

Meghalaya State Public Services Delivery Commission

**Scope of Works and Technical Specifications of the
Geotechnical Investigation Survey
for land at New Shillong Township**

Terms of Reference

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1 Introduction

The Meghalaya State Public Services Delivery Commission has been allotted land measuring 0.64 acres at the New Shillong Township in the same campus with the IT Park for setting up its own campus.

Scope of Work

The Geotechnical investigation is required to be undertaken at the location for selection and design of foundation system of the various structure. The investigation is planned in such a way that the information obtained from the subsurface exploration and subsequent laboratory test is to be incorporated into geotechnical analysis. The objective of this investigation is to ascertain the value and properties of soil available on site at various depths with a view to arrive at the safe bearing capacity of soil for foundation with their capacities. Other information such as mechanical and physical properties, parameters and characteristics like grain-size distribution, sensitivity, any existence of deleterious material in soil or groundwater, etc., are also to be determined. The exploration should also throw light on groundwater level, artesian condition, if any, likely well-sinking and pile driving effort, likely constructional difficulties, etc.

Description:

The Primary goal of this scope of service to obtain subsoil properties to ensure effective design and construction of the office building for the Commission.

Field Work Methodology & Specifications:

The fieldwork shall consist of excavation, drilling of boreholes for the purpose of collection of undisturbed and disturbed samples, standard penetration tests (at 1.5 m interval), other field tests, as specified by the Engineer-In-Charge, and preparation of bore logs. It will also include preservation and testing of disturbed and undisturbed samples and water samples from boreholes, borrow pits, etc. as specified by the Engineer-In-Charge. Undisturbed and disturbed soil samples are to be collected at 1m interval or wherever strata changes. All in-situ tests shall be supplemented by laboratory investigation reports incorporating the observations made during the field investigation and the results of laboratory tests, analysis of all results, foundation recommendations with calculations and other related information along with necessary charts, curves and drawings. Relevant latest Indian Standards such as IS:1498, IS:1892, IS:2131, IS:2132, IS:2720, and Appendix-2 of IRC:78 shall be followed for guidance.

Depth of bore should cover all strata likely to cause undesirable settlement affecting stability. The depth of boreholes below the ground level should be to a maximum of 20 m for required structure locations. However, borings can be terminated at shallower depths when firm strata or bedrock is encountered (beyond N= 100). If highly compressible strata are encountered, the boring may have to be taken deeper.

Exploratory Boreholes:

The location of boreholes is to be finalized in consultation and approval of the Engineer-In-Charge. For all borings, necessary information as detailed below shall be given.

- Location with reference map, showing “N” direction, nearest landmark (as available) and showing the Bore Hole location.
- Pit/ borehole number and dimensions
- Reduced level (RL) of ground surface or other reference point (the RL shall be with respect to GTS datum)
- Dates of starting and completion
- General description of strata met with and depths at which they are met
- The level at which the sub-soil water is met
- Visual description of strata and soil classification showing all characteristics “C” values, OMC etc. as may be required in the design.
- Results of Field tests.
- Laboratory results of tests on disturbed and undisturbed samples.
- Any other information and remarks.
- Recommendation for specific foundation.

No. of Boreholes & Depth:

Below is a summary of the quantity of boreholes and borehole depths.

- Tentative No. of Boreholes = 2
- Tentative Depth of Boreholes (Mtr.) = 15

The quantities and depth as mentioned below are indicative only and subject to change based on actual site condition and shall be updated accordingly. The amount payable will be decided based on actual work done.

Sub-Soil Water:

The subsoil water shall be tested for chemical properties to ascertain whether there is any hazard that may cause deterioration of concrete in foundations. Where dewatering is expected to be required, permeability characteristics shall also be determined.

Laboratory Tests:

Separate laboratory tests are required to be conducted for obtaining the properties of cohesionless and cohesive soils. These tests are enumerated below. These should be carried out, wherever practicable, according to the soil type. While selecting the tests and interpreting the results, limitations of the applicability of the test should be considered.

Tests to be conducted (as applicable):

- ✚ Classification tests, index tests, bulk and dry density determination
- ✚ Shear strengths by triaxial/direct shear
- ✚ Unconfined Compression Test

- ✚ Consolidation Test
- ✚ Particle size distribution
- ✚ Natural moisture content
- ✚ Liquid limit test
- ✚ Plastic limit test
- ✚ Specific gravity

Reports and Recommendations:

Reports are to be submitted in triplicate in hard copy as well as in soft copy containing details and discussions on the type of foundations and recommendations for the site.

The Geotechnical investigation results should be useful to establish the soil parameters that are to be adopted for the finalization of the type of foundation of the structure as per relevant latest IS codes. The Geotechnical investigation report shall include detailed calculations with specific recommendations for the safe bearing capacity of the soil at various depths for different sizes of foundations. If pile foundation is recommended, necessary calculations and details regarding the type, depth, diameter, capacity (vertical, horizontal, and uplift), etc. should be mentioned (single or group of piles).

2 DETAILED TECHNICAL SPECIFICATIONS

This detailed technical specification is intended for carrying out soil investigation.

2.1 SCOPE

This specification covers the technical requirements for a detailed Geotechnical investigation and submission of a detailed Geo-technical report. The work shall include mobilization of all necessary equipment providing necessary engineering supervision and technical personnel, skilled and unskilled labour etc., as required to carry out the entire field as well as laboratory investigations, analysis and interpretation of data collected and preparation of a Geo-technical report including recommendations.

The Contractor shall make his own arrangements for locating the coordinates and positions of bore holes, trial pits, static/dynamic cone penetration tests and other field tests.

All the field and laboratory data shall be recorded with photograph in each case. The contractor shall submit to the Employer's two copies of field bore logs for every bore hole and the entire field records (countersigned by the Employer's Engineer) soon after the completion of each test.

3 GENERAL REQUIREMENTS

The Contractor shall make enquiries and verify regarding earlier use of the site, which can have important bearing on its suitability for the proposed structures. The possibility of damages to the structures, sewers, conduits and drainage system by subsidence shall also be investigated and recorded.

It is essential that the equipment/instruments are properly calibrated prior to the commencement of the work so that they represent true values. The latest certificate of the calibration must be submitted to the employer's engineer before use of the same. If the Employer's Engineer so desires, the Agency shall arrange for having the instruments tested at an approved laboratory at his cost and the test reports/certificates of equipment calibration shall be submitted to the Employer's Engineer. If the Employer's Engineer desires to witness such tests, Contractor shall arrange for the same.

Excavation and site preparation is the responsibility of the Agency, JCB; Hydra shall be arranged by Agency, when necessary. Drilling Water shall be arranged by the Agency itself. All necessary materials are arranged by the Agency like electricity, Drinking water supply, Water for sanitary purpose.

During the testing the onus of ensuring safety to all workers or the nearby properties will lie with the agency at all sites. The utility if damaged, is to be repaired by the agency at their own cost and risk. Employer will not be held responsible for any such incident/s.

4 CODES AND STANDARDS

All standards, specifications and codes of practice referred to herein shall be latest editions including all applicable official amendments and revisions.

In case of conflict between this specification and those IS codes standards referred to herein, the former shall prevail.

All work shall be carried out as per the following standards and codes, which are referred below:

IS: 1080	Code of practice for design and construction of Spread foundations
IS: 1498	Classification and identification of Soils for Engineering purposes
IS: 1888	Method of Load Test on soils
IS: 1892	Code of practice for Subsurface Investigation for Foundation
IS: 1904	Code of practice for design and construction of foundation in soils: General requirements
IS: 2131	Method of Standard Penetration Test for soils
IS: 2132	Code of practice for thin-walled tube sampling
IS: 2720	Method of Test for Soils (relevant parts)

IS: 2809	Glossary of terms and symbols relating to Soil Engineering
IS: 2950	Code of practice for design and construction of raft foundation (Part – I)
IS: 3025	Methods of sampling and Testing (Physical and Chemical) for water used in industry
IS: 4078	Code of practice for Indexing and Storage of Drill Cores
IS: 4434	Code of practice for in-situ vane shear test for soils
IS: 4453	Subsurface Exploration by Pits, Trenches, Drifts, and Shafts - Code of Practice
IS: 4464	Code of practice for presentation of drilling information and core description in foundation investigation
IS: 4968	Method for subsurface sounding for soils Part II: Dynamic method using cone and bentonite slurry Part III: Static cone penetration test
IS: 5249	Determination of dynamic properties of soil - Method of test
IS: 5313	Guide for Core Drilling Observations
IS: 5529	Code of practice for in-situ permeability tests Part I Tests in overburden Part II Tests in bedrock
IS: 6403	Code of practice for determination of allowable bearing capacity on shallow foundation
IS: 6935	Method for determination of water level in boreholes
IS: 8009	Code of practice for calculation of settlement of foundation subjected to symmetrical (Part I) vertical loads: Shallow foundations
IS: 8009	Code of practice for calculation of settlement of foundation subjected to symmetrical (Part II) vertical loads: Deep foundations
IS: 8763	Guide for Undisturbed Sampling of sands
IS: 8764	Method of determination of point load strength index of rocks
IS: 9143	Method for the determination of unconfined compressive strength of Rock Materials
IS: 9179	Method for preparation of Rock Specimen for laboratory testing
IS: 9214	Determination of Modulus of subgrade reaction in field
IS: 9259	Specifications for Liquid Limit apparatus
IS: 9640	Specifications for Split Spoon Sampler
IS: 9669	Specifications for CBR mould and its accessories
IS: 10074	Specification for compaction mould assembly for Light and Heavy compaction
IS: 10108	Code of practice for sampling by thin wall sampler with stationary piston
IS: 10589	Equipment for determination of subsurface sounding of soils
IS: 10837	Specifications of moulds for determination of Relative density and its accessories
IS: 11229	Specifications for Shear Box testing of soils

IS: 11315	Description of Discontinuities in Rock Mass Core Recovery and Rock Quality (Part-II)
IS: 5249	Determination of Dynamic properties of soil – Method of test

5 FIELD INVESTIGATIONS

5.1 Boring

5.1.1 General Requirements

- a. Bore holes shall be taken at the site to obtain information about the sub-soil profile, its nature and strength and to collect soil samples for strata identification and conducting laboratory tests. The minimum diameter of the borehole shall be 150mm and boring shall be carried out in accordance with the provisions of IS: 1892 and as per this specification.
- b. All boreholes shall extend up to depths as agreed by Engineer-in-Charge or shown on the drawings or as indicated elsewhere in this specification. When the boreholes are to be terminated in soil strata, an additional standard penetration test shall be carried out at the termination depth. However, the depth of termination shall be determined after consultation and certification from the Employer's Engineer on the field Borelog.
- c. Casing pipe shall be used in the boreholes to support its sides wherever necessary; it shall be ensured that its bottom and is at all times less than 15 cm above the bottom of the borehole and not below the level at which the test has to be conducted or sampling has to be done. In case of cohesion-less soils the advancement of the casing pipe shall be such that it does not disturb the soil to be tested or sampled. The casing shall be advanced by slowly turning the casing pipe and not by driving.
- d. In-situ tests shall be conducted, and undisturbed samples shall be obtained at specified intervals in the boreholes. Representative disturbed samples shall be preserved for conducting various tests in the laboratory. Water table in the borehole shall be carefully recorded and reported. No water/drilling mud shall be added while boring above ground water table. For cohesion-less soil below water table, the water level in the borehole shall be at all times be maintained sufficiently above the water table.
- e. The borehole shall be cleaned using suitable tools up to the depth of testing or sampling, ensuring that there is minimum disturbance of the soil at the bottom of the borehole. The process of jetting through an open tube sampler shall not be permitted.

- f. In cohesive soils, the borehole may be cleaned using a bailer with flap valve. Gentle circulation of drilling fluid shall be done when rotary mud circulation boring is adopted.
- g. On completion of the boreholes, the Contractor shall backfill all the bore holes with neat cement grout as directed by the Engineer.

5.1.2 Rotary Mud Circulation Boring

This method could be used in all types of soil below water table. In this method boring shall be done by rotating the bit fixed at the bottom of the drill rod. Proper care shall be taken to keep firm contact between the bit and the bottom of the borehole. Bentonite, attapulgitite, or biodegradable mud or mud laden fluids shall be used as the drilling fluid to serve as the protective surface inside the borehole. Use of percussion tool shall be permitted in hard clays and dense sandy deposits. A stable boring shall be maintained at all times to prevent the hole from caving in. No less than 20 kg. each of micatex (or equal) and barite (or equal) shall be kept at drilling location to immediately correct any hole stability problem. The fluid in the borings shall be maintained above the groundwater table at all times. Borings that will be used for installation of observation wells shall be drilled only with casing or with biodegradable mud.

Observations shall be made of groundwater levels in all borings. All water conditions, including gain or loss of water or drilling mud, and the presence of gas or artesian pressure shall be recorded on the boring logs at the depths encountered.

On completion of the boring, the hole shall be filled with a neat cement grout. The approximate proportions of the grout shall consist of 200 litres of water, 80 kg. (2 bags) of cement, and 10 kg of bentonite. The drilling rods shall be placed at the bottom of the hole and the grout shall be pumped into the hole through the rods. The rods shall not be withdrawn from the bottom until the hole is filled. As the rod is withdrawn, grout shall be pumped to maintain the grout level at the top of the hole.

5.1.3 Rock Boring

Rotary type drilling machines shall be used for boring. The Contractor shall take rock core samples by means of a diamond drill, as described in ASTM D 2113-83. Single/double tube core barrels fitted with diamond drill bits shall be used for coring of NX size samples through rock formations. Details of rocks drilling data including RQI. along with the sampling details shall be listed in the respective bore logs.

The term "rock" shall be applied to any materials that cannot be penetrated by the chopping bit. Soft or decomposed rock shall be sampled with a driven sampler whenever possible. When drilling through rock or boulders, the chopping or roller bit shall be used to penetrate all disintegrated rock. The casing shall be firmly seated on the rock by driving and washing out before inserting the core barrel in the hole. The rock shall be drilled until the required depth is reached. When the core is broken off, it shall be withdrawn, labeled, and stored before the drilling is continued.

The drilling into rock shall be done with a double or triple split-tube core barrel and side discharge diamond bit, which will produce a core from the rock penetrated. The core will be a minimum of 55 mm in diameter.

The Contractor shall exercise due care to obtain satisfactory cores with at least 85 percent recovery in bed rock and boulders. In case it is impossible to obtain the required percentage of recovery, the Contractor shall maintain a maximum percentage by regulating the speed and rate of feed of the drill and the amount of drill water. The required core barrel will be at least 1.5 m long. If it proves to be impossible to obtain the necessary recovery through no fault of the Contractor, after he has used special care, methods, and equipment, the Engineer may relax the percentage requirements to fit the field conditions.

The rock cores shall be carefully placed in suitable wooden boxes that are partitioned so that the rock from each core run could be kept separately. Rock cores shall be suitably labelled and arranged neatly in the boxes, in the sequence in which the materials were removed from the hole. The depths of the top and bottom of the run and the amount of recovery shall be clearly marked. Rock cores from two borings shall not be placed in the same box. Core boxes shall be fully equipped with all necessary partitions, covers, hinges, screws for holding down the cover, and suitable identification plates and tags. All precautions will be taken to minimize disturbance of the rock core samples during transportation.

Selected specimen(s) of rock core may be designated by the Site Engineer for special packing and preservation. The selected specimen(s) shall be wrapped with aluminium foil and then placed inside a heavy-duty cardboard cylinder and sealed at both ends with a flexible microcrystalline wax.

5.1.4 Supplementary Borings

In the event of the executed borehole logs exhibiting varying subsurface conditions, the contractor shall forthwith submit in writing, the results of these boreholes to the Employer before demobilization.

The contractor may be required to bore additional boreholes as directed by the Employer's Engineer.

Drilled holes that are abandoned before reaching the specified depth because of mechanical failure of drilling equipment or other causes, shall be supplemented by another hole adjacent to the first, all at the contractor's cost.

Penetration to the depth where the hole was abandoned may be done by any method selected by the contractor that will permit completion of the new hole below the elevation where the last satisfactory sample was obtained in the abandoned hole and penetration shall be made and samples taken in the supplementary hole in the same manner specified for the original hole.

5.2 Standard Penetration Test

This test shall be conducted in all types of soil deposits met within a bore hole to find the variation in the soil stratification by correlating with the number of blows required for unit penetration of a standard penetrometer. This test shall be conducted at 1.5m intervals and every change of strata starting from 1.0m below ground level and as per the direction of the Engineer. The specifications for the equipment and other accessories, procedure for conducting the test and collection of disturbed soil samples shall conform to IS: 2131.

The test shall be carried out by driving a standard split spoon sampler in the bore hole by means of a 650 N. Hammer having a free fall of 0.75m. The sampler shall be driven using the hammer for 450mm recording the number of blows for every 150mm. The number of blows for every 150mm shall be recorded. The number of blows for the last 300mm drive shall be reported as N value. This test shall be discontinued when the blow count is equal to 100 or the penetration is less than 25mm for 50 blows whichever is earlier. At the location where the test is discontinued the penetration and the number of blows shall be reported. Sufficient quantity of disturbed soil samples shall be collected from the split spoon sampler for identification and laboratory testing. The sample shall be visually classified and recorded at the site and shall be properly preserved without loss of moisture content and labelled for future identification.

Retainer baskets, springs, or flap valves shall be used to ensure sample recovery.

Samples obtained shall be placed in ½ litre glass jars or approved equal and sealed with vapor-seal lids. Each jar shall be clearly identified with the use of a waterproof marker, and shall show the job name, boring number, sample number, depth, length of recovery, and standard penetration resistance.

5.3 Sampling

5.3.1 General

- a. Sufficient number of soil samples shall be collected for reliable estimation of soil properties. The samples collected shall be either disturbed or undisturbed. Disturbed soil samples shall be collected for field identification and conducting tests such as sieve analysis, index properties, specific gravity, chemical analysis, etc. Undisturbed samples shall be collected to estimate the physical, strength and settlement properties of the soil.
- b. All the accessories required for sampling and the method of sampling shall conform to IS: 2132. All the disturbed and undisturbed samples collected in the field shall be classified at the site as per IS: 1498.
- c. All the samples shall be identified with date, bore hole number or trial pit number, depth of sampling etc. It is also essential to mark an arrow pointing towards the top surface of the sample as the soil

was in-situ. Care shall be taken to keep the core samples and box samples vertically with the arrow directing upwards. The tube samples shall be properly trimmed at both the ends and suitably capped and sealed with molten paraffin wax.

- d. When the collection of undisturbed soil sample at a specified depth is not possible, the reason for the same shall be indicated in the bore log. In such a case, undisturbed sampling may be replaced by Standard Penetration test for cohesion less soil or by field Vane Shear test for very soft to soft cohesive soil.
- e. Precaution shall be taken to ensure that there shall not be any change in moisture content and disturbance of the soil samples, and they shall be placed in a temporary store at the end of the day's work. The contractor shall be responsible for packing and transporting of all the samples from site to the laboratory within seven days after sampling with proper protection against loss and damage.

5.3.2 Disturbed Sample

- a. Disturbed soil samples shall be collected in bore holes at regular intervals to provide a complete description of soil profile and its variation. Jar samples weighing approximately 10 N shall be collected in boreholes at 1.5m intervals starting from a depth of 0.5m below ground level and at every identifiable change of strata to supplement the boring records. Samples shall be immediately stored in airtight jars and shall fill the jar as far as possible.
- b. In elevated areas, if superficial material is available in plenty, then bulk samples from a depth of about 0.5m below ground level shall be collected to establish all the required properties to use it as a fill material. Disturbed samples weighing about 25 Kg. shall be collected at shallow depths and immediately stored in polythene bags as per IS:1892. The bags shall be sealed properly to avoid any change in moisture content, and they shall be kept in wooden boxes.

5.3.3 Undisturbed Sample

In each borehole undisturbed sample shall be collected at regular intervals of 3.0m and every change of strata and as directed by the Engineer. Samples shall be as per IS code. Samples shall be collected in such a manner that the structure of the soil and its moisture content do not get altered. Undisturbed sampling in sand shall be done using compressed air technique mentioned in IS: 8763. Thin-walled sampler shall be used to collect undisturbed samples by pushing the tube into the soil. The sampling tube shall have a smooth finish on both surfaces and minimum effective length as specified in IS code. The area ratio of sampling tubes shall be less than 10%. However, in case of stiff soils, area ratio up to 20% shall be permitted.

5.3.4 Undisturbed sampling in cohesive soil

Undisturbed samples in soft to stiff cohesive soils shall be obtained using a thin-walled sampler. In order to reduce the wall friction, suitable precautions such as oiling the surfaces shall be taken. The bore hole shall be cleaned and the depth of sampling below the ground level shall be noted. The sampler shall then be attached to the bottom of the boring rods and lowered into the borehole. The sampler shall be pushed into the clay layer by hand or by jacking and soil sample of specified length shall be collected without disturbing the soil. The distance by which the sampler penetrates the soil strata shall be checked, care being taken to ensure that the sampler is not driven too far as this will compress the soil. The sampler shall be rotated to break the core at the bottom of the sampler and then steadily drawn up.

5.3.5 Undisturbed Sampling using Piston Sampler

Undisturbed samples in very loose saturated sandy and silty soils and very soft clays shall be obtained by using a piston sampler consisting of a sampling cylinder and piston system. In soft clays and silty clays, with water standing in the casing pipe, piston sampler shall be used to collect undisturbed samples. During this method of sampling expert supervision is called for.

The interior surface of the sampler shall be smooth, clean and corrosion resistant. Its cutting edge and the ring seats shall be inspected for wear and rejected if worn. Check shall be done to ensure that the moving parts of the sampler function freely before the sampler is lowered into the bore hole. While pushing the system into the soil and till the beginning of the sampling operations, the bottom of the piston shall be flush with the cutting edge of the sampler. At the depth of sampling, the piston should be fixed relative to the ground and the sampler cylinder shall be independently pressed down smoothly and continuously into the ground. If an obstruction is met, the sampler shall be withdrawn, and another sample taken after the obstruction is removed.

Accurate measurements of the depth of sampling, height of sampler, stroke and length of sample recovery shall be recorded. After the sampler is pushed to the required depth, both the sampler cylinder and piston system shall be drawing up together ensuring that there shall not be any disturbance to the sample which shall then be protected from changes in moisture content.

5.3.6 Relaxation during Sampling

- a. The sampler should be pushed into the soil and driving of sampler should be resorted to only when it cannot be pushed into the soil. This shall be done only with the permission of the Engineer and all the details about the same shall be recorded in the bore logs.
- b. In clays when N value is above 30, undisturbed samples may be replaced by standard penetration test.

5.4 Ground Water

- a. One of the following methods shall be adopted for determining the ground water table in bore holes as per IS: 6935 and as per the instructions of the Engineer. In permeable soils, the water level in the borehole shall be allowed to stabilise after depressing it adequately by bailing. When the water level inside the borehole is found to be stable, the depth of water level below ground level shall be measured. Stability of sides and bottom of the bore hole shall be ensured at all times.
- b. For both permeable and impermeable soils, the following method shall be suitable. The bore hole shall be filled with water and then bailed out to various depths. Observations on the rise or fall of water level shall be made at each depth. The level at which either a fall or a rise is observed, this shall be considered as the water table elevation. This shall be established by three successive readings of water level taken at an interval of two hours.

In case any variation in ground water level is observed in any special boreholes, then the water level in these boreholes shall be recorded during the course of the field investigation. Levels in nearby wells, streams, etc. if any shall also be noted whenever these readings are taken.

It is important that some standpipes and piezometers are installed, prior to the coming monsoon, in order to record the local effects and variations in the ground water level during that period.

Standpipes and Piezometers shall consist of 19mm internal diameter rigid unplasticized (UPVC) tubing. All the joints in the tubing shall be made of coupling sleeves. The top of UPVC tubing shall be enclosed in a 75mm diameter galvanised steel pipe of 1.5m length having a galvanised steel screw cap with well-greased threads and the cap shall be tightened such that it would be impossible to loosen by hand. The lower end of the pipe shall have four legs 6mm thick and 100mm long end welded to have projection of 25mm. The pipe shall be sealed into the ground with cement grout so that it does not rotate. The top end of the pipe shall project approximately 300mm above ground level unless otherwise specified by the Engineer.

The perforated tubing or the porous element shall be surrounded by a response zone of well graded sand from 500mm below to 150mm above the lower end of the standpipe or Piezometer, and the borehole above the response zone shall be back filled with natural soil or well graded sand. The later shall compose of particles that vary in amount according to the size in such a manner that the void space formed by the larger particles can be filled by smaller size particles.

5.4.1 Subsoil Water Samples

- a. Sub-soil water samples shall be collected for carrying out chemical analysis thereon. Representative samples of ground water shall be collected when it is first encountered in bore holes before the addition of water to aid boring or drilling. Water samples shall not be collected when bentonite slurry or mud has been used for drilling operation. If water has been added for drilling purposes or if ground

water has been diluted by surface rainwater, then the bore hole shall be dewatered, and water allowed to rise from which the sample may be taken.

- b. The sampling apparatus shall be such that the water at the desired depth can be collected directly without any disturbance and any change in the concentration of the constituents like dissolved gases, etc. Undue agitation shall be avoided. An ordinary suction pump with the suction end inserted up to the required depth in the borehole shall be used for this purpose.
- c. The sample shall be collected in a clean vessel and allowed to settle so that the supernatant liquid can be poured into a clean well-rinsed glass or polythene bottle. Sufficient quantity and number of samples shall be collected to carry out the chemical analysis and sent to a laboratory in airtight bottles with proper labelling, chemical analysis of water samples shall include determination of pH value, turbidity; sulphate, carbonate, nitrate and chloride contents; presence of organic matter and suspended solids.
- d. In some cases, constituents may be mixed and analysed later as specified in the specific test methods. Chemical preservatives may be added to the sample for cases as specified in the test method or IS codes. This shall only be done if analysis cannot be conducted within an hour of collection and shall have the prior written permission and approval of the Engineer.

5.5 Trial Pit

Trial pit shall be of minimum 3m x 3m size at the bottom so as to permit easy access for visual examination of walls of the pit and to facilitate sampling and in-situ testing operations. Pits shall be up to 2m deep or as per the directions of the Engineer. Precautions shall be taken to ensure the stability of pit walls including provision of shoring, if necessary, as per IS:4453. Precautions shall be taken to prevent surface water draining into the pit. Arrangements shall be made for dewatering if the pit is extended below water table. Trial pits shall be kept dry, and a ladder shall be provided for easy access to the bottom of the pit. In-situ tests shall be conducted, and undisturbed samples shall be collected immediately on reaching the specified depth so as to avoid substantial changes in moisture content of the subsoil. Arrangements shall be made for barriers, protective measures and lighting necessary for the period the pits remain open.

A note on the visual examination of soil strata shall be prepared. This should include the nature, colour, consistency and visual classification of the soil, thickness of soil strata, ground water table, if any, etc.

Undisturbed samples shall be collected at 1.0m depth and at the termination depth in all pits.

5.5.1 Chunk Samples

In cohesive soils, undisturbed samples of regular shapes shall be collected. The samples shall be cut and trimmed to a suitable size (0.3 x 0.3 x 0.3m). A square area (0.35 x 0.35m) shall be marked at the centre of the levelled surface at the bottom of the pit. Without disturbing the soil inside the marked area, the soil

around this marking shall be carefully removed up to a depth of 0.35m. The four vertical faces of the soil block protruding at the centre to be trimmed slowly so that its size reduces to 0.3x0.3m. Wax paper cut to suitable size shall be wrapped uniformly covered with two layers of thin cloth over all the 5 exposed surfaces of the soil block and sealed properly using molten wax. A firmly constructed wooden box of size 0.35 x 0.35 (internal dimensions) with the top and bottom open shall be placed around the soil block and held such that its top edge protrudes just above the surface of the block. The space between the soil block and the box shall be filled uniformly and tightly with moist sawdust. The top surface shall also be covered with sawdust before nailing the wooden lid to cover the box firmly taking care that the soil block is not disturbed. The area of contact between the bottom portion of the block and the ground shall be reduced slowly by removing soil in small quantities using small rods, so that the block can be separated from the ground slowly without disturbance. After inverting the wooden box along with the soil block, the bottom portion shall be trimmed and covered with wax paper, cloth and sealed with molten wax. A wooden lid shall be nailed to the box after providing proper saw dust cushion below it. An arrow mark shall be made on the vertical face of the wooden box to indicate the made on the vertical face of the wooden box to indicate the top surface along with the coordinates and depth of sampling.

5.5.2 Tube Samples

Undisturbed tube samples may also be obtained by means of a 100mm diameter sampling tube with a cutting edge. The sampler shall be slightly oiled or greased inside and outside to reduce friction. The sampler shall be pushed into the soil and while doing so, soil around the tube shall be carefully removed. In case it is not possible to push the sample, it may be driven by light blows from a monkey.

After the completion of the test, sampling and visual examination, the pit shall be suitably backfilled as directed by the Engineer. Unless otherwise specified, excavated soil shall be used for this purpose.

In each trial pit the soil in-situ density shall be determined by the sand replacement method. The specifications, equipment, accessories required for the test and test procedure shall be as per IS:2720, Part XXVIII. No separate payment shall be made for this test.

6 LABORATORY TESTING

6.1 Essential Requirements

1. Laboratory should be NABL accredited.
2. Depending on the type of substrata encountered, appropriate laboratory tests shall be conducted on soil and rock samples collected in the field. Laboratory tests shall be scheduled and performed by qualified and experienced personnel who are thoroughly conversant with the work. Tests shall be performed on soil water and rock samples as per relevant IS codes indicated in section 4.0. One copy of all laboratory test data records shall be submitted to the owner progressively every week. Laboratory tests shall be carried out concurrently with field investigation since initial laboratory test results could be useful in planning the later stages of field work. A schedule of laboratory tests shall be established by the Contractor within one week of completion of the first borehole shall be submitted to the Engineer for his approval.
3. Laboratory tests shall be conducted using approved apparatus complying with the requirements and specifications of Indian Standards or other approved standards for this class of work. It shall be checked that the apparatus is in good working condition before starting the laboratory tests. Calibration of all the instruments and their accessories shall be done carefully & precisely. The calibration results shall be made available to the Engineer if desired so. All the laboratory tests shall be conducted at an approved laboratory.
4. All samples, including undisturbed, shall be extracted prepared and examined by competent personnel properly trained and experienced in soil sampling, examination, testing and in using the apparatus as per the specified standards.
5. Undisturbed soil samples retained in liners or seamless tube samples shall be taken out without causing any disturbance to the samples using suitably designed extruders just prior to actual testing. If extruder is horizontal, proper support shall be provided to prevent the samples from breaking. For screw type extruders, the pushing head shall be free from the screw shaft so that no torque is applied to the soil sample, the sample tube shall be cut by means of a high-speed hacksaw to proper test length and placed over the mould before pushing the sample into it with a suitable piston.
6. While extracting a sample from the liner or tube, care shall be taken to see that its direction of movement is the same as that during sampling to avoid stress reversal.
7. The Employer shall have the right of access to contractor's laboratory and/or any other laboratory where tests have been arranged to be carried out during the progress of this investigation. The contractor shall carry out the tests as listed out in the Schedule of Items, and/or as decided by the engi-

neer, in laboratory. He shall furnish the name/s of laboratories where he proposes to have the tests carried out and have them approved by the DSC.

8. Laboratory tests shall be carried out in consultation with the Engineer and as per relevant Indian Standard Codes. After completion of the field work, the contractor shall supply a detailed schedule of laboratory tests proposed, along with the borelogs, to be conducted on the samples collected. Laboratory tests shall commence only after the schedule is approved by the DSC.

6.2 Tests

Tests as indicated in this specification and as called for by the Engineer shall be conducted.

These tests shall include but not be limited to the following:

1. Tests on Undisturbed and Disturbed Samples
 - a. Bulk density and moisture content
 - b. Visual and Engineering classification
 - c. Sieve analysis and Hydrometer analysis
 - d. Attenberg limits test (Liquid, plastic and shrinkage limits)
 - e. Specific gravity
 - f. Chemical analysis
 - g. Swell pressure and free swell index determination (if required)
 - h. Proctor compaction test
 - i. California Bearing Ratio (CBR) Test
2. Tests on Undisturbed Samples
 - a. Bulk density and moisture content
 - b. Relative density (for sand)
 - c. Unconfined Compressive Strength Test
 - d. Triaxial shear test
 - e. Direct Shear Test (in case of sand)
 - f. Consolidation Test
3. Chemical analysis of soil and water samples shall be carried out for pH value, sulphate, chloride and other organic content in ppm and percentage
4. Electrical Resistivity Test

6.3 Salient Test Requirements

- ✚ Remoulded soil specimen, whenever desired, shall be fully reworked at field density and moisture content. For conducting CBR test the sample shall be remoulded to 98% of Modified proctor density or as directed by the Engineer.

- ✚ Direct shear test shall be conducted on undisturbed samples. The three normal vertical stresses for each test shall be 100, 200, 300 KN/sqm or as required as per the soil conditions.
- ✚ Chemical analysis of sub-soil shall include determination of pH value, carbonate, sulphate (both SO_3 and SO_4), chloride and nitrate contents, organic matter, salinity and any other chemical harmful to the foundation material. The contents in soil shall be indicated as percentage (%).
- ✚ Chemical analysis of sub-soil water sample includes the determination of the properties such as colour, odour, turbidity, pH value and specific conductivity both at 25 deg. C and chemical contents such as carbonates, sulphates (both SO_3 and SO_4), chlorides, nitrates, organic matter and any other chemical harmful to the foundation material. The contents such as sulphates etc. shall be indicated as ppm by weight.
- ✚ The lab CBR test shall be performed on remoulded samples for soaked and unsoaked conditions.

7 REPORT

7.1 General

On completion of all the field and laboratory works, the Contractor shall submit report containing Geological information of the region, procedure adopted for investigation, field observations, summarised test data, conclusions, and recommendations. The report shall include detailed bore logs, subsoil sections, field test results, laboratory observations and test results both in tabular as well as graphical form, practical and theoretical considerations for the interpretation of test results, the supporting calculations for the conclusions drawn, etc.

7.2 Data to be furnished

The report shall also include but not be limited to the following:

1. A plot plan showing the locations with nearby landmark, properties etc. showing Latitude/ Longitude. Reduced levels of all field tests e.g., bore holes, trial pits, etc., properly drawn to scale and dimensioned with reference to the established grid lines.
2. A description of regional geology including past observations and historical data, if available, for the area or for other areas having similar soil profile with similar structures in the surrounding areas.
3. A description of the procedures of investigation and testing employed and list of equipment used.

4. A true cross-section of all individual boreholes and trial pits with reduced levels and coordinates showing the classification and thickness of individual stratum, position of ground water table, various in-situ tests conducted, and samples collected at different depths and the rock stratum, if met with.
5. A set of longitudinal and transverse soil/rock profiles vertical scale 1:2000 connecting various boreholes in order to give a clear picture of the variation of the subsoil strata as per IS:6065, for a particular side.
6. The stress-strain diagrams as well as Mohr circle envelopes for unconfined compression tests and triaxial tests.
7. 'e' vs log 'p', compression vs. log 'f' or compression vs. 'square root t' plots depending upon the shape of the plot to determine the coefficient of consolidation
8. 'Cv' and time for 50 and 90 primary consolidation.
9. Coefficient of volume decrease (m_v) and shall be determined and reported. Pre-consolidation pressure shall be determined for each test and shall be taken into consideration in recommending the anticipated settlement along with the time to achieve the same.
10. Plot of Standard Penetration Test (N-values both uncorrected and corrected) with depth for identified areas.
11. The levels at which each separate ground water level is first encountered and at which it comes to rest (standing water level).
12. Any other information of special significance encountered during the investigation and likely to have a bearing on the design and construction of foundations.
13. Photographs of field and laboratory activities shall be included in each copy of the report.
14. Results of all laboratory tests shall be summarised and a consolidated table giving the layer-wise soil and rock properties in a standard format. The relevant tables, graphs, figures, drawings, supporting calculations, conclusions and photographs of representative rock cores and trial pits shall be furnished.

7.3 Recommendations

Recommendations shall be given area-wise duly considering the type of soil, structure, and foundation in the area.

The recommendations shall include but not be limited to the following:

Type of foundations to be adopted for various structures and buildings, duly considering the sub soil characteristics, water table, total settlements permissible for structures and equipment. Minimum depth and width

of foundation in case of shallow foundations and the diameter and length of piles in case of deep foundations shall also be recommended. The provision in relevant IS codes indicated in clause 4.0 shall be considered.

- ✚ For shallow foundations, the safe bearing capacity shall be indicated with comprehensive supporting calculations
- ✚ For deep foundations safe vertical, horizontal & uplift load carrying capacities of piles in of different type including the diameter, length of piles shall be indicated with comprehensive supporting calculations.

7.4 Additional Recommendations:

Suitability of the soil for construction of roads and pavements, their stable slopes for shallow and deep excavations, active and passive earth pressures at rest, coefficient of sub-grade reaction and modulus of elasticity as a function of depth for the design of underground structures.

- ✚ Suitability of locally available soils at site for filling and backfilling purposes.
- ✚ If expansive soil is met within, recommendation on removal or retainment of the same under the structures/roads etc., shall be given. In the latter case detailed specifications of any special treatment required including specifications for materials to be used, construction method, equipment to be deployed, etc. shall be furnished.
- ✚ Protective measures based on chemical nature of soil and ground water with due regard to potential deleterious effects on concrete, steel and other building, materials etc. Remedial measures for sulphate attack and acidity shall be dealt in detail susceptibility of soil to terminate action and remedial measures for the same.
- ✚ Recommendations for dewatering schemes for deep excavations & constructions.
- ✚ Recommendations on the filling/grading of the area along with filling requirement should include type of material, compaction, etc. Recommendations on deep excavations – Excavation methods, Stable slope of excavation for various depths etc.

8 General & Payment Terms and Conditions

8.1 General Terms and Conditions

- ✚ The whole work will be completed within 5 days.
- ✚ Final outputs or deliverables reports of the Geotechnical works will have to begin after 10 days from start of Geotechnical Investigation works.

- ✚ The rates quoted shall remain valid for a period of 6 months. Adequate precaution and protection measures for conducting Geo-technical Investigation at site must be taken by the agency. The Contractor shall be responsible for the setting out of the position of each borehole. The prior approval for working at the site and using the access routes thereto shall be obtained by the Contractor from the Employer before commencing work.
- ✚ The Contractor shall be responsible for the provision of all necessary transport, whether for personnel, plant, stores, equipment or samples
- ✚ Geo-technical Investigation will be checked and verified from time to time by the Employer's Engineer and all instructions shall be strictly followed.

The Contractor is to supply suitable personnel to conduct the subsoil investigation and such personnel are to be skilled in the work required by the Contract. The work is to be done under the proper supervision of fully qualified personnel in their respective duties with regard to making borings, taking samples, identifying soils, carrying out in-situ tests and in carrying out tests in the laboratory.

- ✚ In addition, the Contractor shall maintain at site a representative who will be in overall charge of the works and who shall be thoroughly versed in all aspects of boring, sampling and the field testing work specified herein. The agency also has to depute one coordinator who will maintain liaison with the Employer's Engineer or his representative on day-to-day basis.
- ✚ Detail work plan will be submitted by the agency within 5 days from the date of issuing Work Order
- ✚ All works shall be carried out as per relevant IS codes and to the satisfaction of the Employer.
- ✚ The documents to be submitted by the agency are:
 - Three hardcopies and softcopy in CD/USB Pen drive of draft site wise report to be prepared as mentioned in sub heading 7.2 of this report and submitted to the Employer for their review and comments.
- ✚ For any rectifications/ modifications of report, it will be the responsibility of the agency to do the rectifications/ modifications work at his own risk and cost till the end of the project.
- ✚ The quantities are tentative and can increase or decrease as per field conditions. The rates would remain valid for any such variation. An item may also be totally deleted if decided by the Employer.
- ✚ Progress of work will be monitored regularly by Employer's Engineer. DSC reserves the right to reduce the scope of work or cancel the work order at any time without showing any reasons thereof.

8.2 Terms of Payment

- ✚ No Mobilization Advance
- ✚ 40% on completion of the fieldwork raising the bill with proof of completion of field works – on pro rata basis (Site wise).
- ✚ 20% on receipt of the draft drawings/reports from the Agency.
- ✚ 30% on receipt of corrected drawings/reports from the Agency incorporating the changes suggested or errors rectification and acceptance of the DSC Engineer.
- ✚ 10% will be released after client approval.
- ✚ TDS will be deducted as per rules applicable.