

Table of Contents

1.0 GENERAL REQUIREMENTS 5

1.1 General 5

1.2 Scope of Works 5

1.3 Programmed to be furnished 5

1.4 References Used in the Specification 6

1.5 Site Visit 6

1.6 Method Statement 7

1.7 Site Clearing and Setting Up 8

1.8 Supply of Adequate Plant/Equipment, Materials & Labour 9

1.9 Important facilities that shall be provided by the Contractor at site are: 10

1.10 Traffic Safety and Control (Traffic Safety Measures) 11

 1.10.1 Maintenance of Traffic Flows and Control of Traffic 12

 1.10.2 Temporary Traffic Signs 12

 1.10.3 Temporary Access 12

1.11 Removal of Improper Plant, etc. 13

1.12 Damage to Overhead and Underground Mains and Services 13

1.13 Clearance of Site on Completion..... 13

1.14 Care of Works..... 14

1.15 Laboratory Testing Facilities 14

1.16 Independent Testing by Engineer 14

1.17 Exploratory Bore Hole/Test Location Markers 14

1.18 Photographs 15

1.19 Contractor's Professional Attendance on Site 15

1.20 Submission of Reports 15

1.21 Setting Out And Taking Levels 16

1.22 Watching and Lighting 16

1.23 Facilities for other Contractors 16

1.24 Workman's Accommodation 16

1.25 Water supply 17

1.26 Electrical Power Supply 17

1.27 Storage Facilities 17

2.0 BOREHOLES 17

2.1 Percussion Boring 17

 2.1.1 Scope 17

 2.1.2 Borehole and Casing Diameter 19

 2.1.3 Use of Clay Cutters 19

 2.1.4 Use of Shell and Casing 19

 2.1.5 Addition of Water to Boring 19

Soil Investigation (S.I.) Works Specification

2.1.6 Hard Strata and Obstructions 20

2.2 Rotary Boring..... 20

 2.2.1 Scope 20

 2.2.2 Borehole and Casing Diameter 20

 2.2.3 Casing and Support of Borehole Sides 20

 2.2.4 Heaving of the Bottom of the Borehole 20

2.3 Advancing The Borehole 21

 2.3.1 Borehole..... 21

 2.3.2 Drilling Medium 21

 2.3.3 Water Jetting 21

2.4 Rotary Core Drilling 22

 2.4.1 Scope 22

 2.4.2 Core Barrels Types 22

 2.4.3 Drilling Methods 22

 2.4.4 Core Barrels, Casing and Drill Rods. 23

 2.4.5 Drilling Rigs and Ancillary Equipment..... 24

 2.4.6 Record of drilling equipment 25

 2.4.7 Extraction of Cores 25

 2.4.8 Core Boxes, Packing and Labeling of Cores 26

 2.4.9 Core Recovery Ratio (CRR), Rock Quality Designation (RQD) & Fracture Index (FI). 27

2.5 Hand Auger Boring 27

 2.5.1 Scope 27

 2.5.2 Equipment and Diameter of Boreholes..... 27

 2.5.3 Depth of Hand Auger Boring..... 27

2.6 Backfilling of Boreholes 28

3.0 GROUND WATER 28

 3.1 Ground Water Observations..... 28

 3.1.1 Measurement Accuracy 28

 3.1.2 First encounter 28

 3.1.3 Subsequent encounter 29

 3.1.4 Beginnings and end of shift 29

 3.2 Standpipe 29

 3.2.1 Scope 29

 3.2.2 UPVC Tubing 30

 3.2.3 Grouting 30

Soil Investigation (S.I.) Works Specification

3.2.4 Sand Filter.....	30
3.2.5 Surface installation.....	30
3.2.6 Water levels	30
3.2.7 Checking of Installation.....	31
3.2.8 Maintenance and Protection	31
4.0 SAMPLING	31
4.1 Extent and Frequency of Sampling	31
4.1.1 General requirements	31
4.2 Disturbed Sampling	32
4.2.1 Small disturbed samples.....	32
4.2.2 Bulk disturbed samples.....	32
4.3 Undisturbed Sampling	33
4.3.1 Preparation for sampling.....	33
4.3.2 Sampling tubes	33
4.3.3 Open-tube sampling.....	33
4.3.4 Thin-walled sampling	34
4.3.5 Piston sampling.....	34
4.4 Ground Water Sampling.....	37
4.5 Surface Water Sampling.....	37
4.6 Labeling of Samples	37
4.7 Storage, Protection and Transportation of Samples	38
4.8 Provision of Record Samples	39
4.9 Retention and Disposal of Samples	39
5.0 INSPECTION PITS AND TRIAL PITS (TRENCHING).....	40
5.1 Inspection Pits and Precautions for Underground Services.....	40
5.2 Trenches for Examining and Sampling Soils	40
5.2.1 Scope	40
5.2.2 Excavation Methods and In-situ Tests.....	40
5.2.3 Support to Pit Sides and Safety.....	40
5.2.4 Ground Water	41
5.3 Sampling from Trial Pits	41
5.3.1 Small disturbed samples.....	41
5.3.2 Tube Sampling in Trial Pits.....	41
5.3.3 Bulk disturbed samples.....	42
5.4 Backfilling	42
6.0 FIELD TESTING	43
6.1 Standard Penetration Test (SPT).....	43

Soil Investigation (S.I.) Works Specification

6.1.1 Scope 43

6.1.2 Equipment and Sample Recovery 43

6.1.3 Procedure 43

6.1.4 Use of Solid Cone 44

6.2 Field Vane Shear Test in Borehole 44

6.2.1 Scope 44

6.2.2 Equipment 44

6.2.3 Calibration and Tolerances 44

6.2.4 Procedure 45

6.3 Permeability Testing in Boreholes 46

6.3.1 Scope 46

6.3.2 Equipment and procedure 46

6.4 Deep Sounding Test (Mechanical) 47

6.4.1 Scope 47

6.4.2 Equipment 47

6.4.3 Calibration and tolerances 48

6.4.4 Procedure 48

6.5 Deep Sounding Test (Piezocone) 49

6.5.1 Scope 49

6.5.2 Equipment 49

6.5.3 Calibration and tolerances 50

6.5.4 Procedure for penetration test 51

6.5.5 Procedure for dissipation test 51

6.6 Piezometer 52

6.6.1 Scope 52

6.6.2 Vibrating Wire Type Piezometer 52

6.6.2.1 Piezometer Tip and Cable 52

6.6.2.2 Grouting 53

6.6.2.3 Sand Filter 53

6.6.2.4 Surface installation 53

6.6.3 Pneumatic Piezometer 53

6.6.3.1 Piezometer Tip and Tubing 53

6.6.3.2 Sand Filter 54

6.6.3.3 Grouting 54

6.6.3.4 Installation 54

Soil Investigation (S.I.) Works Specification

6.6.4 Pressure head readings..... 55

6.6.5 Maintenance and Protection 55

6.7 Inclinometer and Extensometer..... 55

6.7.1 Scope 55

6.7.2 Calibration and tolerance 55

6.7.3 Procedure 56

6.7.4 Maintenance and Protection 56

6.8 Pressuremeter 56

6.8.1 Scope 56

6.8.2 Equipment 56

6.8.3 Calibration 57

6.8.4 Installation and Procedures 57

6.9 Penetration Field Vane Shear Test 58

6.9.1 Scope 58

6.9.2 Equipment..... 58

6.9.3 Calibration and tolerances 58

6.9.4 Procedure 59

6.10 Penetration Piston Sampling 60

6.10.1 Scope 60

6.10.2 Equipment and Procedure 60

6.11 Mackintosh Probes 61

6.11.1 Scope 61

6.11.2 Equipment 61

6.11.3 Procedure 61

7.0 LABORATORY TESTING 62

7.1 Schedule of Laboratory Testing 62

7.2 Units to be used..... 62

7.3 Testing Standards 62

7.4 Information Required 62

8.0 REPORTING 63

8.1 Information to be Submitted 63

8.1.1 General Information For All Exploratory Holes, Soundings and Penetration Tests 63

8.2 Daily Journals 63

8.3 Preliminary Records of Exploratory Holes, Soundings and Field Tests..... 63

8.4 Preliminary Laboratory Test Results 64

8.5 Final Report 64

8.6 Approval of Final Report..... 65

1.0 GENERAL REQUIREMENTS

1.1 General

The Works shall be carried out in accordance with the recommendation of the latest editions of the British Standard Code of Practice for Site Investigation (B.S. 5930 - 1999) British Standard Method of Soils in engineering Practice (B.S. 1377 - 1990), Deep, quasi static, cone and friction- cone penetration test of soil (ASTM D3441-79) and Manual of soil laboratory testing (Head, Vol. 3 - 1986) except that in conflict this Specification shall be used. The contractor shall provide full information on the stratification and the engineering properties of all soils encountered and he shall exercise the greatest possible care to ensure that both field and laboratory work are of the highest quality. The units used shall be in Si and as given in the relevant testing standards. The measured accuracy required shall also follow that in the testing standards.

1.2 Scope of Works

The scope of works will include the followings: -

- a) Provide licensed survey for setting, final survey as built location and level for all exploratory boreholes and rock probing. The final survey as built to be endorsed by the licensed surveyor.
- b) Rotary boring in soil and rotary core drilling on rock including sampling and in-situ testing.
- c) A complementary programmed of laboratory testing.
- d) Preparation of proper site investigation reports at the end of investigation.
- e) To carry out Mackintosh Probe works
- f) To carry out Piezocone test works
- g) To carry out soil bulk sampling works and relevant laboratory test on the sample
- h) To carry out field vane shear test
- i) To carry out Standard Penetration Test

1.3 Programmed to be furnished

Immediately on the acceptance of his Tender, the Contractor shall submit to the JPS MALAYSIA Bahagian Pengurusan Banjir (BPB) herein after known as Client and/or Consultant hereafter known as Client's Representative for their approval a programmed showing the order of procedure and method on which the Contractor intends to supply, use or construct as the case may be. The submission and approval by the Client or Client's Representative of such programmed or particulars shall not relieve the Contractor of his duties or responsibilities under the Contract.

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

1.4 References Used in the Specification

The following references are used in the Specification :-

MS 2038 : 2006	: Code of Practice for Site Investigation
MS 1056 : 2005	: Method of Test for Soils for Civil Engineering Purposes
BS 5930 : 1999	: British Standard Code of Practice for Site Investigation
BS 1377 : 1990	: British Standard Method of Soils in engineering Practice
ASTM D 3441-79	: Standard Method for Deep, Quasi-static, Cone and Friction-Cone Penetration Test of Soil
ASTM D 1542	: Standard Practice for Soil Exploration and Sampling by Auger Borings
ASTM D 2113	: Standard Practice for Rock Core Drilling and Sampling of Rock for Site Exploration

ASTM D 1587 : Standard Practice for Thin-Walled Tube Sampling of Fine-Grained Soils for Geotechnical Purposes

1.5 Site Visit

The Contractor shall visit/inspect the site, drawings, Bill of Quantity (BQ) and Specification/contract document before preparation and submission of quotation/tender. The Contractor shall carefully inspect the site and surroundings and satisfy himself as to the nature and conditions of the access/obstructions plus site terrains of the site for all the Soil Investigation (SI) works specified in Clause 1.2 of this Specification. The extent and nature of the specified SI works, equipment and machines necessary for the completion of all the SI field and laboratory works, availability of water, electricity and other services, the means of communication with and access to the site/location of boreholes/tests, the accommodation he may require and generally obtain for himself all necessary information as to risk, contingencies and all circumstances influencing and affecting his tender/quotation. Any claim for additional costs or extension of time due to ignorance of the site constraints or difficult site conditions will not be entertained.

1.6 Method Statement

The method statement shall be prepared by qualified professional specified in Clause 1.19 of this Specification and submit to the Client or Client's Representative for prior

written approval (at least 7 days) before the commencement of SI works. The method statement shall consist of the following scope:

- a) Boring machine (type/model/capacity) & drilling tools plus test equipment to be deployed. Names & curriculum vitae (CV) of team leader/technician/driller in charge;
- b) Setting up and working platform preparation for each borehole/test point;
- c) Type of temporary support (casing, bentonite slurry or both) for collapsible drill holes;
- d) Drilling method/borehole advancing method;
- e) Test method/standards/procedures/precautions for but not limited to in-situ testing (SPT, CPT/CPTU, PMT, DMT, Geonor vane, Permeability test in borehole, Groundwater pressures, Test pits, etc.);
- f) Method/procedure/precautions for sampling (types/details of samplers for undisturbed/ disturbed soil samples & rock samples), etc.;
- g) Details of handling (preservation & transportation to approved laboratory) of undisturbed soil samples and rock samples);
- h) Strata logging format (include typical form of borehole logging for borehole, test pit, etc.)

The method statement shall prescribe how to execute the works in working details with drawings/layout diagrams to comply with the specification and contain among other things the details of sequence of works, specific type of machines or equipment plus necessary staging to be deployed for drilling and testing, sampling, estimated daily works output rate, necessary quality control tests/measurements/ observations plus their respective frequency and acceptance criteria. Remedy or rectification shall also be proposed for cases where the acceptance criteria is not met or achieved. Specific key site personnel including drillers/operators/supervisors (name, IC and CV, etc), full details of specific types of machine/equipment/materials to be used, etc., including catalogs, calibration test certificates and photos of the machine/equipment and materials to be used plus the proposed machines layout for drilling, sampling and testing shall be shown on drawings and shall also be included in the method statement.

The proposals in the method statement shall meet all the requirements shown on the Engineer's drawings and this Specification hereafter. The method statement shall be prepared and endorsed by the qualified professional engineer as specified in Clause 1.19 of this Specification. Numbers of teams or sets of machine/equipment that shall be mobilized to site shall be according to what are provided in the BQ and works program. Each team of boring operation shall have one supervisor, one assistant supervisor/senior operator/driller and at least one more skilled worker.

Unless otherwise provided in the BQ, the supervisor shall be a qualified engineering geologist from recognized university or experienced and qualified technician well versed in English and Bahasa Malaysia (graduated from recognized polytechnic with minimum 3 years of physical working experienced in SI works or at least SPM level with minimum 5 years working experience in SI works). The assistant supervisor or senior operator/driller shall have at least 2 years of working experience in SI works with minimum primary education and well versed in English or Bahasa Malaysia.

1.7 Site Clearing and Setting Up

Site clearing for access and accurate locations of site investigation plus taking reduced levels shall be carried out for all locations of soil investigation works, including boreholes, test pits, water levels and other tests shown on drawings and BQ. The conditions of the access shall be maintained and kept reasonably accessible and safe for all site personnel and Client or Client's Representative.

The Contractor shall be solely responsible for the setting up and measurement of all test locations and for providing records such that the positions of these can be accurately determined and retrieved in relation to the proposed engineering works.

Unless otherwise stated in Drawings or BQ, acceptable tolerances in level shall be

0.01m and position/location shall be 0.1m. The Contractor shall have his Licensed Surveyor to set up the borehole and test locations showing on drawings or as directed by Client or Client's Representative and establish the reduced level of all boreholes/test locations with reference to standard and documented nearby Benchmark.

1.8 Supply of Adequate Plant/Equipment, Materials & Labour

Except otherwise specified, the Contractor shall provide all the necessary and adequate plants, equipment, tools, labor and materials both for temporary and for permanent 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 completion of all the SI works specified in Clause 1.2 of this Specification within the specified time period.

All plants and tools or equipment which the Contractor proposes to use in the SI Works shall be reasonably new/clean and in compliance with the relevant standards/specifications and in good working conditions with all necessary meters in working conditions, calibrations not later than 6 months, unless otherwise stated in Drawings or BQ.

The Contractor shall provide such suitable platforms as may be necessary to keep machine or drill rigs stable when putting down vertical boring on sloping land or when boring in a body of water in river, sea or waterlogged swampy areas.

Unless otherwise approved, all boring shall be rotary open hole drilling and rotary core drilling using proper drill rods with proper drilling tools/drill bits to advance the boreholes. The Contractor shall provide suitable pump to generate water pressure for side discharge in drill bits through the drill rods. Water jetting through casing for advancement of borehole before sampling and in-situ testing shall strictly not be allowed.

The boring equipment, tools and supplies deployed or used shall have adequate capacity to drill through all types of subsoil conditions including boulders, hard obstructions to the depth and size specified on drawing or BQ or to maximum depth of 70 meter unless otherwise approved in writing by Client or Client's Representative. Boring machine and pump without proper meters/gauge to show rate of rotation (rpm), working hydraulic pressure, etc., in working conditions are not allowed to be used.

1.9 Important facilities that shall be provided by the Contractor at site are:

- a) The Contractor shall provide all necessary facilities to ensure site working conditions are reasonably safe. Adequate safety helmets, safety boots, safety jacket, hand gloves, etc., for all workers and visitors shall be provided. For SI in hazardous locations such as near road/highway, steep slopes, deep water areas, etc., adequate safety measures and traffic cones/barriers in compliance with the relevant authorities requirements shall be provided by the Contractor. First aid kit box facility and full time standby transport with driver to send to the nearest clinic/hospital in case of injuries or emergency.
- b) Digital camera (minimum effective resolution of 8.0 mega pixels) to take photos for site and test conditions, sample conditions of all disturbed soil samples in split samplers, all rock samples in core box and undisturbed samples before any laboratory tests with labels for necessary identification and verification. Soft copy of the photos (full camera resolution) shall be sent/emailed daily to the Client or Client's Representative soonest possible. Refer Clause 1.18 of this Specification.
- c) Relevant SI Code of practice/test manuals/test standards about boring, sampling and in-situ testing procedures shall be made available at site at all times for reference and inspection by the site personnel and the Client or his representatives.
- d) The Contractor shall make his own arrangement for water, electricity, storage facilities, etc., for all the SI works requirements and all the costs involved are deemed to be included.

- e) Unless otherwise approved, the Contractor shall provide a full time qualified geologist/engineer with minimum 2 years working experience in SI works at site to manage and coordinate the SI works.
- f) All the site personnel and workers shall be adequately covered by PERKESO and accident insurances. All risk insurance of at least RM100,000.00 or 10% of the total contract sum, whichever is the higher, shall be included.
- g) The Contractor shall in connection with the works provide and maintain all lights, guards, fencing and watching when and where necessary or required by the Client 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.

The Contractor shall only be allowed to proceed the SI works if all the facilities and suitable plants/equipment, etc., as listed/specified are made available at site.

1.10 Traffic Safety and Control (Traffic Safety Measures)

- a) The Contractor shall provide, erect and maintain such traffic signs, warning lamps, barriers and traffic control signals and such other measures as may be necessitated by the construction of the Works in accordance with the requirements of the relevant Traffic Signs and Regulations of PLUS, JKR's Arahan Teknik (Jalan 12C/85) "Manual on Traffic Control Devices, Temporary Signs and Work Zones Control" and any amendments thereof. Where the circumstances of any particular case are not covered by the recommendations the Contractor shall submit proposals for dealing with such situations to the Client or Client's Representative for approval. Compliance with this Clause shall not relieve the Contractor of any of his other obligations and liabilities under the Contract and under the relevant provisions of the Highway Acts.
- b) The Contractor shall take into account information about particular localities contained in the Contract drawings when planning the traffic safety measures.
- c) The Contractor shall, after consultation with any statutory or other authority

concerned, submit to the Client or Client's Representative for their approval a program based on such consultation showing the scheme of traffic management he proposes for carrying out the works before commencing any which affects the use of the public road and thereafter furnish such further details and information as necessitated by the Works or as the Client may require.

- d) The Contractor shall not commence any work which affects the public road until all traffic safety measures necessitated by the work are fully operational.
- e) The traffic signs, warning lamps, barriers and traffic control signals shall be in accordance with the requirements of the relevant Traffic Signs Regulations current at the date of the execution of the Work.
- f) Traffic signs and road danger lamps shall comply with JKR (Arahan Teknik Jalan) except that the flashing rate for flashing lamps shall be within the range 120 to 150 flashes per minute. The minimum luminous intensity of the lamps shall be 0.5 candela for steady lamps, 1.0 candela for ripple lamps at their peak, and 1.5 candela for flashing lamps at their peak.
- g) The Contractor shall keep clean and legible at all times all traffic signs, warning lamps, barrier and traffic control signals and he shall position, re-position, cover or remove them as necessitated by the progress of the Works.

1.10.1 Maintenance of Traffic Flows and Control of Traffic

One lane must be maintained at all times during the period of contract. The Contractor shall limit his working such that the overall length of any continuous or nearby continuous section of lane closure shall not exceed 150m.

Any work involving the reduction in the number of traffic lanes, particularly on heavily trafficked commuter routes, should not take place between the hours of 7.30am to

8.30am & 5.00pm to 6.30pm without the express permission of the Client.

1.10.2 Temporary Traffic Signs

The Contractor shall at all times take full and sufficient precaution to ensure the safety of all traffic through and around the work site and of traffic that is diverted by the works.

To this end, the Contractor shall erect and maintain on site and a prescribed points on the approaches to the site all traffic signs necessary for the direction and control of traffic. The sizes of all such signs and lettering and the wording thereon shall be approved by the Client or Client's Representative before the erection. Construction and excavations shall be sign posted and during periods of darkness, flood lighted to the approval of the Client or Client's Representative.

Temporary traffic signs shall comply with the requirements of the Manual on Traffic control Devices, Traffic Signs and Work Zones Control. JKR/ARAHAN TEKNIK (Jalan) 2C/65 and Arahan Teknik Lembaga Lebuhraya Malaysia.

1.10.3 Temporary Access

The Contractor shall provide all temporary roads and gangways required for the execution of the Works. He shall provide at all times during the progress of the works proper means of access with ladders, gangways, boats, etc. and the necessary attendance for inspection of the Works by the Engineer or his Representative as directed.

1.11 Removal of Improper Plant, etc.

The Engineer 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.

1.12 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. The Contractor shall be fully responsible for any damage and for claims for consequential damages.

The Client or Client's Representative 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 Client or Client's Representative responsibility to change the locations of the affected boreholes or other tests.

1.13 Clearance of Site on Completion

As soon as the investigation work is completed, all test pits, boreholes, etc. shall be back-filled to the satisfaction of the Client or Client's Representative. 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 and clean and tidy to the satisfaction of the Client or Client's Representative.

1.14 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 Client or Client's Representative's instructions.

1.15 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 accredited laboratory to the Client or Client's Representative for approval as required by Conditions of Contract.

1.16 Independent Testing by Engineer

Independent laboratory testing may be carried out by the Engineer and for this purpose the Engineer reserves the right to instruct the Contractor to send samples to an independent laboratory for testing. Unless otherwise specified, all costs associated with these instructions shall be borne by the Client.

1.17 Exploratory Bore Hole/Test Location Markers

The positions of Exploratory Bore Holes/Test Locations or as instructed by the Client or Client's Representative carried out on land shall be permanently marked by markers immediately after their completion. Each marker shall comprise a 600 mm long steel rod of 20 mm diameter which shall be cast into not less than 0.03 cubic meters 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.

1.18 Photographs

The Contractor shall supply color photographs of rock cores, soil samples, trial pits or such portion of the Works in progress as may be directed by the Engineer from time to time. The camera to be used is approved Digital Camera having image quality of at least 8.0 megapixel. Proofs shall be supplied to the Engineer within seven (7) days of the photographs being taken in the form of two (2) images per high quality digital printing paper of A4 size and each image shall be described. All such pictures shall be presented in TIFF or JPEG format on a Compact Disc (CD) or Digital Versatile Disc (DVD) and each such disc shall include list describing each photograph. No pictures may be supplied to any person or persons except with the authority of the Client or Client's Representative. Where videos of the works are available, these will be presented in MPEG I or MPEG II format on a CD or DVD.

1.19 Contractor's Professional Attendance on Site

The Contractor shall provide an engineer or engineering geologist of experience full time on site during the site who shall be responsible for the whole of site operations and approved by the Client or Client's Representative, which approval may be withdrawn at any time, and who shall be responsible for the technical direction and output of the whole of the investigation. Such person will be contractor's representative on site and will be required to ensure quality work, compliance with Specification and taking site instructions from the Client or Client's Representative. Where more than one plant is operating on site, each plant shall have trained operator answerable to the contractor's representative. Such operator will have adequate experience and be capable of logging samples according to specified standards and keeping records of all observations.

1.20 Submission of Reports

On completion of the Works, the Contractor shall submit Factual Report as specified below:

Six (6) sets of FACTUAL REPORT with Digital Copy of the said report shall consist of true and faithful reporting of all findings, equipment and material used and test results obtained, codes of practice followed and any variations thereof. The Digital Copy of photographs shall be in full camera resolution of minimum 8 Megapixels.

1.21 Setting Out And Taking Levels

The Engineer shall 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 Operations 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 Client or Client's Representative prior to commencing any Site Operations at that location.

Reduced levels shall be measured by the Contractor for all locations of Exploratory Holes or test locations. 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 lines on the site plan.

1.22 Watching and Lighting

The Contractor shall in connection with the works provide and maintain all lights, guards, fencing and watching when and where necessary or required by the Client or Client's Representative 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.

1.23 Facilities for other Contractors

The Contractor in accordance with the requirements of the Client or Client's Representative shall not obstruct and afford all reasonable access to any other contractors employed by the engineer and their workmen and for the workmen of the Engineer and of any other properly authorized 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 Client or Client's Representative may enter in connection with or ancillary to the Works.

1.24 Workman's Accommodation

The Contractor shall be responsible for the proper housing at site for his labor force to the satisfaction of the relevant Health Authorities. Alternatively, the Contractor may provide proper accommodation off-site.

1.25 Water supply

The Contractor shall provide water required in connection with 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.

1.26 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.

1.27 Storage Facilities

The Contractor shall provide 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 Centigrade and from wetting or drying out due to weather exposure.

2.0 BOREHOLES

2.1 Percussion Boring

2.1.1 Scope

Percussion boring, where required, shall be carried out at locations shown on the Drawings or as instructed by the Client or Client's Representative and shall comprise the formation of a borehole using a cable percussion rig and attachments such as shell, clay cutter, chisel and sinker bar. Method employed for advancing of boreholes using percussion boring must be to the approval of the Client or Client's Representative.

2.1.2 Borehole and Casing Diameter

The minimum diameter of boring or internal diameter of casing shall be 150mm. Where boring 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 soil volume which is to be sampled. Where clay cutters are permitted they shall be of a pattern approved by the Client or Client's Representative, and the combined weight of clay cutter and any sinker bar shall not exceed 150 kg.

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 Boring

The Contractor shall not add water during boring unless boring in dry granular soils or in very stiff clay. 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 boring 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 ground water.

2.1.6 Hard Strata and Obstructions

In boring 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 Client or Client's Representative who shall instruct the Contractor either to continue chiseling or to change to a different method of boring or to terminate the borehole.

2.2 Rotary Boring

2.2.1 Scope

Rotary boring shall be carried out at locations shown on the Drawings or as instructed by the Client or Client's Representative 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. Boreholes shall not be advanced by either surging action of the casing, by the chopping or twisting action of bits via the rods. Unless otherwise specified, all reference to boring in this contract will be deemed to be rotary boring.

2.2.2 Borehole and Casing Diameter

The diameter of boreholes casing shall be such that the requirements of rotary boring, 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 Client or Client's Representative. Other methods of stabilization of the borehole may be used subject to the prior approval of the Client or Client's Representative of the procedure used. In any case, casing shall be used when there is doubt as to the effectiveness of the method of stabilization proposed or practiced.

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 ground water. This condition shall be strictly observed in formations consisting of sand or coarse silt, or in operations involving undisturbed sampling and in-situ testing. In very soft ground or when instructed by the Client or Client's Representative, the Contractor shall use heavy drilling fluid in addition to full depth of casing to stabilize the borehole.

2.3 Advancing The Borehole

2.3.1 Borehole

Advancing of the borehole will be carried out using compatible drill rods with suitable drill bits and casing or where permitted, proper drilling fluids. In every case, advancing of the borehole will be such that the disturbance to and contamination of the soil(s) immediately below the borehole will be kept to minimum. Any method of advancing borehole other than that described in Clause 2.0, 2.1 and 2.2 of this Specification will require prior written approval of Client or Client's Representative.

2.3.2 Drilling Medium

Any drilling medium other than clear water will only be used with prior approval of the Client or Client's Representative. Where water is used as drilling medium, re-circulated water will only be used where water is extremely difficult to obtain and only

with prior approval of the Client or Client's Representative. Generally any medium that affects, in the opinion of the Client or Client's Representative, the proper identification of soil strata's will not be acceptable.

2.3.3 Water Jetting

Water Jetting is a method of advancing borehole using pipe or casing alone. Advance of borehole is achieved by rotating and surging of casing and usage of water at high pressures. Water Jetting shall be carried only at locations shown on the Drawings or as instructed by the Client or Client's Representative and shall comprise of forming a hole in the ground either over land or over water by water jetting to bedrock. No samples or tests will be permitted in any hole created using water jetting without the previous approval of the Client or Client's Representative. Samples obtained from boreholes created by water jetting, disturbed or otherwise will clearly state the method of boring as water jetting.

2.4 Rotary Core Drilling

2.4.1 Scope

Rotary core drilling shall be carried out at locations shown on the Drawings or as directed by the Client or Client's Representative. Drilling shall be carried out in accordance with good practice and detailed in ASTM D 2113 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 re-drill all or part of a borehole at his own expense should the Client or Client's Representative so direct.

2.4.2 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 of not less than 50

mm diameter (N size). The detachable inner liner shall be used to transport and store the sample.

When drilling competent and relatively unweathered 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 designs shall be acceptable. The triple tube system is preferred. When using these non-retractable core barrels the minimum core diameter shall be 45 mm.

2.4.3 Drilling Methods

The methods 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 Specifications 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 rods and 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 1.5 m. 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 Client or Client's Representative. If less than 50% recovery is achieved the following run shall not exceed 0.5 m 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 Client or Client's Representative. No adapters allowing use of different rod sizes than that required as compatible with sampling and borehole sizes will be allowed without prior approval of the engineer and only in extreme cases.

2.4.4 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 Client or Client's Representative, all accessories and spare parts shall be as supplied or recommended by the manufacturer. Substitute core barrels and bits, locally manufactured or not, are proposed to be used contractor shall ensure that these are not sub-standard and such usage will only be with the prior approval of Client or Client's Representative. The Contractor shall provide sufficient numbers of core barrels and accessories in order to carry out the scheduled work without delay. 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 0.75 m. 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 straight and in good condition, and shall be cleaned thoroughly before use to ensure that all 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.

2.4.5 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 10 kN to 15 kN. 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 10 mm 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 liter/second. The pump shall 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, in full working order, capable of operating in the range 0 kN/m² to 2000 kN/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 700 kN/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 air-stream 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 liter/sec. Details of the proposed foam additive and mixes shall be submitted to the Engineer for approval and the use of a foam stabilizer shall not be permitted unless this has been agreed with the Client or Client's Representative.

The Contractor shall ensure that the proposed foam is either fully biodegradable or water soluble and make arrangements for the collection and removal or dispersal of the foam returns when required. The Contractor shall provide recent certified calibration for all gauges and measuring equipment used. Calibration shall have taken place within three months of intended use.

2.4.6 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 for each core run.

2.4.7 Extraction of Cores

Core shall be extracted from double tube core 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 Client or Client's Representative in respect of delays resulting

from this requirement. Cores from triple tube barrels with continuous inner liners shall be carefully removed from the core barrel, sealed and labeled 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. Client or Client's Representative may instruct certain core lengths to be sealed in aluminum foil and waxed before sealing inside the plastic tube. Where air/foam is used as the flushing medium a 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 Client or Client's Representative.

2.4.8 Core Boxes, Packing and Labeling of Cores

Core boxes shall be constructed of sound materials such as timber, galvanized 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 50 kg 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 25 mm 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 in numbers at least 20 mm high and facing the box lid. Each core box shall be marked in Bahasa Malaysia or English identifying the site 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 minimize disturbance during transportation. All cores, boxes and samples shall be delivered to Contractor's store and shall remain the property of the Client or Client's Representative.

2.4.9 Core Recovery Ratio (CRR), Rock Quality Designation (RQD) & 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 meter 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.

2.5 Hand Auger Boring

2.5.1 Scope

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

2.5.2 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 boring shall be 100 mm and casing shall not be required.

2.5.3 Depth of Hand Auger Boring

The hand auger holes shall be stopped when the sides of the hole starts to collapse or when the resistance to augering is so great that the auger cannot be advanced with the force of two healthy workers of average Malaysian physique.

2.6 Backfilling of Boreholes

Exploratory holes shall be backfilled as soon as practicable after the hole is completed, unless otherwise directed by the Client or Client's Representative. 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.

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 dipmeter that permits measurements with an accuracy of ± 25 mm.

3.1.2 First encounter

For boreholes advanced without use of drilling fluid (including water) 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 level to water shall

then be recorded at 5 minutes 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 Client or Client's Representative, this shall be recorded together with the depth to water below ground level and exploratory hole shall then be continued.

If casing is used and this forms a seal against the entry of ground water, 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 Beginnings 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 0.3 m 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 recordings shall be repeated daily while boring for that particular borehole is in progress. The casing shall be capped 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

3.2.1 Scope

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

3.2.2 UPVC Tubing

50mm ϕ UPVC pipe slotted shall be installed with approved filter fabric wrapped around the whole slotted end.

3.2.3 Grouting

A grout of cement and bentonite in the proportions of 1:4 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 Client or Client's Representative.

3.2.4 Sand Filter

The sand filter surround to the slotted tubing shall be clean sand with particles sizes not greater than 1.2 mm and not less than 0.21 mm the volume of the sand filter

placed shall be recorded. The Contractor's arrangements shall ensure that no sand adheres to the soil to 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.

3.2.5 Surface installation

The top of the UPVC tubing shall be covered by a plastic cap or similar as approved by the Client or Client's Representative. An air vent shall be provided. Arrangement to protect the top of the UPVC tubing shall consist of a loose fitting cap and hook. The top end shall be set in concrete.

3.2.6 Water levels

The ground water level shall be recorded immediately before and after installation of the standpipe. Before readings are commenced the standpipe shall be filled with slightly warm water and its correct functioning demonstrated to the Client or Client's Representative. Each installation shall be clearly and permanently labeled with a metal stamp or tag giving the exploratory hole/test number. During the site operations the Contractor shall record the ground water level in standpipe as instructed by the Client or Client's Representative.

3.2.7 Checking of Installation

The correct installation and functioning of all standpipe 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 tip is located to within 0.1m of the

required depth and that the 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 Maintenance and Protection

The Contractor shall ensure that proper maintenance and protection be provided for the installation throughout the monitoring period so that correct readings are obtained.

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. All sampling is to be carried out strictly in accordance with relevant standards and good geotechnical engineering practice.

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 1.0 kg. These samples shall be immediately wrapped in thin plastic sheets such that soil structure remains intact, the sample shall be wrapped again and then placed in a plastic bag and sealed adequately to avoid moisture losses. The samples shall then be placed in appropriate container for transporting to the laboratory or location designated by the Client or Client's Representative or his representative.

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 30 kg.

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 minimize heave in 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 weld seams, burrs and dents. Sample tubes that are corroded or susceptible to corrosion or have non-machined cutting edges or have seams 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 boring using open-tube sampler and equipment as described in MS 2038 : 2006 . The sampler shall have diameter compatible with size of the borehole or casing diameter and a minimum length of 450mm. Inside of the casing shall be clean, smooth and without seams or obstruction of any kind. The cutting shoes shall be clean, sharp and without burred edges. The cutting edge taper shall not exceed 20 degrees. 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. Minimum outside diameter of the tube shall be compatible with size of bore hole or casing adopted or the size approved by the Client or Client's Representative and nominal length of the tube shall be 600 mm or the length approved by the Client or Client's Representative. Wall thickness shall be between 1.5 mm and 2.0 mm with an inside clearance of 0.5% to 1.0%. Inside of the tube shall be smooth without burrs or seams, cutting edge shall be properly machined. The area ratio shall be 10% nominally. The tube shall be pushed into the base of the borehole by a continuous thrust and steady motion without driving, impact or twisting. The drilling rig or boring plant used shall be capable of exerting a static thrust of 10 kN on the sampler.

4.3.5 Piston sampling

For detailed investigation of soft cohesive soils, stationary piston sampling equipment shall be used unless otherwise specified. Minimum outside diameter of the tube shall be compatible with size of boring or casing adopted or the size approved by the Client or Client's Representative and nominal length of the tube shall be 1000 mm or the length approved by the engineer. Wall thickness shall be between 1.5 mm and 2.0 mm. The sampling tube shall be stainless steel and shall have smooth surfaces. The area ratio shall be 10% nominally. The cutting edge shall be machined and taper angle shall be between 6 degrees and 10 degrees and the inside clearance ratio shall be 0% to 0.5%, inside of the tube shall be smooth without burrs or seams. 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 200 mm/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 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.

- (a) Following the sampling procedure of Clause 4.3.5 of this Specification 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 or plastic bags 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.
- (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 minimize wax impregnation.
- (e) Melted non-shrinking micro-crystalline 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.

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

- (k) The sample tube shall be labeled 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 1.27 of this Specification.

Where an attempt to take an undisturbed sample fails the bore hole 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 other means of sampling as agreed with the Client or Client's Representative.

4.4 Ground Water Sampling

Ground water samples shall be taken in accordance with MS 2038 : 2006 on each occasion that ground water is encountered during boring. In percussion boring where water has not been added and in hand auger boring 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 Client or Client's Representative, 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. Where above is not possible due to shallow water table or soils ingressing into borehole, a hand auger hole should be put down near to bore hole for water sampling purposes. Approximately 1.0 liter 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 water-tight screw cap.

4.5 Surface Water Sampling

Water samples shall be taken from streams, ditches or standing water as directed by the Client or Client's Representative. 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 of this Specification.

4.6 Labeling of Samples

All samples shall be labeled 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, reference number and job number
- date of sampling
- Exploratory Hole reference number (for surface water, give relevant details)

Soil Investigation (S.I.) Works Specification

- 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:-

Percussion Boring	PH
Rotary Boring	BH
Auger Boring	HA
Trial Pit	TP
Mazier Core Sample	MS
Rotary Core Sample	C
Stationary Piston Undisturbed Sample	UP
Thin-walled Tube Undisturbed Sample	UT
Open Tube Undisturbed Sample	UD
Small Disturbed Sample	DS
Sample from SPT Spoon	SPT
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 1.27 until they are dispatched to the designated laboratories or as directed by the Client or Client's Representative.

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.

The contractor shall describe the methods of sample transport in his final report.

4.8 Provision of Record Samples

The Contractor shall take 150 gram of representative soil sample from each undisturbed, bulk disturbed and split spoon sample collected. These samples shall be known as "record samples" and shall be delivered as directed by the Client or Client's

Representative. 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 Client or Client's Representative. The Client or Client's Representative may request that certain of the samples be retained either by the Contractor.

5.0 INSPECTION PITS AND TRIAL PITS (TRENCHING)

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 0.5 m² in plan and not more than 1.5 m 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 presence or otherwise of all such services has been established. The position depths and dimensions of all services encountered shall be measured and recorded in the daily Journal, and strata recorded as set out in Clause 8.1.1.

5.2 Trenches for Examining and Sampling Soils

5.2.1 Scope

Trenches shall be excavated at locations shown on the Drawings or as instructed by the Client or Client's Representative.

5.2.2 Excavation Methods and In-situ Tests

The Contractor shall excavate trenches by hand or machine to permit in-situ examination of soil, soil sampling and in-situ testing as required. The plan area of any trenches shall be about 6 m x 1.8 m and depth of excavation shall be at least 1.0 m below top of pile cap. In-situ density tests using sand replacement method as described in MS 1056:2005 shall be carried out on the embankment fill at 0.5 m intervals or as directed.

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 minimize 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 below 1.5 m depth 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 insofar 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 1.0 kg shall be taken at each change in soil type, change in consistency or as instructed by the Client or Client's Representative. 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 Engineer, open tube undisturbed samples shall be taken in trial pits using U100 samplers using approved thin-walled sampler tubes as described in MS 2038: 2006.

Prior to sampling in trial pits, the area over-lying the soil to be samples 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 30 kg shall be collected over a depth interval of 0.5 m at specified depths or as instructed by the Client or Client's Representative. 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 0.2 kg 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 Client or Client's Representative in accordance with MS 1056:2005 Part 9. 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 MS 1056:2005. 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, labeled and stored as required for "small disturbed samples" in Clause 4.2.1 of this Specification. If no sample is recovered in the split spoon sampler a small disturbed sample shall be recovered from the position of the test.

6.1.3 Procedure

All SPT tests 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 75 blows are required before 150mm penetration is reached, then record penetration for 50 blows and terminate test drive.

Test drive : number of blows for further 300mm penetration. If 75 blows are required before 300mm penetration is reached, then record penetration for 75 blows and terminate test drive.

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 Engineer, 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 Shear 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 Engineer in accordance with Method 4.4 MS 1056:2005 Part 9 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 **MS 1056:2005**. The torque head shall be of a type such that torque is applied through a worm and pinion mechanism. Minimum vane diameter shall be 50 mm. For tests in soft clay minimum vane diameter shall be 65 mm.

6.2.3 Calibration and Tolerances

The instrument used for the measurement of torque shall be checked and calibrated as required by MS 1056:2005. 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 Client or Client's Representative in his office and a copy made available at site for the Client or Client's Representative's retention before the start of testing. Testing shall not start until the specified calibration certificates are received by the Engineer. Calibration shall be repeated after completion of the site works. Permitted tolerances on vane dimensions shall be ± 0.5 mm 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 tolerance 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 MS 1056:2005, 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/minute and readings of torque shall be recorded every 2 degrees rotation of the torque head. In stiffer materials which reach failure in less than 10 degrees rotation, readings shall be taken every 1 degree.

- (e) The procedure for remolding shall follow the requirements of MS 2038:2006.
- (f) For both peak and remolded 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 minutes to 5 minutes except in very soft clay where it may be as much as 10 minutes 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 by the Engineer in accordance with MS 2038:2006 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 tests the water level in the borehole shall be raised by adding water

to a level agreed by the Client or Client's Representative. 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.

For rising head tests, the water level in the borehole shall first be lowered by bailing to a level agreed by the Client or Client's Representative.

The water level shall be recorded at 10 second intervals during the early stages of the test and at less frequent intervals in the latter 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)

6.4.1 Scope

The deep sounding test (mechanical) (also known as the "Dutch Cone Penetration Test") shall be carried out at locations shown on the Drawings or as indicated by the Client or Client's Representative 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 : 0 to 1.6 MPa and 0 to 25 MPa;
- heavy load cell : 0 to 10 MPa and 0 to 100 MPa.

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 arrangement of load cells and pressure gauges may be used with the Client or Client's Representative'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 Client or Client's Representative.

The capacity of the jacking equipment and the amount of available reaction shall be

as instructed by the Client or Client's Representative. At locations as instructed by the Client or Client's Representative, available reaction shall be increased by the use of kentledge or anchors.

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 Client or Client's Representative 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 $\pm 5\%$ 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 different parts of the cone, then the cone shall not be used.

The mechanical cone shall be advanced into the ground at a rate of 20 mm/s, ensuring that the sounding rods are vertical and taking the required sets of readings every 200 mm. 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 Client or Client's Representative 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 re-advanced 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 as indicated by the Client or Client's Representative using an electric 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 used shall be that designed for this method of testing. Equipment shall follow the requirements of ASTM D 3441 with the following additional requirements:

- (a) The type of cone used shall be suitable for the testing of soils from very soft to firm clay, peats and organic clays to sands.
- (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 Client or Client's Representative. The filter shall be saturated in a de-aired 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 saturating liquid will not be permitted unless approved by the Client or Client's Representative. A new filter shall be used for each test and shall be fitted onto the cone within a reservoir or the same liquid used to saturate the filter.
- (c) An inclinometer shall be incorporated in the piezocone capable of measuring the inclination of the cone from the vertical.
- (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 test:
 - 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 0.01 MPa
- local friction 0.1 kPa
- pore water pressure 1 kPa
- inclination 1 degree

The recording equipment shall be housed in a weatherproof cabin.

- (f) A friction reducer 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 Client or Client's Representative 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 Client or Client's Representative. 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.

The piezocones shall be advanced into the ground at a rate of 20mm/s, ensuring that the sounding tubes are vertical. Contractor shall ensure that this rate of penetration is maintained for the full depth of the test. 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 Engineer prior to the commencement of site works. The Client or Client's Representative 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 Client or Client's Representative, 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 Engineer to suit the ground conditions encountered.

6.6 Piezometer

6.6.1 Scope

Piezometers shall be installed at locations shown on the drawings or as instructed by the Client or Client's Representative. The final details of any piezometer installation will be decided by the Client or Client's Representative and will depend upon the actual subsoil and ground conditions found and the supplier's recommendations. The piezometer shall be either vibrating wire type or pneumatic type for the measurement of pore pressure.

6.6.2 Vibrating Wire Type Piezometer

6.6.2.1 Piezometer Tip and Cable

The piezometer tip shall incorporate a filter and transducer for the measurement of pore pressure. The piezometer tip shall consist of a Porous ceramic element or other suitable element with average pore diameter of 0.001 mm. The ceramic element should be soaked in boiled water for 24 hours prior to installation. Cables should be laid in continuous lengths without any joints. The joints between the tips and cables shall be wrapped with approved corrosion resisting tape. Cables should be placed loosely to allow for settlements or lateral displacements.

6.6.2.2 Grouting

A grout of cement and bentonite in the proportions of 1:4 shall be used. Bentonite should be made in the form of pellets to seal.

6.6.2.3 Sand Filter

The sand filter surround to the porous element shall be clean and fall wholly between the limits of grading 1.2 mm and 0.21 mm and the volume of the sand filter shall be recorded.

The Contractor's arrangement shall ensure that no sand adheres to the soils in the sides of the unlined boreholes. The Contractor shall allow sufficient time for all the sand to settle. The piezometer tip shall be placed in the hole and the remaining sand filter shall then be added as described above. The above procedure could be repeated for all other elevations of piezometer installations.

6.6.2.4 Surface installation

All necessary steps has to be taken to take care of the exposed parts of the cable from damaging, by the Contractor. Before installing it has to be sent to the Client or Client's Representative for approval.

6.6.3 Pneumatic Piezometer

6.6.3.1 Piezometer Tip and Tubing

The piezometer tip shall comprise a porous element integral with a diaphragm transducer, installed either in a borehole or by pushing to shallow depths in soft soil. Twin nylon tubes in polythene sheath covering, connect the transducer to a terminal panel or readout unit. The piezometer tip is soaked in water for at least 24 hours before connecting to the twin tubing.

For lower pressures up to 350m head of water and tube lengths up to 500 m, pneumatic readout with either a Bourdoun tube or digital display shall be used. For high pressures, up to 2000 m head of water or for tube lengths greater than 500 m hydraulic readout shall be used.

6.6.3.2 Sand Filter

The sand filter surround to the porous element shall be coarse, clean and fall wholly between the limits of grading 1.2 mm and 0.21 mm and the volume of sand filter shall be recorded. Filter sand is poured and tamped until tip is covered by at least 150 mm.

6.6.3.3 Grouting

A plug to prevent entry of grout into the sand filter is placed in the form of balls of stiff bentonite or bentonite granules dropped through the water and tamped into place. Backfilling is completed to ground surface with an impervious grout, generally a bentonite-cement mix placed through a tremie pipe which is positioned above the bentonite plug and withdrawn as grouting proceeds.

6.6.3.4 Installation

The hole, diameter 75 mm to 150 mm, is driven in soils using shell and auger and in rocks with rotary water flush drilling. Air flush and consequent entrapment of air in the ground should be avoided. The sides of the hole in the vicinity of the piezometer tip should be free from mud-cake and debris; the hole should be flushed clean before installation of the piezometer tip. If the hole requires casing, this is withdrawn to keep pace with the installing operation.

Coarse, clean sand filter material is placed through water to the proposed base of the piezometer tip, and is compacted. The piezometer tip, soaked in water for at least 24 hours, is connected to the twin tubing and inserted in the borehole using placing tubes. Further filter sand is poured and tamped until the tip is covered by at least 150 mm.

The piezometer tubes must be protected from mechanical damage. They may be run in protective conduits or cast into concrete. The tubes should be looped where they cross an interface and at joints.

6.6.4 Pressure head readings

The pressure head level shall be recorded immediately after the installation of the piezometer. Before readings are commenced, the correct functioning is demonstrated to the Client or Client's Representative. Each piezometer shall be clearly and permanently labeled with a metal stamp or tag giving the borehole location number. During the site operation, the Contractor shall record the pressure head levels as instructed by the Client or Client's Representative.

6.6.5 Maintenance and Protection

The Contractor shall ensure at all times throughout the monitoring period that proper maintenance and protection be given to the installations and surface terminals on site so that correct measurements are obtained.

6.7 Inclinator and Extensometer

6.7.1 Scope

The inclinometer and extensometer tests shall be carried out at borehole locations and depths given on the Drawings or as instructed by the Client or Client's Representative. This shall be done to study the settlement and lateral movement of the embankment foundations. The installation details shall be in accordance with the manufacture's recommendations and as directed by the Client or Client's Representative.

6.7.2 Calibration and tolerance

The inclinometer and extensometer shall be calibrated for use and copies of the calibration certificates shall be provided before or at the commencement of work at the site to the Engineer. It shall consist of a graph or listing of figures. Calibration shall not be carried out more than 3 months before the start of the site work.

The diameter ratio of the borehole and the tubing shall be between 10% to 15%.

6.7.3 Procedure

The inclinometer and extensometer shall be installed in the boreholes as instructed by the Client or Client's Representative. The rotary drilling shall be carried out until a hard strata and the inclinometer tubing's tip should be tied to that, and the subsequent tubes are fixed on that. Before installation, the orientation of key ways must be established and if possible maintained throughout the installation. The tubing is lowered in a pre-grout borehole and they are jointed with the next. A hydro-static head is maintained with clean water to stop the grout from entering through a joint. During the extraction of the casing the orientation of the tube shall be checked after each length is pulled. The horizontal displacement of the ground below the embankment is measured using the inclinometer at 0.5 m intervals with depth for the whole compressible clay strata. On the other hand, the vertical displacements or settlements in the clay strata is measured by the use of magnetic targets placed at 1.5 m depth intervals on the outside of the inclinometer tubing. Monitoring of the readings during the site operations and subsequent period shall be as instructed by the Client or Client's Representative.

6.7.4 Maintenance and Protection

The Contractor shall ensure at all times throughout the monitoring period that proper maintenance and protection be given to the installations and surface terminals on site

so that correct measurements are obtained.

6.8 Pressuremeter

6.8.1 Scope

The pressuremeter test shall be carried out at location shown on the drawing or as instructed by the Engineer. It shall be carried out to find Parameters Limit pressure PL, Deformation Modulus E and in-situ horizontal stresses.

6.8.2 Equipment

- (a) The type of standard metallic probe covers will allow testing in majority of soils from very soft to hard clay, fills, embankments, organic clay to sands. However, self boring type pressuremeter is required for very soft, sensitive clay.

- (b) The equipment shall have the capability of reading
 - up to 20 to 25 bars pressure in soils
 - up to 50 to 70 bars in rocks

6.8.3 Calibration

In a pressuremeter testing instrument accuracy is always important to obtain the corrected pressure-volume curve, or pressure-radius curve. Therefore, the instrument has to be calibrated for each borehole or as instructed by the Client or Client's Representative. Calibration for Pressure losses 'Probe Calibration' shall be done by inflating the Pressuremeter in air. Calibration dates and method or calibration shall be given to the Client or Client's Representative from time to time.

6.8.4 Installation and Procedures

During the drilling care shall be taken for least disturbance of the borehole. Boring shall be carried out with bentonite slurry. Contractor shall take all necessary steps to ensure borehole from collapsing. All other types of problems considering different type of soils the Contractor shall use the Standard methods in practice with prior approval from the Client or Client's Representative. The corrected pressure-volume curve shall be plotted on the site immediately after the test and a copy shall be submitted to the Client or Client's Representative.

When the volume variation for a pressure increment of 1.0 bar, becomes less than 0.5m^3 , the volumetric shunt must be used, magnifying 50 times the sensitivity of the volume readings.

The test is standardized and should be carried out with ten equal loading increments up to the point of failure. Readings of deformation with respect to time are taken for each pressure increment of 15 seconds, 30 seconds and 1 minute after the application of this increment.

6.9 Penetration Field Vane Shear Test

6.9.1 Scope

The penetration field vane test shall be carried out at locations and intervals given on the Drawings or as instructed by the Engineer in accordance with Method 4.4 MS 1056:2005 Part 9 and shall comprise the measurement of peak and residual vane shear strength without the use of a borehole.

6.9.2 Equipment

The equipment shall be in accordance with MS 1056:2005 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 instructed by the Client or Client's Representative.
- (b) Two sizes of vane shall be available for different ranges of shear strength measurement as follows :-

Vane size 55 x 110mm for the measurement of undrained shear strength between 50 to 100 kPa

Vane size 65 x 130mm for the measurement of undrained shear strength between 0 to 60 kPa.

- (c) The reaction and capacity of the jacking equipment shall be sufficient to reach the maximum depth required.
- (d) Bearings shall be provided every 3.0 m between the outer tube and inner rod of the vane test apparatus.

6.9.3 Calibration and tolerances

The instrument used for the measurement of torque shall be checked and calibrated as required by MS 1056:2005. 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 Engineer and a copy made available at site for the Client or Client's Representative's retention before the start of testing. Testing shall not start until the specified calibration certificates are received by the Engineer. Calibration shall be repeated after completion of the site works.

Permitted tolerances on vane dimensions shall be plus or minus 0.5 mm 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 tolerance on the torque head measurements shall be plus or minus 5% of the measured value.

6.9.4 Procedure

The field vane test shall be carried out in accordance with MS 1056:2005, with the following additional requirements

- (a) Once the vane within the protecting shoe reaches the required level before pushing the vane to the final test depth, the upper extension tube 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 remolding shall follow the requirements of MS 2038:2006 .

- (f) For both peak and remolded 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 minutes to 5 minutes except in very soft clay where it may be as much as 10 minutes to 15 minutes.
- (g) On completion of a test, the vane shall be withdrawn back into the protecting shoe, then advanced to the next test depth.
- (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.

6.10 Penetration Piston Sampling

6.10.1 Scope

The penetration piston sampling shall be carried out at locations shown on the Drawings or as directed by the Client or Client's Representative 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.

6.10.2 Equipment and Procedure

The stationary piston sampling equipment and procedures shall be in accordance with MS 2038:2006 and Clause 4.3.5 of the Specification with the following additional requirements :

- (a) The jacking equipment shall have 2.5 tonne minimum capacity with an

available reaction sufficient to allow full mobilization 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.

6.11 Mackintosh Probes

6.11.1 Scope

The Mackintosh Probe shall be carried out at locations shown in the Drawings or as indicated by the Client or Client's Representative and shall consist of driving a standard probe into the ground and recording the resistance to penetration.

6.11.2 Equipment

The apparatus used shall be the standard Mackintosh Probe apparatus.

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 a means of extracting the rods and cone. The guide shall be such that not more than 1.2 m of rod is unsupported at any one time and if the driving device is not separately provided with a guide then not more than 0.6 m of rod shall be unsupported where the blow count is in excess of 15 blows per 300 mm.

6.11.3 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 300 mm increment of penetration.

The probing shall be stopped when the resistance has reached 400 blows/300mm penetration unless otherwise directed by the Client or Client's Representative.

7.0 LABORATORY TESTING

7.1 Schedule of Laboratory Testing

The Client or Client's Representative will decide the laboratory test 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 Client or Client's Representative has received the relevant preliminary records as detailed in Clause 8.3. The Contractor shall inform the Client or Client's Representative 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 International System of Units (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 as specified in Clause 1.4 of this Specification.

7.4 Information Required

In addition to the information required by the relevant specified standards, additional information as listed in Laboratory Test Schedule 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, Ferum (Fe) staining, veins, fossils and stress relief cracks.

8.0 REPORTING

8.1 Information to be Submitted

8.1.1 General Information For All Exploratory Holes, Soundings and Penetration Tests

The following general information where appropriate shall be submitted on record sheets of all Exploratory Holes and any other tests or installations, soundings and field tests in daily journals, preliminary records and the final Report.

- (a) Contract Title and Reference Number
- (b) Contractor's Name
- (c) Exploratory Hole, sounding, or field test reference number, location (coordinates and chainage and offset) and diameter or size
- (d) Dates of exploration referred to the depth at the end of each working day or shift.

- (e) Equipment used
- (f) Details of services or drains located
- (g) Data on the stability of the Exploratory Hole and details of casing/shoring used related to progress.
- (h) Site photograph presented in the form of 2 photos in one A4 page.

8.2 Daily Journals

The Contractor shall prepare for each Exploratory Hole, Sounding and field test, a daily Journal which shall be of a form to be approved by the Client or Client's Representative. The Journals for each Exploratory Hole Sounding and field test shall be submitted to the Client or Client's Representative at the beginning of the next working day following the day to which they refer. The journal shall contain the information required in Clause 8.1 where relevant.

8.3 Preliminary Records of Exploratory Holes, Soundings and Field Tests

The Contractor shall prepare preliminary records which shall be submitted to the Client or Client's Representative in duplicate within seven (7) working days of the completion of each Exploratory Hole, Sounding and field tests to which they refer and shall contain the information required in Clause 8.1 where relevant.

8.4 Preliminary Laboratory Test Results

The information to be submitted shall be as given in Clause 7.4. In addition a single copy of each laboratory test result sheet shall be submitted together with any calculations carried out.

8.5 Final Report

The Final Report shall consist of a factual report on the Soils Investigation authenticated by the Contractor's own Professional Engineer or Professional Geologist as described under Clause 25 of the Instruction to Tenderers. The Report shall be bound in loose leafed hard backed multiple ring binders with not more than 50 mm thickness of pages in each volume, or as otherwise directed by the Client or Client's Representative. The cover of the report shall highlight the Client or Client's Representative, the title of the project, the contractor and the duration dates of the field works (in that order). The Contractor is encouraged to follow Final Report format attached in Appendix A. The Final Report shall contain the following information :

- (a) A brief factual description of the works, stating the aim and scope of the Works, code of practice adopted, the numbers and types of Exploratory Holes, Soundings and field tests, duration and time of year, weather conditions encountered, a brief description of the Site Operations and List of laboratory tests including testing standards used.
- (b) A brief description of equipment and procedures used for forming Exploratory Holes, Soundings and carrying out field tests.
- (c) Records of Exploratory Holes, Soundings and field test including all the information required in Clause 8.1 where relevant. The records shall include all the information presented in the preliminary records updated as necessary based on laboratory test results and further examination of samples.
- (d) Standpipe and piezometer records, including relevant permeability test results.
- (e) All laboratory test records and results.
- (f) Summary sheets of all test results.
- (g) Site plans showing locations of all Exploratory Holes, Soundings, other tests

and areas covered by the Soils Investigation, including the Scale and North sign.

- (h) All soil description presented shall take into account laboratory test results strictly in accordance with latest MS 1056:2005 or relevant Malaysian Code of Practice
- (i) The Contractor shall submit six (6) sets of Report to the Client including 1 Digital Copy.

8.6 Approval of Final Report

Two draft copies of the final Report shall be submitted to the Client or Client's Representative for approval before submission of the Final Report. The Contractor shall allow two weeks in his Program for the Client or Client's Representative to grant this approval and he shall include amendments, if any, as required by the Client or Client's Representative in the Final Report. The number of copies of the Final Report to be submitted shall be six (6) hard copies plus one (1) soft copy in the form of CD or DVD as mentioned in the Bill of Quantities.

RINGKASAN SEBUT HARGA

SEBUTHARGA KERJA-KERJA PENYIASATAN TANAH BAGI PERKHIDMATAN PERUNDING BAGI REKABENTUK TERPERINCI BAGI CADANGAN TEBATAN BANJIR SG. PERMATANG RAWA (BAHAGIAN HULU) DI KG. TANAH LIAT, DAERAH SEBERANG PERAI TENGAH, PULAU PINANG

PREAMBLE

Related Documents

The Agreement, Specifications and the Drawings shall be read in conjunction with the Bills of Quantities. The prices entered into the Bills of Quantities shall provide for full compliance with all the provisions of the above documents.

Clauses Quoted

A reference clause number set against any item in the Bills of Quantities indicates a clause in the Specifications in which work covered by the item is described. Further requirements for the work in question may also be stated in other clauses in the Specifications or on the Drawings and the Contract Rates shall be deemed to cover also the cost of complying with any such further requirements.

Rates and Prices

The rates and prices in the Bills of Quantities (comprehensively referred to as the Contract Rates) shall, except insofar as may be otherwise expressly provided for in the Contract, be deemed to cover all the Contractor's liabilities and obligations under the Contract and for all matters and things necessary for the proper execution and completion the Works. No payment shall be made in respect of anything described in the Contract for which no corresponding item is given in the Bills of Quantities, and the cost thereof shall be deemed to be included in and covered by the Contract Rates as aforesaid. Overheads, profits, insurances, etc., shall all be deemed to have been included in the Contract Rates.

General descriptions of work and materials are not necessarily repeated in the Bills of Quantities and reference should be made to the Specifications for this information. The rates and prices inserted in the Bills of Quantities shall be the full inclusive cost of the work described and of all general liabilities and obligations set forth or implied in the documents on which the tender is based. All items in the Bills of Quantities shall be priced in Ringgit Malaysia.

Every item shall be priced. Payment for items in the Bills of Quantities against which rates or prices have not been entered by the Contractor shall be deemed to be included in the rates or prices entered against other items in the Bills of Quantities.

Quantities

All quantities in the Bills of Quantities are provisional and shall be subjected to re-measurement.

The quantities of the various items are approximate only and shall not be considered as limiting or extending the amount of work to be provided by the Surveyor under the Contract. The basis payment shall be the actual quantities ordered and carried out as measured by the S.O. and valued at the rates or prices quoted in the Bills of Quantities where applicable or otherwise at such rates or prices which may be fixed within the terms of the Contract.

There shall be no claims for variations whatsoever if the final quantities are higher or lower than those shown in the Bills of Quantities.

Measurement

Except where an item in the Bills of Quantities clearly indicates to the contrary, the measurement of the Works shall be as described in the Specifications.

Lump Sum Items

Progress payment against all Lump Sum items will be paid in proportion to the extent the relevant services have been provided, in the opinion of the S.O. at the end of the period in question.

Units of Measurement

Except where expressly shown to the contrary, the metric/SI units of measurement shall apply throughout the Contract. The following are some abbreviations used:-

<u>Units</u>	<u>Abbreviation</u>
kilometer	km
meter	m
millimeter	mm
square millimeter	mm ²
square meter	m ²
cubic meter	m ³
liter	l
diameter	dia.
outside diameter	od / OD
finished internal diameter	fid / FID
kilogram	kg
tonne	t
hectare	ha
lump sum	LS
provisional sum	PS
number	nr / No.
set	set
second	s
minute	min
hour	h
day	d
week	wk
month	mth
man hour	man-h
man-month	man-mth
percentage	%
Ringgit Malaysia	RM