are encountered. The procedure for carrying out all tests shall be as follows:

Seating drive: number of blows for first 150mm penetration. If 25 blows are required before 150mm penetration is reached, then record penetration for 25 blows and terminate test drive.

Test drive: number of blows for further 300mm penetration for penetration resistance (N). If 50 blows are required before 300mm penetration is reached, then record penetration for 50 blows and terminate test drive.

For weak rock test drive shall be terminated after 100 blows if penetration of 300mm not reached.

6.1.4 Use of Solid Cone

When tests are performed in soils containing boulders or cobbles, or in weathered rocks of high resistance, and when agreed by the SO, the split barrel sampler may be replaced by a solid 60 degree cone. In this case, a small disturbed sample shall be recovered from the position of the test.

6.2 Field Vane Test in Borehole

6.2.1 Scope

The field vane test shall be carried out in boreholes at intervals given in the specification or where indicated by the Employer in accordance with BS 1377: and shall

comprise the measurement of peak and residual vane shear strength and obtaining a disturbed sample of the soil tested.

6.2.2 Equipment

The equipment shall follow the requirements of BS 1377. The torque head shall be of a type such that torque is applied through a worm and pinion mechanism. Minimum vane diameter shall be 50mm. For tests in soft clays minimum vane diameter shall be 65mm.

6.2.3 Calibration and Tolerances

The instrument used for the measurement of torque shall be checked and calibrated as required by BS 1377. The maximum period between calibration and use on site shall be 3 months. Calibration certificates from an approved standards agency shall be given to the SO in his office and a copy made available at site for the SO's retention before the start of testing. Testing shall not start until the specified calibration certificates are received by the SO. Calibration shall be repeated after completion of the site works.

Permitted tolerances on vane dimensions shall be plus or minus 0.5mm due to either manufacture or wear. However, the actual vane dimensions shall be measured at the start of works to an accuracy of plus or minus 0.1mm, and these actual dimensions shall be used in calculations. The vane dimensions shall be checked at the end of the works. Permitted tolerances on the torque head measurements shall be plus or minus 5% of the measured value.

6.2.4 Procedure

The field vane test shall be carried out in accordance with BS 1377, with the following additional requirements :-

a) Before starting the test, the torque head measuring instrument shall be firmly secured against rotation and vertical movement with respect to ground level.

b) During the execution of the test a period of 5 minutes shall be allowed to elapse between pushing the vane to its final depth and commencing rotation.

c) The torque head measuring instrument shall be zeroed before being placed over the upper extension tube.

d) During testing the vane shall be rotated at a rate of 6 degrees/min. and readings of torque shall be recorded every 2 degree rotation of the torque head. In stiffer materials which reach failure in less than 10 degree rotation, readings shall be taken every 1 degree.

e) The procedure for remoulding shall follow the requirements of BS 5930.

f) For both peak and remoulded tests, rotation of the vane shall be terminated when the soil has conclusively sheared or when the readings are either constant or falling for at least 20 degrees of rotation. The time to failure is generally 2 to 5 minutes except in very soft clays where it may be as much as 10 to 15 minutes.

g) The full operation of the field vane shall include the taking of a representative small disturbed sample from the same level as the test.

h) On completion of all vane tests in any one borehole the vane head assembly shall be stripped down, cleaned and lubricated following the manufacturer's instructions.

6.3 Permeability Testing in Boreholes

6.3.1 Scope

Permeability testing shall be carried out in boreholes as indicated in the drawings in accordance with BS 5930 and shall consist of falling or rising head tests.

6.3.2 Equipment and Procedure

The borehole shall be cleaned out before carrying out a permeability test and the casing raised to expose a length of borehole wall equal to approximately two times the borehole diameter. For materials which are likely to collapse if unsupported a suitable filter material shall be placed in the base of the borehole to support the uncased part.

For falling head test the water level in the borehole shall be raised by adding water to a level agreed as in the drawings. It may be necessary to raise the water level above the ground surface and sufficient length of casing shall be provided to project above ground level. The water in the borehole should be allowed to stand for a minimum of 30 minutes to saturate the surrounding soil prior to commencement of the test.

For rising head tests, the water level in the borehole shall first be lowered by bailing to a level agreed by the SO.

The water level shall be recorded at 10 second intervals during the early stages of the test and at less frequent intervals in the later stages in order that a representative record of the fall or rise in the water level relative to time can be obtained.

The level of the natural ground water table shall be established at the time of testing.

In cases where the stratum being tested may be partially saturated, the initial part of the test may be repeated a number of times until a repeatable result is obtained.

6.4 Deep Sounding Test (Mechanical)

GEOTECHNICS

6.4.1 Scope

Deep sounding test (also known as "cone penetration test") shall be carried out at locations shown on the Drawings using a mechanical friction cone in accordance with ASTM D 3441 and shall comprise the measurement of cone resistance and local friction.

6.4.2 Equipment

The equipment shall follow the requirements of ASTM D 3441 with the additional requirement that the cone shall have a tapered mantle similar to the mantle cone. A friction reducer shall be used for all tests. The Contractor shall have two load cells available, each equipped with two pressure gauges capable of measuring the following ranges of equivalent cone resistance:

- medium load cell: 0MPa to 1.6MPa and 0MPa to 25MPa
- heavy load cell: 0MPa to 10MPa and 0MPa to 100MPa

The Contractor shall use the load cell and gauges most suitable for the soils penetrated. If necessary during a test the load cells shall be changed to suit the type of material penetrated. Alternative arrangements of load cells and pressure gauges may be used with the SO's approval provided that they give similar ranges of sensitivity to those specified above. Cones with an electric measuring and recording mechanism shall only be used with the prior approval of the SO.

The capacity of the jacking equipment and the amount of available reaction shall be sufficient to fully utilise the full capacity of the specified cone.

Guides shall be provided for the part of the sounding rods protruding above the soil and for the rod length exposed in water in order to prevent buckling.

6.4.3 Calibration and Tolerances

Calibration of the load cells shall be carried out no more than 6 months before the start of site work. The calibration certificate shall consist of a graph or listing of figures in which loads or pressures measured by the load cells are compared to loads or pressures measured by a standard load cell from an approved standards agency. The SO shall be provided with two copies of the calibration certificate before the commencement of site work.

Permitted tolerances on equipment dimensions shall be as given in ASTM D 3441. Permitted tolerances on load cells shall be plus or minus 5% of the measured value.

6.4.4 Procedure

The penetrometer jacking equipment shall be set up on a firm and level platform. If stones, hardcore or similar material are present at or just below ground level, then a small starter hole shall be formed through this material at the test location.

Before starting each test the cone, sounding tubes and inner rods shall be thoroughly cleaned of all oil, grease and soil particles. The cone shall be extended and compressed several times in a reservoir of water until the telescopic action is smooth and requires little force. If the cone has a tendency to stick or jam, or if there is noticeable play or looseness between the difference parts of the cone, then the cone shall not be used.

The mechanical cone shall be advanced into the ground at a rate of 20mm/s, ensuring that the sounding rods are vertical and taking the required sets of readings every 200mm. As testing proceeds, the space between the inner rod and the outer sounding tube shall be kept full of water. Penetration shall be continued until the safe working limits of the equipment as determined by the Contractor are reached. The SO may require that the test be terminated before the safe working limits of the equipment as determined by the Contractor are reached.

If during testing the inner rod fails to return to the correct position after the outer sounding tubes have been advanced to a measurement depth, then a note shall be made on the record sheet against the affected measurements. If the inner rod fails to return to the correct position during five consecutive readings, then the test shall be temporarily terminated and the cone extracted from the ground, inspected, cleaned and if necessary replaced. the cone shall then be readvanced directly to the depth of temporary termination and the test continued.

6.5 Deep Sounding Test (Piezocone)

6.5.1 Scope

The deep sounding test (piezocone) (also known as the "piezocone test") shall be carried out at locations shown on the Drawings or in Appendix 2 or as indicated by the SO using an electric friction cone in accordance with ASTM D 3441. The cone shall incorporate a filter and transducer for the instantaneous measurement of pore water pressure and the test shall comprise the measurement of cone resistance, local friction and pore water pressure.

6.5.2 Equipment

The equipment shall follow the requirements of ASTM D 3441 with the following additional requirements :

a) The type of cone used shall be the compression type and such that the full range capacity shall be from 0kN to 30kN for cone resistance measurements

b) The filter used to measure pore water pressure shall be located between the cone and the friction sleeve. The filter shall be of the same external diameter as the friction sleeve, and shall be to the approval of the SO. The filter shall be saturated in a desired silicon oil or similar approved liquid and the same liquid shall be used to fill the space within the cone between the filter and the pore pressure transducer. The use of ceramic filter elements and/or water as the saturing liquid will not be permitted unless approved by the SO. A new filter shall be used for each test and shall be fitted onto the cone within a reservoir of the same liquid used to saturate the filter.

c) An inclinometer and temperature sensor shall be incorporated in the piezocone capable of measuring the inclination of the cone from the vertical and the temperature respectively.

d) The penetration test jacking equipment shall be capable of 10 tonne hydraulic capacity with an available reaction of 4 tonne. The Contractor shall make arrangements to ensure that testing is carried out to a sufficient depth.

e) Monitoring and recording equipment shall be capable of providing the following records of the measured parameters during the execution of the tests :

- a continuous or quasi-continuous record of all measured parameters stored on digital magnetic tape or similar media device to be used for eventual production of the final plots;
- an instantaneous pen plot or graphical display of at least three measured parameters, cone resistance, local friction and pore water pressure.
- a hard copy of measured numerical parameters recorded at intervals of 100mm or less.

The equipment shall have the capability of reading to the following minimum values: -

- cone : 0.01MPa
- local friction : 0.1kPa
- pore water pressure : lkPa
- inclination : 1°
- ground temperature readings : 1°

The recording equipment shall be housed in a weatherproof cabin.

f) Friction reducers shall be used for all tests.

6.5.3 Calibration and Tolerances

The cone and measurement system shall be calibrated for use in a range of soil types from very soft to firm clays, peats, and organic cohesive soils to sands. The SO shall be provided with two copies of the calibration certificates before or at the commencement of site work. The calibration certificate shall consist of a graph or listing of figures in which loads or pressures recorded by the piezocone measurement system are compared to loads or pressures measured by a standard load cell or pressure measuring device from an approved standards agency. Calibration shall be carried out no more than 3 months before the start of site work.

The Contractor shall have available on site throughout the duration of the site work a calibration load cell suitable for on-site use to enable gross error checks to be carried out.

Permitted tolerances on equipment dimensions shall be as given in ASTM D 3441. Permitted tolerances on load and pressure monitoring devices shall be plus or minus 5% of the measured value.

6.5.4 Procedure for Penetration Test

The penetration test jacking equipment shall be set up on a firm and level platform at locations indicated by the SO. If stones, hardcore or similar material are present **at** or just below ground level, then a small starter hole shall be formed through this material at the test location.

Before advancing the piezocone the cone apparatus shall be temperature conditioned to approximately the ground water temperature ± 2 degree Celsius and held for at least 30 minutes zeroing of the various load cell readings as well as stability of the system electrically.

The piezocone shall be advanced into the ground at a rate of 20mm/s, ensuring that the sounding tubes are vertical. Data shall be recorded using the specified recording equipment. Penetration shall be continued until the safe working limits of the equipment as determined by the Contractor are reached. These safe working limits shall be agreed with the Employer prior to the commencement of site works. The SO may require that the test be terminated before the safe working limits of the equipment as determined by the Contractor are reached.

6.5.5 Procedure for Dissipation Test

At locations and depths to be decided by the SO, penetration of the piezocone shall be stopped and excess pore water pressure shall be allowed to dissipate. During these periods loading on the sounding tubes shall be removed. Dissipation of excess pore pressure shall be recorded on a time scale.

In addition to any graphical plots, numerical values of pore water pressure shall be recorded at least at the following times after ceasing penetration: 0, 0.5, 1, 1.5, 2, 3, 4, 6, 8, 10, 15, 20, 25, 30, 35, 40, 50, 60 minutes. It is expected that a one hour period of dissipation will generally be sufficient, but this period may be altered by the SO to suit the ground conditions encountered.

6.6 Penetration Field Vane Test

6.6.1 Scope

The penetration field vane test shall be carried out at locations and intervals given on the Drawings or in Appendix 2 or as instructed by the SO in accordance with BS 1377 and shall comprise the measurement of peak and residual vane shear strength without the use of a borehole. The apparatus shall be calibrated immediately before use on site.

6.6.2 Equipment

The equipment shall be in accordance with BS 1377 with the following additional requirements :

a) The vane test apparatus shall be Geonor penetration type or similar approved which shall be capable of penetration to the maximum depth indicated on the Drawings or Appendix 2.

b) Two sizes of vane shall be available for different ranges of shear strength measurement as follows :

- Vane size 55mm x 110mm for the measurement of undrained shear strength between 50kPa to 100kPa
- Vane size 65mm x 130mm for the measurement of undrained shear strength between 0kPa to 60kPa

c) The reaction and capacity of the jacking equipment shall be sufficient to reach the maximum depth required.

d) Bearings shall be provided every 3.0m between the outer tube and inner rod of the vane test apparatus.

6.7 Penetration Piston Sampling

6.7.1 Scope

The penetration piston sampling shall be carried out at locations shown on the Drawings or Appendix 2 or as directed by the SO and shall comprise the taking of undisturbed samples using stationary piston sampler with sampler pushed into the ground with jacking equipment without the use of a borehole.

6.7.2 Equipment and Procedures

The stationary piston sampling equipment and procedures shall be in accordance with BS 5930 and Clause 4.3.5 of the Specification with the following additional requirements :

a) The jacking equipment shall be 2.5 tonne minimum capacity with an available reaction sufficient to allow full mobilisation of the jack capacity.

b) The penetration jacking equipment shall be set up on a firm and level platform. If stones, hardcore or similar material are present at or just below ground level, then a small starter hole, shall be formed through this material at the test location.

6.8 JKR or Mackintosh Probes

6.8.1 Scope

The JKR or Mackintosh Probe shall be carried out at locations shown in the Drawings or Appendix 2 or as indicated by the SO and shall consist of driving a standard probe into the ground and recording the resistance to penetration.

6.8.2 Equipment

The apparatus used shall be the standard JKR Probe or the Mackintosh Probe. Details of the JKR and Mackintosh Probes are shown in Figure 6.1. (Note that Figure 6.1 may be omitted from Contracts in which probes are not required).

The probing rig shall consist of a stable frame for driving the extension rods and cone vertically, with a guide to provide lateral support for that part of the extension rods protruding above the soil or exposed in water, the means of handling and operating the driving device and means of extracting the rods and cone. The guide shall be such that not more than 1.2m of rod is unsupported at any one time and if the driving device is not separately provided with a guide then not more than 0.6m of rod shall be unsupported where the blow count is in excess of 15 blows per 300mm.

6.8.3 Procedure

The probing rig shall be erected so that the deviation from the vertical of the first extension rod shall not be greater than 2%. Maximum deviation from the vertical of **the** extension rods during driving shall be 5%.

The driving shall be as continuous as possible but in no case shall interruptions longer than 5 minutes be allowed unless recorded on the Journal. The hammer shall be raised in such a way as not to carry it more or less than the defined height above the driving head. The cone shall be driven at a rate of between 15 to 30 blows per minute, and the number of blows shall be recorded for each 300mm increment of penetration.

The probing shall be stopped when the resistance has reached 400 blows/300 mm penetration unless otherwise directed by the SO.

6.9 Specification for Pressuremeter Test

This specification outlines minimum requirements for pressuremeter testing using the Menard-type pressuremeter (MPM) test - in which the pressuremeter device is lowered into a pre-formed hole.

6.9.1 Tender Information

General

The following information is provided :

a) Preliminary details of the proposed structure
b) Anticipated ground conditions including information from any preliminary stage investigation if possible
c) Pressuremeter measurements required: in-situ stress, modulus or strength

Probe

The length to diameter ratio of the membrane shall be greater than five. The measurement system shall be capable of sustaining a minimum pressure of 8MPa without leakage. All air bubbles shall be removed from the probe and tubings before use. The sheath type and maximum radial expansion shall be agreed with the SO prior to use. The actual requirements depend on the soil or weak rock to be tested, together with accuracies required for measurement of pressure, volume and pore pressure where appropriate.

6.9.2 Pressuremeter Calibration

Calibration

The pressuremeter must be properly calibrated at frequent intervals. The pressuremeter should be recalibrated once a day, or after every 10 tests, or after repairing the pressuremeter. Some of the recalibration tests may require more frequent checks depending upon the results obtained.

Volume or Radius Measurements

Methods of calibrating the volume or radius measurement system should be specified. These include inflating the pressuremeter in close fitting (10% expansion) and loose fitting (80% expansion) steel cylinders, and calibrating individual feeler arms against a suitable micrometer or calliper gauge. Repeatable results to within the required accuracy have to be obtained. The results from individual feeler arms should be reported where appropriate.

Pressure Measurements

Test certificates shall be provided for all pressure-measuring devices prior to commencing the contract. An independent Bourdon gauge or equivalent device should be maintained on site to check the calibration of the pressuremeter. Methods of calibrating the pressure measuring systems should be specified and shall comply with Sirim guidelines. These should include the inflation of the pressuremeter in air at the proposed testing rate. The repeatability of these tests shall be established.

6.9.3 Operators

The operators of the equipment shall have at least three months experience of the instrument under the full time supervision of a technician with a minimum of two years experience in the use of the pressuremeters. The operators shall be responsible to a Supervisor who has a minimum of five years experience in pressuremeter testings and is fully conversant with the operation of pressuremeters and the interpretation of the data obtained.

6.9.4 Installation

The pre-formed hole shall be circular, minimum diameter 60mm, with a ratio of hole diameter (Dh) to pressuremeter diameter (Dpm), (Dh/Dpm)< 1.10. Forming the hole should cause minimal disturbance to the surrounding ground. Where drilling fluids are used, the fluids shall be introduced in such a manner that the walls of the pre-formed hole shall not be excessively disturbed. Only tests with pressure-volume curves corresponding to the central curve shown in Figure 1 will be accepted. The pressuremeter should be installed and the test commenced immediately after forming the test hole.

The Contractor shall maintain on site the following equipment for pre-forming holes :

a) a range of different types of core barrels of appropriate size
b) hand auger equipment of appropriate diameter (for shallow tests)
c) a sampling tube with an internal chamfer, with an external diameter slightly larger than the pressuremeter
d) borehole callipers
e) bentonite drilling mud

(Note : This list should be amended to suit the anticipated ground conditions.)

If instructed by the SO, trials should initially be conducted on the major strata on the site to identify the best method of pre-forming holes. (If it is concluded from these initial trials that it is not possible to perform meaningful pressuremeter tests in the strata, the provisionally planned programme of tests can be cancelled.)

6.9.5 Test Procedure

The following information is required :

a) The test procedure shall be decided in consultation with the Engineers including details of stress or strain control, with details of the stress increments and rate of application included. For each test location, pressure loading shall be applied to the probe in increments of 25kPa from 0kPa to 200kPa probe pressure. From 200kPa to 500kPa probe pressure the incremental pressure may be increased to 50kPa. From 500kPa to 1000kPa probe pressure the incremental pressure shall be 100kPa and there after the increment shall be no greater than 500kPa.

   Constant cell pressure shall be maintained for 1.0 minute at each test pressure with measurement of the volume of water or gas injected into the probe. Volumetric readings shall be taken at 15 seconds, 30 seconds and 60 seconds after each pressure is reached.

b) The pressure loading sequence shall allow for unload-reload cycles at the direction of the Engineer. Details of frequency, magnitude and strains at which they are to be conducted will be given by the Engineer on site.

c) Recording of pore pressures, if appropriate

d) The pressuremeter manufacturer's manual: to be available upon request and present on site during the tests

e) The format and information recorded on the test data sheets: to be agreed prior to commencing the Contract. Whether a factual or interpretative report is required should be considered.

Strain Controlled Tests

The pressuremeter shall be pressurised until either the maximum pressure capacity is reached, or any one of the displacement transducers has reached its full working range or there is undue risk of damage to the equipment. The pressuremeter shall be unloaded, both during the unload-reload cycle and the final unloading at the same rates as the loading stage.

The reduction in stress during any unloaded-reload loop shall be limited to ensure that it remains within the elastic range of the ground under test.

The output from the transducers shall be recorded at a minimum frequency of 10 seconds intervals throughout the test.

The duration of the test shall be no longer than 90 minutes.

Stress Controlled Test

Stress controlled tests shall be carried out at a constant rate of pressure increase, with one unload-reload loop included in the loading sequence when either the cavity has increased in diameter by between 1% and 3%, or when the pressure has reached 8MPa whichever occurs first. The increments shall be no greater than 0.5MPa and shall be adjusted to ensure that there are at least 10 increases in pressure throughout the loading stage (excluding any unload-reload cycles). The size of the pressure increment shall be adjusted during the early stage of the test to ensure that a sufficient number of readings are taken to accurately define when the membrane comes in contact with the side of the pre-formed borehole and shall be no greater than 0.2MPa.

Any additional unload-reload loops and any time required to maintain construct pressure before commencement of any unloading shall be agreed with the Engineer.

Each pressure increment shall be held constant for 30 seconds. The output from the transducers shall be recorded at 10 seconds intervals throughout test.

The pressuremeter shall be pressurised until either the maximum pressure capacity is reached, or any one of the displacement transducers has reached its full working range or there is undue risk of damage to the equipment.

During any unloading and subsequent reloading, the pressure increment shall be similar in magnitude to the increments used in the loading stages.

The stress reduction during any unload-reload loop shall be limited to ensure that it remains within the elastic range of the ground under test.

The duration of the test shall be no longer than 90 minutes.

6.9.6 On Site Data Processing and Analysis

Both the raw data and corrected (reduced) data have to be provided in the report. This shall include data from individual feeler arms, where appropriate.

The calculation methods used to estimate in-situ horizontal stress, modulus and strength should be agreed.

Preliminary data reduction and interpretation shall be made as work is conducted on site.

6.9.7 Information to be Submitted

Information required from Contractor at Tender Stage

- Details of the pressuremeter proposed for use, including relevant aspect of the manufacturer's specification.
- Details of previous contracts on which the pressuremeter has been used, including ground conditions.
- Names of operator and supervisor, together with previous pressuremeter testing experience.
- Drilling equipment to be used including details of equipment for pre-forming the holes.
- Typical test data sheets the Contractor propose to use.
- Typical result sheets and examples from previous contracts demonstrating tests of reasonable quality and determination of shear modulus from unload-reload cycle.
- Calculation methods and facilities available for interpreting test data.

Preliminary results for each Test.

The following information shall be submitted for each test within one working day of the completion of that test.

- Contract name and number, borehole number, depth of the top of the test zone, depth of the displacement axes.
- Names of drilling and testing personnel.
- Details of equipment used.
- Details of boring, drilling, including date and time of start and finish of all drilling, description and estimate of any drilling fluid return.
- A plot of total pressure against volumetric strain.
- A preliminary assessment of the parameters as outlined previously.

6.9.8 Information to be Submitted in the Report.

The information submitted in the report shall be as specified but incorporating any amendments required as a result of calibration and interpretation of the data.

7.0 LABORATORY TESTING

7.1 Schedule of Laboratory Testing

The SO will decide the laboratory tests required and will provide the Contractor with one or more Schedules of Laboratory Tests. It may be necessary to specify additional testing after the results of the original testing are available. The Contractor shall therefore ensure that the portions of samples remaining after extraction of test specimens are properly resealed and stored. Testing schedules will not be prepared until the SO has received the relevant preliminary records as detailed in Clause 8.3. The Contractor shall inform the SO within seven (7) working days from the receipt of the testing schedule if the sample is not adequate for all the tests specified.

7.2 Units to be Used

The units used shall be in S.I. The measured accuracy required shall follow that in the testing standards.

7.3 Testing Standards

The relevant testing standards and the additional testing requirements for all the tests shall be specified in Table 7.1.

7.4 Information Required

In addition to the information required by the relevant specified standards, additional information as listed in Table 7.1. shall be submitted with the results of all the tests referred to in the Specification and Bill of Quantities.

When strength tests have been scheduled on samples of residual soils the Contractor shall describe in detail and before testing any surface features of the material i.e. sandy pockets, relict joints, mineral lineation, foliation, iron-staining, veins, fossils and stress relief cracks.

GEOTECHNICS

Item	TEST (with Standards and Additional Testing Requirements)	Additional Information to be submitted
1	GENERAL To be submitted for all tests.	- contract title and reference number - exploratory hole number and sample number - date of testing - depth of sample - description of soil, including fabric and structure - comment on any unusual tests results
2	CLASSIFICATION TESTS Moisture contest - BS 1377	
3	Liquid limit, plastic limit and plasticity index - BS 1377 - to be carried out in natural state - if material greater than 0.425mm is present, then use manual selection or air drying.	- natural moisture content of the sample - method of obtaining liquid limit (cassangrande cone penetration) - history of sample whether natural state, air dried or unknown - percentage of material less than 0.425mm recorded
4	Special gravity - BS 1377 - for highly organic soils, use kerosene in place of water	- method of testing - report specific gravity at 20°C - specific gravity of liquid used in case of highly organic or soluble salts
5	Particle size distribution - BS 1377	- result shall be clearly plotted as measured data points, joined by fine straight lines and also reported as table showing percentage by weight passing end of the sieve
6	Particle size distribution for fine grained soils - BS1377	- as in Item 5 - method of testing - percentage of material passing 63μm BS sieve

Table 7.1 Testing Standards and Additional Testing Requirements

Item	TEST (with Standards and Additional Testing Requirements)	Additional Information to be Submitted
	CHEMICAL TESTS	
7	Organic matter content - BS 1377	- where applicable the organic matter shall be described based on Von Post scale.
8	Organic Content Test Loss on ignition - BS 1377 part 3,4	- ditto
9	Total sulphate content of soil - BS 1377 - When sulphate content exceeds 0.3%, redetermine sulphate content with 2:1 water: soil extract in accordance with	
10	Sulphate content of ground water and aqueous soil extracts - use 2:1 water : soil extract	
11	pH value	- method of testing (electrometric or chlorimetric)
12	Chloride content - BS 1377 part 3,7	
13	Carbonate content - BS 1377 part 3,6	
14	COMPACTION TESTS Dry density/moisture content Relationship (2.5kg rammer method) - BS 1377 - at least 2 determinations either side of optimum moisture content - fresh sample to be used for each moisture content	- zero air voids line based on measured specific gravity

Table 7.1 (cont'd) Testing Standards and Additional Testing Requirements

Item	TEST (with Standards and Additional Testing Requirements)	Additional Information to be Submitted
15	Dry density/moisture content Relationship (4.5 kg rammer method) - BS 1377 - at least 2 determinations either side of optimum moisture content - fresh sample to be used for each moisture content	As in item 14
16	CONSOLIDATION TESTS One-dimensional consolidation (standard) - BS 1377 - 24 hours per loading stage - loading stages to be as specified - graph of settlement against both square-root time and logarithm time shall be used to assess consolidation characteristic. Square-root time to obtain corrected zero, and logarithm time for t_{50}.	- initial and final moisture content void ratio and degree of saturation - liquid and plastic limits of soil from which the consolidation test specimens were taken - initial dimensions - measured specific gravity - graph of void ratio (e) against logarithm of pressure (p) in kN/m2 - graph of coefficient of consolidation (Cv) in m2 /year and coefficient of volume (Mv) against logarithm of mean consolidation pressure - graph of void ratio (e) against logarithm of coefficient of permeability - tabulation of void ratio (e), compression index (Cc), and preconsolidation pressure (Pc) in kN/m2 - tabulation of coefficient of consolidation (Cv) m2 /year for each loading stage using bulk methods

Table 7.1 (cont'd) Testing Standards and Additional Testing Requirements

Item	TEST (with Standards and Additional Testing Requirements)	Additional Information to be Submitted
17	One-dimensional consolidation (rapid loading), end of primary tests - BS 1377 part 5 - loading stages to be specified - graph of settlement against both square-root time and logarithm time shall be used to assess consolidation characteristics	- as in Item 16
18	One-dimensional consolidation (single increment) - BS 1377 part 5 - loading pressure to be specified	- initial and final moisture content, void ratio and degree of saturation - initial dimensions - measured specific gravity - liquid and plastic limits on soil from which the consolidation test specimens were taken - graph of settlement and swelling against logarithm of time
19	STRENGTH TESTS California bearing ratio (CBR) - BS 1377 - use soaking procedure for 96 hours	- CBR value of top and bottom - method of compaction to be mentioned - surcharge used - moisture content of top, centre and bottom of specimen - dry density after compaction - if soaked, duration of soaking and recorded swell

Table 7.1 (Cont'd) Testing Standards and Additional Testing Requirements

Item	TEST (with Standards and Additional Testing Requirements)	Additional Information to be submitted
20	CBR dry density/moisture content relationship - BS 1377 - compaction in CBR mould - at least 2 determinations either side of optimum moisture content - fresh sample to be used for each moisture content	- as in Item 14 and 19
21	Unconfined compression test - BS 1377 part 7	- description of soil type - orientation of failure plane - moisture content and dry density - strain as percentage of total length
22	Undrained triaxial compression test without measurement of pore water pressure on a specimen of 38mm, 50mm, 70mm or 100mm diameter - BS 1377	- stress-strain curves of test - type of failure of specimen (plastic, brittle or compound) & corresponding strain and time of failure - undrained shear strength - rate of strain, percent per minute (based on the rate of drive of the machine ignoring the stiffness of the measuring system
23	Undrained triaxial compression test without measurement of pore water pressure on single specimen of same diameter as undisturbed sample - BS 1377	- as in Item 22

Table 7.1 (Cont'd) Testing Standards and Additional Testing Requirements

Item	TEST (with Standards and Additional Testing Requirements)	Additional Information to be Submitted
24	Consolidated undrained triaxial compression test with pore water pressure and volume change measurements, on a set 3 specimens of 38mm, 50mm, 70mm or 100mm diameter as instructed - BS 1377 part 8 - consolidation stage to be continued until 98% consolidation (measured at the base of the specimen) is reached - rate of shearing to be calculated as required for the consolidated drained triaxial tests, based on t_{100} from, pore water pressure dissipation	- stress path diagram t/s' space, as defined in Head, Vol.3 - side drains are not permitted
25	Consolidated drained triaxial compression test with volume change measurements, on a set of 3 specimens of 38mm, 50mm, 70mm or 100mm diameter as instructed - BS 1377 part 8 - consolidation stage to be continued until 98% consolidation (measure at the base of the specimen) is reached - rate of shearing to be based on t_{100} from, pore water pressure dissipation	- side drains are not permitted
26	Drained shearbox test on a set of 3 specimens including residual strength - BS 1377 part 7 - peak strength only	- dimensions of test specimen - whether specimen was un-disturbed or recompacted, and how prepared - initial bulk density moisture content, dry density - rate of displacement - plot of vertical measurement and shear stress against strain - coulomb envelope for peak and residual strength as applicable
27	Drained shearbox test on a set of 3 specimens including residual strength - BS 1377 part 7	- as in Item 26

Table 7.1 (Cont'd) Testing Standards and Additional Testing Requirements

Item	TEST (with Standards and Additional Testing Requirements)	Additional Information to be submitted
28	ROCK TESTING Natural water content - ASTM D2216	
29	Dry density - ASTM D7263	- the method of testing
30	Point load - ASTM D5371	- failure description - Index strength, Is(50)
31	Uniaxial compressive strength - ASTM D2938	- failure description

Table 7.1 (Cont'd) Testing Standards and Additional Testing Requirements

8.0 MATERIAL IDENTIFICATION AND CLASSIFICATION

8.1 General Guidance

8.1.1 Purpose and Scope

The following Clauses are to establish a standard procedure for logging and description of samples such that an accurate and comprehensive record of the geological conditions encountered, together with any other relevant information during exploration and boring is provided. These following clauses are based upon existing Standards of Codes of Practice, established market procedures, and current literature.

Nevertheless, it is recognised that other descriptive methods and terminology may still be required for particular cases. In all such cases and where alternative schemes are to be SO, this shall only be agreed in advance and with the approval of the Employer.

8.1.2 Definitions of Soil and Rock

The engineering definitions of Soil and Rock shall follow the recommendations of the Geoguide 3. Guide to Rock and Soil Descriptions by the Geotechnical Control Office (GCO), Hong Kong, (1988).

In engineering terms, a "soil" is any naturally formed earth material or fill which can be broken down by hand into its constituent grains; conversely, a ‘rock’ cannot be broken down, or may only be partially broken down by hand, depending on its weathered condition. "Superficial Deposits" in geological terms refer to any geologically recent unlithified transported material of sedimentary origin (Bermet, 1984). Therefore, to reconcile the engineering and geological terms, engineering soils are defined as all "superficial deposits" and fill plus those rocks which have weathered in-situ to the condition of a "soil" in engineering terms.

As noted in Geoguide 3, there would be exceptions to the above definitions, and it shall be appropriate to use different definitions as approved by the Employer.

8.2 Method of Rock Description

8.2.1 Scope

The method of rock description to be used in the Report shall follow the procedures as detailed in the following Clauses, Standards and References are : -

Quarterly Journal of Engineering Geology (1983). The Logging of Rock Cores for Engineering purposes. Geology Society Engineering Group Working Party Report Geological Society of London. Vol 3, No. 1. pp. 1 -24.

Lee, S.G. & de Freitas, M.H. (1989). A Revision of the Description and Classification of Weathered Granite and its Application to Granite in Korea. QJEG, vol. 22, pp. 31-48 Brown, E.T (1981) - Rock Characterisation, Testing and Monitoring. ISRM Suggested Methods, Pergamon Press, Oxford, U.K.

Moye, G. D. (1955). Engineering Geology for the Snowly Mountains Scheme. Journal Institution of Engineers Australia, 27, pp. 281-299.

International Association Engineering Geology (1981). Rock and Soil Description and classification for Engineering Geological Mapping Report IAEG commission on Engineering Geological Mapping. Bulletin No. 24.

Geotechnical Control Office (GCO), 1988. Guide to Rock and Soil Descriptions. Government of Hong Kong.

Should there be any discrepancy or conflict between the Standards or Reference and this Specification, then this Specification shall be apply.

8.2.2 Basic Principles

The main purpose of a rock description for engineering purpose is to give an indication of the likely engineering properties of the rock. A complete description shall comprise the rock name, qualified by selected descriptive terms for colour, strength, texture or structure, state of weathering and alteration.

The rock name shall also include a description of the grain size. Discontinuities and other characteristics shall also be described in an accompanying text, as appropriate.

The order used for the constituent parts of the rock description shall be as given below unless otherwise directed by the SO.

(a) Colour (material)
(b) Strength (material)
(c) Texture and fabric (material)
(d) State of weathering (material)
(e) Alteration of material
(f) Rock name, including grain size (material)
(g) Additional geological information e.g. discontinuities - separate text as appropriate.

8.2.3 Colour

Colour shall be expressed qualitatively in terms of two parameters as follows : -

(a) Hue - the basic colour or a mixture of basic colours, and
(b) Value - the lightness of the colour.

The description system for colour shall follow the terms as listed below, or as approved by the SO.

Parameter	Term
Value	Light, Dark
Hue	Pink, Red, Yellow, Orange, Brown, Blue, Purple, White, Grey & Black, etc.

For uniform colour distribution, choose a hue and then supplement if necessary with a value. For non-uniform colour distribution consist of two or more component the later term in each component to indicate the dominant colour which is under lined e.g. light pink-grey spotted with dark-brown.

Alternative scheme for term and description of colour proposed by the contractor may be adopted with the approval of the SO.

8.2.4 Strength

The strength shall be based on the results obtained from Uniaxial Compressive Strength Testing (UCS) as given in Table 8.1. Simple field identification tests shall also be carried out so that the strength may be estimated prior to any laboratory testing for purposes of description in the field logs. These tests shall be based on classification given by ISRM (1988).

8.2.5 Texture and Fabric

The general physical appearance of the rock shall broadly be referred to as 'texture'. It cover the geometric aspects, such as size and shape of the component grains or crystal and the relationships between these aspects (e.g. distribution of various grain sizes and crystallinity or the degree to which crystals have developed). The term is usually applied to small scale features visible in hand specimens with/without the aid of a hand lense.

Fabric shall refer specifically to the arrangement of the constituent grains or crystals in a rock. Preferred orientation of these constituents is often the most noticeable aspect of the rock fabric. Fabric shall also include any small discontinuities or planes of separation through or between grains or crystals. All such fabric features (also termed microfractures) as a result of mechanical weathering, tectonic activity, stress relief or other such factors shall be included in the description and as an accompanying text as appropriate.

8.2.6 State of Weathering

The state of weathering or material decomposition of the rock shall be described by a weathering grade system depending on the classification of the rock type. The rock type classifications shall follow the scheme as given in Table 8.2. For the igneous rocks, the weathering grade classification shall be based upon the classification system of the Geotechnical Control Office, Hong Kong as given in Geoguide 3: Guide to Rock and Soil Descriptions (1988). In case of sedimentary and metamorphic rocks the weathering grades shall follow the recommendation by Anon (1977). The weathering grade shall be according to scheme as given in Table 8.3a and 8.3b.

8.2.7 State of Alteration

The alteration of rock by circulation of hot gases and fluids associated with later stage intrusion shall also be described in an accompany text, as appropriate. The term "alteration" must be used together with description of weathering grades of rock. The state of alteration shall be described according to the scheme as given in Table 8.4.

8.2.8 Rock Name

The rock name including the description of the grain size shall follow the system as given in Table 8.5. The grain size, which shall refer to the average dimension of the mineral or rock fragment comprising the rock, shall be included implicity in the rock name or is a specific qualifying term. If the rock name is in doubt, this shall be indicated in the description by use of a suitable qualifying term (e.g."probably") or a question mark.

In cases, where the rock cannot be satisfactorily identified the grain size shall be written quantitatively as part of the description together with an appropriate textural term (e.g.

"megacryst rock with large grains, 10 to 25 mm set in ground mass of fine grains 2mm to 4 mm).

8.2.9 Additional Information

Any additional features of importance in assessing the nature and engineering properties of the material shall be described in an accompanying text, as appropriate, after the rock name. For all recovered samples and borehole cores, the discontinuities in the samples shall be assessed in detail to provide a complete description of this features, including where applicable the nature, orientation, spacing, persistence, roughness, aperture infilling and seepage aspects. In determine the qualitative the description of these feature, reference shall be made to ISRM (1988).

The description of discontinuities of borehole cores shall include Total Core Recovery (TCR), Solid Core Recovery (SCR), Rock Quality Designation (RQD), and Fracture Index (FI) and shall be reported for each core run. Solid core is defined as intact core having a fully circular circumference.

The definition and terms given below are based on the recommendation made by Norbury et al (1984) and as illustrated in Figure 8.1.

(a) Total Core Recovery, TCR (%) is the percentage ratio of core recovered (whether solid, intact with no full diameter, or non-intact) to the total length of core run.

(b) Solid Core Recovery, SCR (%), is the percentage ratio of solid core (full diameter core) recovered to the total length of core run.

(c) Rock Quality Designation, (RQD) %, is the total length of solid core pieces, each greater than 100mm between natural fracture, expressed as a percentage of the total length of core run.

(d) Fracture Index, FI (No/m run), is the number of clearly identifiable fractures per metre run of intact core pieces, measured over core lengths of reasonably uniform character. This index does not necessary apply to whole core runs and may indeed extend into adjacent core run. If there is a marked change in fracture frequency during a core run, the fracture index should be calculated for each part of the run separately.

The term 'non-intact' (NI) should be used when the core is fragmented. Additional detail can be given by quoting the maximum, mean and minimum length of core pieces recovered for any core length of reasonably uniform character. These four quantative fracture indices are illustrated schematically in Figure 8.1.

Only natural geological fracture should be taken into account for the description of fracture state. Artificial fractures produced by drilling should be excluded from the assessment, although precise interpretation of fracture origin may be difficult. In case of doubt, it is customary to regard the discontinuity as natural.

8.3 METHOD OF SOIL DESCRIPTION

8.3.1 Scope

The method of soil description to be used in the Report shall follow the procedures as detailed in following Clauses, Standard and References are :

BS 5930: 1981. Code of Practice for Site Investigations. British Standards Institution, London, 1981.

A.O. Landva, E.O. Korpijaakko and P.E. Pheeney. Geotechnical Classification of Peats and Organic Soils, ASTM STP 820, 1983, 37-51.

Geotechnical Control Office, 1988 Geoguide 3. Guide to Rock and Soil Descriptions. Government of Hong Kong, 1988.

Should there be any discrepancy or conflict between the Standards or Reference and this Specification, then this Specification shall be apply.

8.3.2 Basic Principles

The basic principles of soil description used in the report shall follow BS 5930:1981. Modifications shall only be used as outlined in these Clauses or as approved by the Employer. The order used for the constituent parts of a soil description shall be as given below unless otherwise directed by the SO.

(a) Colour
(b) Strength
(c) Particle Shape & Composition - (if applicable)

(d) Structure - (if applicable)
(e) Soil Name (with items e.g. inclusions, etc)
(f) Geological Formation

The following notes give the identifications used for each of the above constituent parts of the soil description. For the details reference shall be made to BS 5930: 1981.

8.3.3 Colour

Soil colour shall be described according to the scheme given in the Table 8.6. The colour of the sample shall be described immediately upon retrieval from the borehole or sampling tube in its natural and undisturbed condition whenever possible. Surface and structural features showing distinctive colour change when compared with surrounding soil matrix shall also be noted separately where applicable.

8.3.4 Strength (consistency or relative density)

For cohesive (fine) soils two methods of consistency definition are used depending on the type of test carried out. In the softer soils where vane tests (S_{ufv}) or undrained triaxial tests (S_{utc}) are carried out to measure undrained shear strength directly, the following scale taken from BS 5930:1981 shall be used : -

CONSISTENCY	**S_{ufv} or S_{utc} RANGE (kPa)**
very soft	0 – 20
soft	20 – 40
firm	40 – 75
stiff	75 – 150
very stiff	150 and greater

For soils where normally the Standard Penetration Test (SPT) (ref: BS 1377: 1975) is carried out, the following consistency scale taken from American practise based on "SPT-N value" shall be used.

GEOTECHNICS