

SECTION-III

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**TECHNICAL SPECIFICATION
(SECTION – III)**

SURVEY & SOIL INVESTIGATION

1. General Information & Scope Of Work

1.1 The technical specifications covers detailed survey including route alignment, profiling, tower spotting, optimization of locations, check survey, contouring, and soil investigation for the transmission lines / part of the transmission lines covered under this specification as included in the BPS.

1.1.1 The scope of work inter-alia shall include the following:-

- a. Detailed Survey using DGPS, Total Work stations, or alternatively using ALTM (Airborne Laser Terrain Modeling) techniques, inter-alia including :
 - i. Digitised profiling along the selected route along with plan details.
 - ii. Computer aided tower spotting & optimization
 - iii. Soil resistivity measurement along the route
- b. Check survey including digitised contouring at undulated / hilly tower locations.
- c. Soil Investigation
- d. Preparation of Survey reports including estimation of Bill of Quantities, identification and explanation of route constraints (like Forest, Animal/Bird sanctuary, reserve coal belt areas, oil pipe line/underground inflammable pipe lines etc.), infrastructure details available en-route etc.
- e. Wherever, the scope of work is only for part of the line for route changes if any necessitated during execution on account of site constraints and done at the instance of Owner and where survey data for balance stretches have been provided by the Owner, the Contractor may use the satellite imageries/ digitized maps already available with the Owner to the extent applicable.

1.2 The Provisional quantities for the scope of work are indicated in relevant Price Schedules of BPS. The final quantities for route alignment & detailed survey (quantities in “km” unit) shall be the route length along the approved route alignment. For contouring at undulated/hilly tower locations and soil investigations (quantities in “Locs.” unit), the actual quantities to be executed shall be decided by Site Engineer-in-charge during execution stage and the final quantities shall be as approved by Site Engineer-in-charge. The route alignment, detailed survey, including profiling & tower spotting, contouring, soil

investigation etc shall be carried out by the Contractor as per the technical specifications stipulated herein.

- 1.3 The Contractor must note that the Owner shall not be responsible for loss or damage to properties, trees etc. due to contractor's work during survey. The Contractor shall indemnify the Owner for any loss or damage to properties, trees etc. during the survey work.
- 1.4 The Contractor should note that Owner will not furnish NRSA satellite imageries or topographical maps prepared by survey of India but will make available assistance that may be required in obtaining these by providing letters of recommendation to the concerned authorities. Further, in case the contractor opts for use of ALTM techniques for detailed survey, he shall be responsible for obtaining necessary clearances/permissions, as may be required from concerned authorities. The Owner will provide assistance that may be required in obtaining these clearances / permissions by providing letters of recommendation to the concerned authorities.
- 1.5 The bidder shall give along with their bid clause by clause commentary indicating their confirmation / comments/ observation in respect of all clauses of technical specification.
- 1.6 The work shall be carried out by the contractor using modern surveying techniques. The bidder shall indicate in his offer, the detailed description of the procedure to be deployed. The details of the equipment & facilities including computer aided tower spotting etc. available with the bidder or his associates shall also be furnished with the bid.
- 1.7 The Contractor shall also engage services of a reputed geo-technical consultant or experts from independent educational/research institutions for examining stability aspects of the selected transmission line route/locations in hilly terrain wherever required.
- 1.8 After carrying out the detailed survey and soil investigations, the contractor shall estimate complete BOQ of the transmission lines and submit the same (as per the BOQ format enclosed with the Technical Specifications) to the Owner.

2. Route Alignment

- 2.1 Wherever the route Alignment has already been carried out for the line using satellite imageries of NRSA (PAN & LISS-III merged product) and Survey of India topographical maps (scale 1:50000), any changes necessitated during execution stage in the route alignment, same shall be carried out by the contractor using satellite imageries / topographical maps.
- 2.2 **Requirement of Transmission Line Routing** (for changes if any necessitated on account of site constrains etc.):

- 2.2.1. The Re-alignment, if any required, of the transmission line shall be most economical from the point of view of construction and maintenance. The contractor shall identify & examine alternative route alignments and suggest to the Owner the optimal route alignment.
- 2.2.2. Routing/Re-routing of transmission line through protected/reserved forest area should be avoided. In case it is not possible to avoid the forests or areas having large trees completely, then keeping in view of the overall economy, the route should be aligned in such a way that cutting of trees is minimum.
- 2.2.3. The route should have minimum crossings of Major river, Railway lines, National/State highways, overhead EHV power line and communication lines.
- 2.2.4. The number of angle points shall be kept to minimum.
- 2.2.5. The distance between the terminal points specified shall be kept shortest possible, consistent with the terrain that is encountered.
- 2.2.6. Marshy and low lying areas, river beds and earth slip zones shall be avoided to minimize risk to the foundations.
- 2.2.7. It would be preferable to utilize level ground for the alignment.
- 2.2.8. Crossing of power lines shall be minimum. Alignment will be kept at a minimum distance of 300 m from power lines to avoid induction problems on the lower voltage lines.
- 2.2.9. Crossing of communication line shall be minimized and it shall be preferably at right angle. Proximity and parallelism with telecom lines shall be eliminated to avoid danger of induction to them.
- 2.2.10. Areas subjected to flooding such as nalah shall be avoided.
- 2.2.11. Restricted areas such as civil and military airfield shall be avoided. Care shall also be taken to avoid aircraft landing approaches.
- 2.2.12. All alignment should be easily accessible both in dry and rainy seasons to enable maintenance throughout the year.
- 2.2.13. Certain areas such as quarry sites, tea, tobacco and saffron fields and rich plantations, gardens & nurseries which will present the Owner problems in acquisition of right of way and way leave clearance during construction and maintenance should be avoided.
- 2.2.14. Angle points should be selected such that shifting of the point within 100 m radius is possible at the time of construction of the line.

- 2.2.15. The line routing should avoid large habitations, densely populated areas, Forest, Animal/Bird sanctuary, reserve coal belt areas, oil pipe line/underground inflammable pipe lines etc. to the extent possible.
- 2.2.16. The areas requiring special foundations and those prone to flooding should be avoided.
- 2.3 For examination of the alternatives & identification of the most appropriate route, besides making use of information/data/details available/extracted through Survey of India Topographical maps and computer-aided processing of NRSA's satellite imagery, the contractor shall also carryout reconnaissance/preliminary survey as may be required for verification & collection of additional information /data /details.
- 2.4 The contractor shall submit his preliminary observations & suggestions along with various information/data /details collected and also processed satellite imagery data, scanned topographical map data marked with the alternative routes etc. The final evaluation of the alternative routes shall be conducted by the contractor in consultation with Owner's representatives and optimal route alignment shall be proposed by the contractor. Digital terrain modeling using contour data from topographical maps as well as processed satellite data shall be done by the contractor for the selected route. A fly through perspective using suitable software(s) shall be developed for further refinement of the selected route, if required. Site visit and field verification shall be conducted by the contractor jointly with the Owner's representative for the proposed route alignment.
- 2.5 Final digitized route alignment drawing with latest topographical and other details/features including all rivers, railway lines, canals, roads etc. up to 8 kms on both sides of selected route alignment shall be submitted by the contractor for Owner's approval along with report containing other information/details as mentioned above.
- 2.6 Changes in the route alignment, if any, during detail survey, shall be incorporated in the final digitized route alignment drawings.

3. Detailed Survey

- 3.1 The detailed survey shall be carried out using DGPS, Total stations, etc. along the approved route alignment. As an alternative, the contractor may also use ALTM (Airborne Laser Terrain Modeling) techniques of equal or better accuracy for the detailed survey.
- 3.2 Soil resistivity, along the route alignment shall be measured in dry weather by four electrode method keeping inter-electrode spacing of 50 mtrs. For calculating soil resistivity formula $2\pi ar$ (Where $a=50$ m and $r=$ megger reading in ohms)

shall be adopted. Measurement shall be made at every 2 to 3 km along the length of the route. In case soil characteristics changes within 2 to 3 km, values shall have to be measured at intermediate locations also. Megger reading and soil characteristics should also be indicated in the soil resistivity results.

3.3 Route Marking

3.3.1. The route of the transmission line shall be recorded using GPS/DGPS of positional accuracy less than 3m.

3.3.2. The co-ordinates of all the angle points as well as other important crossings, landmarks etc. shall be recorded using GPS for easy relocating.

3.3.3. At the starting point of the commencement of route survey the co-ordinates shall be recorded. A punch mark on the top section of the angle iron shall be made to indicate location of survey instrument. The co-ordinates of the location of the survey instrument shall also be recorded. Further, the co-ordinates at prominent position at intervals of not more than 750 meter along the transmission line to be surveyed up to the next angle point shall also be recorded. Wooden peg 50 x 50 x 650 mm size shall also be driven at prominent position at intervals of not more than 750 meters along the transmission line to be surveyed up to next angle point. Wire nails of 100 mm length should be fixed on the top of these pegs to show the location of instrument. The pegs shall be driven firmly into the ground to project 100mm only above the ground level. Wherever the line alignment crosses the EHT line, Railway line, P&T line or roads, the contractor shall record co-ordinates on the points of crossing. Wherever line route alignment passes over permanent land marks such as rock, boulders, culverts etc. suitable white paint marks with directional and Owner markings shall be made and co-ordinates recorded. At angle position stone / concrete pillars of 150 x 150 x 1000 mm in size with TPTL marked on them shall be embedded into the ground for easy identification.

3.4 Profiling

3.4.1. The complete profiling along the route shall be carried out using modern surveying equipments viz. total stations, DGPS etc. Reference levels at every 20 metres along the route are to be recorded. R/Ls at other undulations along the route as well as in the route plan and other enroute details viz. crossings, building & structures, trees & other infrastructure etc shall also be recorded. Areas along the route, which in the view of the contractor, are not suitable for tower spotting, shall also be marked.

3.4.2. The complete profiling details shall be digitized and the data shall be prepared & stored in the format compatible to computer-aided tower spotting software.

3.4.3. A printed/plotted output of the digitized profiling shall be submitted by the contractor to Owner site-in-charge for review before taking up computer-aided tower spotting.

3.5 Optimisation of Tower Location / Tower Spotting

3.5.1. Optimisation of tower locations including profiling shall be done by the contractor using computer-aided tower spotting software - PLSCADD and shall furnish sample calculations and manual tower spotting drawings for some typical sections.

3.5.2. The sag-tension characteristics of the conductor as well as tower spotting data shall be furnished by the Owner to the contractor during execution stage. Sag template curves , if any required for tower spotting, shall be prepared by the contractor.

3.5.3. General description of towers is indicated in Section-I of this specification for information of the Bidders.

3.5.4. Tower Spotting

While profiling & spotting the towers, the following shall be borne in mind:

a) Span

The number of consecutive spans between the section points shall not exceed 15 spans or 5 Km in plain terrain and 10 spans or 3km in hilly terrain. A section point shall comprise of tension point with DB type or DC type or DD type towers as applicable.

b) Extension/Truncation

An individual span shall be as near to the normal design span as possible. In case an individual span becomes too short with normal supports on account of undulations in ground profile, one or both the supports of the span may be extended by inserting standard body/leg extension. In case of locations where the ground clearance is available, truncated towers may be spotted. The provisions kept in the design of towers w.r.t. body/leg extns , truncations shall be intimated to the contractor by the Owner during execution stage.

c) Loading

There shall not be any upward force on suspension towers under normal working conditions and the suspension towers shall support at least the minimum weight span as provided in the designs. In case uplift is unavoidable, it shall be examined if the same can be overcome by adding standard body

extensions to the towers failing which tension towers designed for the purpose shall be deployed at such positions.

d) Road Crossing

At all important road crossings, the tower shall be fitted with normal suspension and tension insulator strings depending on type of tower but the ground clearance at the roads under maximum temperature and in still air shall be such that even with conductor broken in adjacent span, ground clearance of the conductor from the road surfaces will not be less than specified minimum ground clearance. At all national highways DD type towers with double tension insulator strings shall be used and crossing span will not be more than 250 meters.

e) Railway Crossings

All the railway crossings coming-enroute the transmission line shall be identified by the Contractor. At the time of detailed survey, the railway crossings shall be finalised as per the regulation laid down by the Railway Authorities. The following are the important features of the prevailing regulations (revised in 1987)

- i) The crossings shall be supported on DD type tower on either side depending on the merits of each case.
- ii) The crossing shall normally be at right angle to the railway track.
- iii) The minimum distance of the crossing tower shall be at least equal to the height of the tower plus 6 meters away measured from the centre of the nearest railway track.
- iv) No crossing shall be located over a booster transformer, traction switching station, traction sub-station or a track cabin location in an electrified area.
- v) Minimum ground clearance above rail level of the lowest portion of any conductor under condition of maximum sag shall be maintained at 17.90 m for 400KV transmission lines.
- vi) The crossing span will be limited to 300 meters.

f) River Crossings

In case of major river crossing, towers shall be of suspension type along with anchor towers of DD type tower on either side of the main river crossing. Alternately on the basis of economics and / or site/ execution constraints crossing of rivers using extended angle towers also shall be considered. For navigable rivers, clearance required by navigation authority shall be provided. For non

navigable river, clearance shall be reckoned with respect to highest flood level (HFL).

g) Power line Crossings

Where the line is to cross over another line of 132 kV or above voltage DD type tower with suitable extensions shall be used depending upon merit of the prevailing site condition. For line crossings of lower than 132kV level suspension / tension tower with suitable extension may be used depending upon merit of the prevailing site condition. Provisions to prevent the possibility of its coming into contact with other overhead lines shall be made in accordance with the Indian Electricity Rules, 1956 as amended up-to-date. In order to reduce the height of the crossing towers, it may be advantageous to remove the ground-wire of the line to be crossed (if this is possible, and permitted by the Owner of the line to be crossed).

Minimum clearance in metres between lines when crossing each other:

Sl. No.	Nominal System Voltage	110-132KV	220KV	400KV	765KV
1.	110-132KV	3.05	4.58	5.49	7.94
2.	220KV	4.58	4.58	5.49	7.94
3.	400KV	5.49	5.49	5.49	7.94
4.	765KV	7.94	7.94	7.94	7.94

h) Telecommunication Line Crossings

The angle of crossing shall be as near to 90 degree possible. However, deviation to the extent of 30 degree may be permitted under exceptionally difficult situations.

When the angle of crossing has to be below 60 degree, the matter will be referred to the authority in charge of the telecommunication System. On a request from the Contractor, the permission of the telecommunication authority may be obtained by the Owner.

Also, in the crossing span, power line support will be as near the telecommunication line as possible, to obtain increased vertical clearance between the wires.

i) Details En-route

All topographical details, permanent features, such as trees, building etc. 23 m for 400 KV line on either side of the alignment shall be detailed on the profile plan.

3.6 Clearance from Ground, Building, Trees etc.

Clearance from ground, buildings, trees and telephone lines shall be provided in conformity with the Indian Electricity Rules, 1956 as amended upto date.

3.6.1. The Contractor shall count, mark and put proper numbers with suitable quality of paint at his own cost on all the trees that are to be cut by the Owner at the time of actual execution of the work as detailed below. Contractor may please note that Owner shall not pay any compensation for any loss or damage to the properties or for tree cutting due to Contractor's work.

3.6.2. To evaluate and tabulate the trees and bushes coming within 23 m for 400 KV line on either side of the central line alignment the trees will be numbered and marked with quality paint serially from angle point 1 (I) onwards and the corresponding number will be painted on the stem of trees at a height of 1 meter from ground level. The trees list should contain the following:

- a) Girth (circumstances) measured at a height of 1 meter from ground level.
- b) Approximate height of the tree with an accuracy of +2 meters.
- c) Name of the type of the species/tree.
- d) The bushy and under growth encountered within the 46 m for 400 kV line should also be evaluated with its type, height, girth and area in square meters, clearly indicating the growth in the tree/bush statement.

3.6.3. The contractor shall also intimate the Owner his assessment about the likely amount of tree & crop compensation etc. required to be paid by the Owner during execution stage. This assessment shall be done considering prevailing practices/guidelines, local regulations and other enquiries from local authorities.

3.6.4. The Contractor shall also identify the forest/non forest areas involved duly authenticated by concerned authorities.

- a) A statement of forest areas with survey/compartament Nos.(all type of forest RF/PF/Acquired forest/Revenue forest/Private forest/Forest as per dictionary meaning of forest etc.)
- b) A statement of non-forest areas with survey/compartament nos.
- c) Tree cutting details(Girth wise & specie wise)

- d) Marking of forest areas with category on topo sheets 1:2,50,000 showing complete line route, boundaries of various forest divisions and their areas involved.
- e) Village forest maps of affected line and affected forest area and marking of the same.
- f) Forest division map showing line and affected forest area.

3.6.5 The Contractor shall finalize the forest clearance proposal on the prescribed format as per requirements of the state/MOE&F, duly completed in all respects for submission by the Owner to the Forest Department.

3.7 Preliminary Schedule

The profile sheets showing the locations of the towers together with preliminary schedules of quantities indicating tower types, wind & weight spans, angle of deviation, crossing & other details etc. shall be submitted by the contractor for review & approval by Owner's site-in-charge.

3.8 Check Survey of Tower Locations

3.8.1. The check survey shall be conducted to locate tower locations on ground conforming to the approved profile and tower schedule.

3.8.2. The co-ordinates of all the tower locations shall also be recorded using GPS/DGPS of positional accuracy less than 3m for easy relocating. The position of all tower locations shall be marked in the final digitized route alignment drawing with relative distances from any permanent bench mark area.

3.8.3. The contractor shall also collect required data at each tower location in respect of soil strata, ground water level, history of water table in adjacent areas/surface water, distance from permanent bench mark (these details to be furnished in a tabulated form) and classify the suitable type of foundation at each tower location based on the data collected at each location and detailed soil investigations carried out at selected locations etc.

3.9 Contouring at hilly/undulated locations

3.9.1. The levels up or down of each pit centre with respect to centre of tower location shall be recorded at intervals of 2m using total stations/GPS/digital theodolite and digitized contour plans shall be made. Based on the digitized elevation plans, the quantities of benching & protection work vis-à-vis possible unequal leg extensions shall be optimized using suitable computer-aided techniques/software. Required tower and foundation details, cost data for comparative evaluation for benching & protection work vis-à-vis unequal leg

extensions shall be provided by the Owner to the Contractor during execution stage.

3.10 The changes desired by the Owner in the preliminary tower schedule or as may be required based on detailed survey of tower locations & contouring by the contractor, shall be carried out by the contractor and the final tower schedule shall be submitted for approval of Owner. The tower schedule shall show position of all type of towers, span length, type of foundation for each tower, benching & revetment requirement, unequal leg extensions, deviation at all angles, crossings & other details etc.

3.11 Survey Methodology & Precision

3.11.1. All elevations shall be referenced to benchmarks established by the survey of India. Survey operations shall begin and end at benchmarks approved by the Owner.

3.11.2. During the leveling of the profile, check surveys will be effected at intervals not exceeding 50 km with benchmarks of known elevations. The difference in elevations as surveyed by the contractor and as declared by Survey of India for these benchmarks shall not exceed the precision required for 3rd order surveys $e \leq 24k$ where k is the distance between benchmarks in km and e is the difference between elevations in mm.

3.11.3. In the absence of suitable benchmarks the leveling shall be done by two independent leveling parties working in opposite directions along the same line. The difference in elevations between the two surveys shall not exceed the precision required for 3rd order surveys as stated above.

3.11.4. All important objects and features along the transmission line centerline (railways, highways, roads, canals, rivers, transmission lines, distribution lines, telephone lines etc.) shall be surveyed and located with a positional accuracy of 1:2000 between points of known horizontal position.

3.12 Survey Report

3.12.1. Complete BOQ of the transmission lines as per format enclosed with this technical specifications at Annexure-A shall be furnished in the survey report.

3.12.2. Each angle point locations shall be shown with detailed sketches showing existing close by permanent land marks such as specific tree(s), cattle shed, homes, tube wells, temples, electric pole/tower, telephone pole, canal, roads, railway lines etc. The relative distance of land marks from the angle points and their bearings shall be indicated in the sketch. These details shall be included in the survey report.

- 3.12.3.** Information w.r.t infrastructure details available en-route, identification and explanation of route constraints, etc shall also be furnished in the Survey report and shall inter-alia include the following:
- 3.12.3.1.** Information regarding infrastructural facilities available along the final route alignment like access to roads, railway stations, construction material sources (like quarry points for stone, sand and availability of construction water), labour, existing transport facilities , fuel availability etc. shall be furnished in the survey report.
 - 3.12.3.2.** All observations which the Contractor thinks would be useful to the construction of the transmission lines mentioned under scope of work are to be reported.
 - 3.12.3.3.** Suggestions regarding the number of convenient zones (line segments / portions) in which the entire alignment can be divided keeping in view the convenience of corporation are to be given.
 - 3.12.3.4.** Suggestions regarding location for setting up stores during line construction in consultation with Owner's representative shall also be provided by the contractor.
 - 3.12.3.5.** Working months available during various seasons along the final route alignment, with period, time of sowing & harvesting of different type of crops and the importance attached to the crops particularly in the context of way leave problems and compensation payable shall be stated by the Contractor.
 - 3.12.3.6.** Availability of labour of various categories and contractors of civil works shall also be reported.
 - 3.12.3.7.** Some portions of the line may require clearance from various authorities. The Contractor shall indicate the portion of the line so affected, the nature of clearance required and the name of concerned organizations such as local bodies, municipalities, P&T (name of circle), Inland navigation, Irrigation Department, Electricity Boards and Zonal railways, Divisional Forest Authorities etc.
- 3.12.4.** All the requisite data for processing the case for statutory clearances such as PTCC, Forest and Railway shall be provided along with the report.
- 3.12.5.** The contractor shall also collect & report (as per Formats enclosed at B) details pertaining to pollution levels envisaged along the transmission line.
- 3.12.6.** Six copies of survey reports shall be furnished by the contractor to the Owner.

4. Geotechnical Investigations

4.1 General

4.1.1. Owner requires that a detailed Geotechnical investigation be carried out at various tower locations to provide the designer with sufficiently accurate information, both general and specific, about the substrata profile and relevant soil and rock parameters at site on the basis of which the foundation of transmission line towers can be classified and designed rationally.

4.1.2. These specifications provide general guidelines for geotechnical investigation of normal soils. Cases of marshy locations and locations affected by salt water or saltpeter shall be treated as special locations and the corresponding description in these specifications shall apply. Any other information required for such locations shall be obtained by Contractor and furnished to Owner.

4.2 Scope

4.2.1. The scope of work includes detail soil investigations and furnishing bore log data at various tower locations. The provisional quantities have been indicated in Bill of Quantities. However, during actual execution of work, the quantities shall be decided by the Engineer - in - Charge, depending upon the soil strata and terrain. Based on the bore log data / soil parameter /soil investigation results, the Contractor shall recommend the type of foundations suitable for each locations and the same shall be got approved by the Owner.

4.2.2. These specifications cover the technical requirements for a detailed Geotechnical investigation and submission of a detailed Geotechnical Report. The work shall include mobilization of all necessary tools and equipment, provision of necessary engineering supervision and technical personnel, skilled and unskilled labour, etc. as required to carry out the entire field investigation as well as laboratory tests, analysis and interpretation of data collected and preparation of the Geotechnical Report. Contractor shall also collect data regarding variation of subsoil water table along the proposed line route. The aforementioned work shall be supervised by a graduate in Civil Engineering having at least 5 years of site experience in geotechnical investigation work.

4.2.3. Contractor shall make his own arrangements to establish the co-ordinate system required to position boreholes, tests pits and other field test locations as per the drawings/sketches supplied by Owner. Contractor shall determine the reduced levels (R.L's) at these locations with respect to benchmarks used in the detailed survey. Two reference lines shall be established based on survey data/details. Contractor shall provide at site all required survey instruments to the satisfactions of the Owner so that the work can be carried out accurately

according to specifications and drawings. Contractor shall arrange to collect the data regarding change of course of rivers, major natural streams and nalas, etc., encountered along the transmission line route from the best available sources and shall furnish complete hydrological details including maximum velocity discharge, highest flood level (H.F.L), scour depth etc. of the concerned rivers, major streams and nalas (canals).

- 4.2.4. The filed and laboratory data shall be recorded on the proforma recommended in relevant Indian Standards. Contractor shall submit to Owner two copies of field bore logs (one copy each to Owner site and Corporate Office) and all the field records (countersigned by the Owner) soon after the completion of each boreholes/test.
- 4.2.5. Whenever Contractor is unable to extract undisturbed samples, he shall immediately inform the Owner. Payment for boring charges shall be subject to Owner being satisfied that adequate effort has been made to extract undisturbed samples. Special care shall be taken for locations where marshy soils are encountered and Contractor in such cases shall ensure that specified number of vane shear tests are performed and the results correlated with other soil parameters.
- 4.2.6. One copy of all field records and laboratory test results shall be sent to Owner on a weekly basis. Owner may observe, at the laboratory testing procedures.
- 4.2.7. The Contractor shall interact with the Owner to get acquainted with the different types of structures envisaged and in assessing the load intensities on the foundation for the various types of towers in order to enable him to make specific recommendation for the depth, founding strata, type of foundation and the allowable bearing pressure.
- 4.2.8. After reviewing Contractor's geotechnical investigation draft report, Owner will call for discussions, to be held normally within one week at Owner's site Office, in order to comment on the report in the presence of Contractor's Geotechnical Engineer. Any expenditure associated with the redrafting and finalising the report, traveling etc. shall be deemed included in the rates quoted for the geotechnical investigations.
- 4.2.9. Contractor shall carry out all work expressed and implied in these specifications in accordance with requirements of the specification.
- 4.2.10. The contractor shall prepare and submit soil profile along the transmission line route (in digitized form, with digitized route alignment drawing as base) indicating salient soil characteristics / features, water table etc based on detailed soil investigations and other details / information collected during detailed survey.

4.3 General Requirements

- 4.3.1. Wherever possible, Contractor shall research and review existing local knowledge, records of test pits, boreholes, etc., types of foundations adopted and the behaviour of existing structures, particularly those similar to the present project.
- 4.3.2. Contractor shall make use of information gathered from nearby quarries, unlined wells excavation etc. Study of the general topography of the surrounding areas will often help in the delineation of different soil types.
- 4.3.3. Contractor shall gather data regarding the removal of overburden in the project area either by performing test excavations, or by observing soil erosion or land slides in order to estimate reconsolidation of the soil strata. Similarly, data regarding recent land fills shall be studied to determine the characteristics of such land fills as well as the original soil strata.
- 4.3.4. The water level in neighboring streams and water courses shall be noted. Contractor shall make enquiries and shall verify whether there are abandoned underground works e.g. worked out ballast pits, quarries, old brick fields, mines, mineral workings etc.
- 4.3.5. It is essential that equipment and instruments be properly calibrated at the commencement of the work. If the Owner so desires. Contractor shall arrange for having the instruments tested at an approved laboratory at its cost and shall submit the test reports to the Owner. If the Owner desires to witness such tests, Contractor shall arrange for the same.

4.4 Codes and Standards for Geotechnical Investigations

- 4.4.1. All standards, specifications and codes of practice referred to herein shall be the latest editions including all applicable official amendments and revisions. In case of conflict between the present specifications and those referred to herein, the former shall prevail. Internationally accepted standards which ensure equal or higher performance than those specified shall also be accepted.
- 4.4.2. All work shall be carried out in accordance with the following Indian Standards and Codes:

Indian Standards (IS)	Title	International Standard/Code
IS:1080-1990	Codes of Practice for Design and Construction of Simple Spread Foundations.	
IS:1498-1992	Classification and Identification of Soils for General Engineering purposes.	ASTM D 2487 ASTM D2488
IS:1892-1992	Code of Practice for Subsurface Investigation for Foundation	
IS:1892-1992	Code of Practice for Subsurface Investigation for Foundation	
IS:1904-1986	Code of Practice for Design and Construction of foundation in Soils: General Requirements.	
IS:2131-1992	Method of Standard Penetration Test for Soils	ASTM D 1586
IS:2132-1992	Code of Practice for Thin Walled Tube Sampling of Soils	ASTM D 1587
IS:2720-1992	Method of Test for Soils(Relevant Parts)	ASTM D 420
IS:2809-1991	Glossary of Terms and symbols Relating to Soil Engineering	ASTM D 653
IS:2911-1980	Code of Practice for Design and construction of Pile Foundations (Relevant Parts).	
IS:3025	Methods of Sampling and Testing(Physical and Chemical) for water used in Industry	
IS:3043-1991	Code of Practice for Earthing	
IS:4078-1990	Code of Practice for Indexing and Storage of Drill Cores.	
IS:4091-1987	Code of Practice for Design and Construction of Foundations for Transmission Line Towers and Poles.	
IS:4434-1992	Code of Practice for In-situ Vane Shear Test for Soils	ASTM D 2573 ASTM D 4648
IS:4453-1992	Code of Practice for Exploration by Pits, Trenches, Drifts and Shafts.	
IS:4464-1990	Code of Practice for Presentation of Drilling information and core description in Foundation	

Indian Standards (IS)	Title	International Standard/Code
	investigation	
IS:4968(Part-II)1992	Method for Subsurface sounding for soils, dynamic method using cone and Bentonite slurry.	
IS:5313-1989	Guide for Core Drilling observations.	
IS:6403-1990	Code of Practice for Determination of Allowable Bearing Pressure on Shallow Foundation.	ASTM D 194
IS:6926-1990	Code of Practice for Diamond Core Drilling for Site Investigation for River Valley Projects.	
IS:6935-1989	Method of Determination of Water level in a Bore Hole.	
IS:7422-1990	Symbols and Abbreviations for use in Geological Maps Sections and subsurface Exploratory Logs (Relevant parts).	
IS:8009(Part-I)-1993	Code of Practice for Calculation of Settlements of Foundations (Shallow Foundations subjected to symmetrical Vertical Loads).	
IS:8764-1991	Method of Determination of Point Load Strength Index of Rocks.	
IS:9143-1991	Method of Determination of Unconfined Compressive Strength of Rock Materials.	ASTM D 2938
IS:9179-1991	Method of Preparation of Rock Specimen for Laboratory Testing.	ASTM D 4543
IS:9259-1992	Specification for Liquid Limit Apparatus.	ASTM D 4318
IS:9640-1992	Specification for Split Spoon Sampler.	ASTM D 1586
IS:10050-1991	Method of Determination of Slake Durability Index of Rocks.	ASTM D 4644
IS:11315(Part-II)-1991	Description of Discontinuities in Rock Mass-Core Recovery and Rock Quality.	

4.5 Field Investigation for Soils

Tentative numbers of detailed soil investigation to be done is given in BPS

4.5.1. Boring

Boreholes are required for detailed soil investigations.

4.5.1.1. General Requirements

- a) Boreholes shall be made to obtain information about the subsoil profile, its nature and strength and to collect soil samples for strata identification and for 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 the present specification:
- b) All boreholes shall be 10m deep for normal soil conditions. The depth of boreholes at river crossings and special locations shall be 40m. If a strata is encountered where the Standard Penetration Test Records N values greater than 100, with characteristics of rock, the borehole shall be advanced by coring atleast 3m further in normal locations and at least 7m further for the case of river crossing locations with prior approval of the Owner. When the boreholes are to be terminated in soil strata, an additional Standard Penetration Test shall be carried out at the termination depth. No extra payment shall be made for carrying out Standard Penetration Tests.
- c) Casing pipe shall be used when collapse of a borehole wall is probable. The bottom of the casing pipe shall at all times be above the test of sampling level but not more than 15cm above the borehole bottom. In case of cohesionless 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 preferably be advanced by slowly rotating the casing pipe and not by driving.
- d) In-situ tests shall be conducted and undisturbed samples shall be obtained in the boreholes at intervals specified hereafter. Representative disturbed samples shall be preserved for conducting various identification tests in the laboratory. Water table in the bore hole shall be carefully recorded and reported following IS:6935. No water or drilling mud shall be used while boring above ground water table. For cohesion less soil below water table, the water level in the borehole shall at all times be maintained slightly above the water table.
- e) The borehole shall be cleaned using suitable tools to the depth of testing or sampling, ensuring least or minimum disturbance of the soil at the bottom of the borehole. The process of jetting through an open tube sampler shall not be permitted. In cohesive soils, the borehole may be cleaned by using a bailer

with a flap valve. Gentle circulation of drilling fluid shall be done when rotary mud circulation boring is adopted.

- f) On completion of the drilling, Contractor shall backfill all boreholes as directed by the Owner.

4.5.1.2. Auger Boring

Auger boring may be employed in soft to stiff cohesive soils above the water table. Augers shall be of helical or post hole type and the cuttings brought up by the auger shall be carefully examined in the field and the description of all strata shall be duly recorded in the field borelog as per IS:1498. No water shall be introduced from the top while conducting auger boring.

4.5.1.3. Shell and Auger Boring

- 4.5.1.3.1. Shell and auger boring may be used in all types of soil which are free from boulders. For cohesion less soil below ground water table, the water level in the borehole shall always be maintained at or above ground water level. The use of chisel bits shall be permitted in hard strata having SPT-N value greater than 100 Chisel bits may also be used to extend the bore hole through local obstructions such as old construction. Boulders rocky formations, etc. The requirements in Clause 4.5.1.2 shall apply for this type of boring also.

- 4.5.1.3.2. Rotary method may be used in all types of soil below water table. In this method the boring is carried out by rotating the bit fixed at the lower end of the drill rod. Proper care shall be taken to maintain firm contact between the bit and the bottom of the borehole. Bentonite or drilling mud shall be used as drilling fluid to stabilise and protect the inside surface of the borehole. Use of percussion tools shall be permitted in hard clays and in dense sandy deposits.

4.5.2. Standard Penetration Test (SPT)

- 4.5.2.1. This test shall be conducted in all types of soil deposits encountered within a borehole, to find the variation in the soil stratification by correlating with the number of blows required for unit penetration of a standard penetrometer. Structure sensitive engineering properties of cohesive soils and sifts such as strength and compressibility shall not be inferred based on SPT values.

- 4.5.2.2. The test shall be conducted at depths as follows:

Location	Depths (m)
Normal Soils	2.0, 3.0, 5.0, 7.0, 10.0
River crossings and special Locations.	2.0, 3.0, 5.0, 7.0, 10.0 and thereafter at the rate of 3m intervals to 40m

4.5.2.3. The spacing between the levels of standard penetration test and next undisturbed sampling shall not be less than 1.0m. Equipments, accessories and procedures for conducting the test and for the collection of the disturbed soil samples shall conform to IS:2131 and IS:9640 respectively. The test shall be conducted immediately after reaching to the test depth and cleaning of bore hole.

4.5.2.4. The test shall be carried out by driving a standard split spoon sampler in the bore hole by means of a 650N hammer having a free fall of 0.75 m. The sample shall be driven using the hammer for 450mm recording the bumper of blows for every 150mm. The number of blow for the last 300mm drive shall be reported as N value.

4.5.2.5. This test shall be discontinued when the blow count is equal to 100 or the penetration is less than 25 mm for 50 blows. At the level where the test is discontinued, the number of blows and the corresponding penetration 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 as well as properly preserved without loss of moisture content and labeled.

4.5.3. **Sampling**

4.5.3.1. **General**

- a) Sufficient number of soil samples shall be collected. Disturbed soil samples shall be collected for soil identification and for conducting tests such as sieve analysis, index properties, specific gravity, chemical analysis etc. Undisturbed samples shall be collected to estimate the physical bearing capacity and settlement properties of the soil.
- b) All accessories and sampling methods shall conform to IS:2132: all disturbed and undisturbed samples collected in the field shall be classified at site as per IS:1498
- c) All samples shall be identified with date, borehole or test pit number, depth of sampling, etc. The top surface of the sample in-situ shall also be marked. Care shall be taken to keep the core and box samples vertical, with the mark directing upwards. The tube samples shall be properly trimmed at one end and suitably capped and sealed with molten paraffin wax. The Contractor shall be responsible for packing, storing in a cool place and transporting all the samples from site to the laboratory within seven days after sampling with probe, protection against loss and damage.

4.5.3.2. Disturbed Samples

- a) Disturbed soil samples shall be collected in boreholes at regular intervals. Jar samples weighing approximately 1 kg shall be collected at 0.5m 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 stored immediately in air tight jars which shall be filled to capacity as much as possible.
- b) In designated borrow areas, bulk samples, from a depth of about 0.5m below ground level shall be collected to establish the required properties for use as a fill material. Disturbed samples weighing about 25kg (250N) shall be collected at shallow depths and immediately stored in polythene bags as per IS:1892. The bags shall be sealed properly to preserve the natural moisture content of the sample and placed in wooden boxes for transportation.

4.5.3.3. Undisturbed Samples

In each borehole undisturbed samples shall be collected at every change of strata and at depths as follows:

Location	Depths (m)
Normal Soils	1.0, 4.0, 6.0, 8.0
Special Locations	1.0, 4.0, 6.0, 8.0, 11.0 and thereafter at the rate of 3 m intervals up to 33m

4.5.3.3.1. The spacing between the top levels of undisturbed sampling and standard penetration testing shall not be less than 1.0m. Undisturbed samples shall be of 100mm diameter and 450mm in length. Samples shall be collected in a manner to preserve the structure and moisture content of the soil. Accessories and sampling procedures shall conform to IS:1892 and IS:2132

- a) 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 sampling tube shall have a smooth finish on both surfaces and a minimum effective length of 450mm. The area ratio of sampling tubes shall be less than 12.5%. However, in case of very stiff soils area ratio up to 20% shall be permitted.

- b) Undisturbed sampling in very loose, saturated, sandy and silty soils and very soft clays :

Samples shall be obtained using a piston sampler consisting of a 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 in the presence of expert supervision.

Accurate measurements of the sampling depth, dimensions of sampler, stroke and length of sample recovery shall be recorded. After the sampler is pushed to the required depth, the cylinder and piston system shall be drawn up together, preventing disturbance and changes in moisture content of the sample;

c) Undisturbed sampling in cohesion less soils

Undisturbed samples in cohesion less soils shall be obtained in accordance with IS:8763. Sampler operated by compressed air shall be used to sample cohesion less soils below ground water table.

4.5.4. Ground Water

4.5.4.1. One of the following methods shall be adopted for determining the elevation of ground water table in boreholes as per IS:6935 and the instructions of the Owner:

- a) In permeable soils, the water level in the borehole shall be allowed to stabilize after depressing it adequately by bailing before recording its level. Stability of sides and bottom of the boreholes shall be ensured at all times.
- b) For both permeable and impermeable soils, the following method shall be suitable. The borehole 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 neither fall nor rise is observed shall be considered the water table elevation and confirmed by three successive readings of water level taken at two hours interval.

4.5.4.2. If any variation of the ground water level is observed in any specific boreholes, the water level in these boreholes shall be recorded during the course of the filed investigation. Levels in nearby wells, streams, etc., if any, shall also be noted in parallel.

4.5.4.3. Subsoil water samples

- a) Subsoil water samples shall be collected for performing chemical analysis. Representative ground water samples shall be collected when first encountered in boreholes and before the addition of water to aid boring or drilling.
- b) 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. Chemical preservatives may be added to the sample for cases as specified in the test methods or in applicable Indian Standards. 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 Owner.

4.5.5. Dynamic Cone Penetration Test (only at Special locations)

a) With bentonite slurry

Dynamic cone penetration test shall be conducted to predict stratification, density, bearing capacity of granular soils, etc. The test shall be conducted to the specified depth or refusal, whichever comes first. Refusal shall be considered when the blow count exceeds 100 for 300mm penetration. Equipment, accessories test procedures, field observations and reporting of results shall conform to IS:4968, Part-II. The driving system shall comprise of a 650 N weight hammer having a free fall of 750mm. The cone shall be of 60° and of 65mm diameter provided with vents for continuous flow of bentonite slurry through the cone and rods in order to avoid friction between the rods and soil. On completion of the test the results shall be presented as a continuous record of the number of blows required for every 300mm penetration of the cone into the soil in a suitable chart supplemented by a graphical plot of blow count for 300mm penetration vs. depth. On completion of the test, the results shall be presented on the proforma approved by the Owner.

b) Without bentonite slurry

This test shall be conducted with 50mm diameter 60° cone fitted loosely to the driving rod through a cone adopter. The cone shall be driven in to the soil by allowing 650 N weight hammer top fall freely through a height of 750mm each time. The number of blows for every 75mm penetration shall be recorded. The process shall be repeated till the cone is driven to the required depth. The penetration depth shall be limited to 5m in cohesion less soil and 10m in mixed soil with some binding material. The cone driving rods, driving head, hoisting equipment shall conform to IS: 10589. The test report should be prepared as per guidelines of IS: 4968 (Part I).

4.5.6. Vane Shear Test. (required for boreholes where UDS is not possible) (Only at Special Locations)

Field vane shear test shall be performed inside the borehole to determine the shear strength and bearing capacity of cohesive soils, especially of soft and sensitive clays, which are highly susceptible to sampling disturbance. Equipment, accessories, test procedures, field observations shall correspond to IS:4434. Tests may also be conducted by direct penetration from ground surface.

If the cuttings at the test depth in the borehole show any presence of gravel, sand shells, decomposed wood, etc., which are likely to influence the test results substantially, the test at that particular depth may be omitted with the permission of the Owner. However, the test shall be conducted at a depth where these obstructions cease to occur. On completion of the test, the results shall be reported in an approved proforma as specified in IS:4434, Appendix - A.

4.6 Field Investigation for Rock

4.6.1. Rock Drilling

4.6.1.1. If, during the investigations, large hard fragments or natural rock beds are encountered, work shall proceed with core drilling methods. The equipment and procedures for this operation shall conform to IS:1892. The starting depth of drilling in rock shall be certified by the Owner. At the end of the investigation, the hole drilled in rock shall be backfilled with grout consisting of 1 part cement and 3 parts sand by weight.

4.6.1.2. Drilling shall be carried out with NX size tungsten carbide (TC) or diamond tipped drill bits, depending on the type of rock and according to IS:6926. Suitable type of drill bit (TC/Diamond) and core catchers shall be used to ensure continuous and good core recovery. Core barrels and core catchers shall be used for breaking off the core and retaining it when the rods are withdrawn. Double tube core barrels shall be used to ensure better core recovery and to retrieve cores from layers of bedrock. Water shall be circulated continuously in the hollow rods and the sludge conveying the rock cuttings to the surface shall be collected. A very high core recovery ratio shall be aimed at in order to obtain a satisfactory undisturbed sample. Attempt shall be made to recover cores of 1.5m in length. Normally TC bit shall be used. Change over to a diamond bit shall require the specific written approval of the Owner, and his decision as to whether a TC or a diamond bit is to be used shall be final and binding on Contractor.

4.6.1.3. No drilling run shall exceed 1.5 m in depth. if the core recovery is less than 80% in any run, the length of the subsequent run shall be reduced to 0.75m. During drilling operations observations on return water, rate of penetration etc. shall be made recorded and recorded as per IS:5313.

a) The colour of return water at regular intervals, the depth at which any change of colour of return water is observed, the depth of occurrence and amount of flow of hot water, if encountered, shall be recorded.

b) The depth through which a uniform rate of penetration was maintained, the depth at which marked change in rate of penetration or sudden fail on drill rod occurs, the depth at which any blockage of drill bit causing core loss, if any, shall be recorded.

- c) Any heavy vibration or torque noticed during the drilling should be recorded together with the depth of occurrence.
- d) Special conditions like the depth at which grouting was done during, drilling, presence of artesian conditions, loss of drilling fluid, observations of gas discharge with return water, etc., shall also be observed and recorded.
- e) All the observations and other details shall be recorded as per daily drill and reported in a proforma as given in IS:5313, Appendix A.

4.6.2. Core Sampling

4.6.2.1. Core samples shall be extracted by the application of a continuous pressure at one end of the core with the barrel held horizontally without vibration. Friable cores shall be extracted from the barrel directly into a suitably sized half round plastic channel section. Care shall be taken to extrude the samples in the direction of coring to avoid stress reversal.

4.6.2.2. Immediately after withdrawal from the core barrel, the cores shall be placed in a tray and transferred to boxes specially prepared for this purpose. The boxes shall be made from seasoned timber or any other durably material and shall be indexed on top of the lid according to IS:4078. The cores shall be numbered serially and arranged in the boxes in a sequential order. The description of the core samples shall be recorded as instructed in IS:4464. Where no core is recovered, it shall be recorded as specified in the standard. Continuous record of core recovery and rock quality designation (RD/DD/QD) are to be mentioned in the bore log in accordance with IS:1 1315 (Part-II).

4.7 Laboratory Testing

4.7.1. Essential Requirements

- a) Depending on the types 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 indicated in the schedule of items shall be performed on soil, water and rock samples as per relevant IS codes. One copy of all laboratory test data records shall be submitted to Owner progressively every week. Laboratory tests shall be carried out concurrently with the field investigations as initial laboratory test results could be useful in planning the later stages of field work. A schedule of laboratory tests shall be established by Contractor to the satisfaction of the Owner within one week of completion of the first borehole;
- b) Laboratory tests shall be conducted using approved apparatus complying with the requirements and specification of Indian Standards or other approved standards for this type of work. It shall be checked that the

apparatus are in good working condition before starting the laboratory tests. Calibration of all the instruments and their accessories shall be done carefully and precisely at an approved laboratory.

- c) All samples, whether undisturbed or disturbed shall be extracted, prepared and examined by competent personnel properly trained and experienced in soil sampling. examination, testing and in using the apparatus in conformance with the specified standards;
- d) Undisturbed soil samples retained in liners or seamless tube samplers shall be removed, without causing any disturbance to the samples, using suitably designed extruders just prior to actual testing. If the extruder is horizontal, proper support shall be provided to prevent the sample from breaking. For screw tube extruders, the pushing head shall be free from the screw shaft so that no torque is applied to the soil sample in contact with the pushing head. For soft clay samples, 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;
- e) While extracting a sample from a liner or tube, care shall be taken to assure that its direction of movement is the same as that during sampling to avoid stress reversal;

4.7.2. Tests

4.7.2.1. Tests as indicated in these specifications and as may be requested by the Owner, shall be conducted. These tests shall include but may not be limited to the following :

- a) Tests of undisturbed and disturbed samples
 - Visual and engineering classification;
 - Sieve analysis and hydrometric analysis;
 - Liquid, plastic and shrinkage limits;
 - Specific gravity;
 - Chemical analysis
 - Swell pressure and free swell index determination
 - Proctor compaction test.
- b) Tests of undisturbed samples:
 - Bulk density and moisture content;
 - Relative density(for sand),

- Unconfined compression test;
 - Box shear test (for sand);
 - Triaxial shear tests (depending on the type of soil and field conditions on undisturbed or remoulded samples):
 - i. Unconsolidated undrained;
 - ii. Consolidated drained test;
 - Consolidation.
- c) Tests on rock samples
- Visual classification;
 - Moisture content , porosity and density;
 - Specific gravity;
 - Hardness
 - Stake durability
 - Unconfined compression test (both saturated and at in-situ water content);
 - Point load strength index;
 - Deformability test(both saturated and dry samples).
- d) Chemical analysis of sub soil water.

4.7.3. Salient Test Requirement

- a) Triaxial shear tests shall be conducted on undisturbed soil samples, saturated by the application of back pressure. Only if the water table is at sufficient depth so that chances of its rising to the base of the footing are small or nil, the triaxial tests shall be performed on specimens at natural moisture content. Each test shall be carried out on a set of three test specimens from one sample at cell pressures equal to 100, 200 and 300 KPa respectively or as required depending on the soil conditions:
- b) Direct shear test shall be conducted on undisturbed soil samples. The three normal vertical stresses for each test shall be 100, 200 and 300 KPa or as required for the soil conditions;
- c) Consolidation test shall have loading stages of 10, 25, 50, 75, 100, 200, 400 and 800 KPa. Rebound curve shaft be recorded for all samples by unloading the

specimen at its in-situ stress. Additional rebound curves shall also be recorded wherever desired by the Owner;

- d) Chemical analysis of subsoil shaft include determination of PH value, carbonate, sulphate (both SO_3 and SO_4). chloride and nitrate contents, organic matter, salinity and any other chemicals which may be harmful to the foundation material. Their contents in the soil shall be indicated as percentage(%);
- e) Chemical analysis of subsoil water samples shall include the determination of properties such as colour, odour, turbidity, PH value and specific conductivity, the last two chlorides, nitrates, organic matter and any other chemical harmful to the foundation material. The chemical contents shall be indicated as parts per million (PPM) based on weight.

4.8 Geotechnical Investigation Report

4.8.1. General

Contractor shall submit a formal report containing geological information of the region, procedures adopted for geotechnical investigation, field observations, summarised test data, conclusions and recommendations. The report shall also 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, supporting calculations for the conclusions drawn, etc. Initially, Contractor shall submit three copies of the report in draft form for Owner's review;

- a) Contractor's Geotechnical engineer shall visit Owner's Corporate Office for a detailed review based on Owner's comments in order to discuss the nature of modifications, if any, to be done in the draft report. Contractor shall incorporate in the report the agreed modifications and resubmit the revised draft report for approval. Ten copies of the detailed final approved report shall be submitted to Owner together with one set of reproducible of the graphs, tables etc.
- b) The detailed final report based on field observations, in-situ and laboratory tests shall encompass theoretical as well as practical considerations for foundations for different types of structures.

4.8.2. Data to be furnished

4.8.2.1. The report shall also include the following

- a) A plot plant/location plan showing the locations and reduced levels of all field test e.g. boreholes, trial pits, static cone penetration tests, dynamic cone

penetration tests, etc., property drawn to scale and dimensioned with reference to the established grid lines;

- b) A true cross section of all individual boreholes and test pits with reduced levels and co-ordinates showing the classification and thickness of individual stratum, position of ground water table, various in-situ tests conducted, samples collected at different depths and the rock stratum, if encountered;
- c) Geological information of the area including geomorphology, geological structure, lithology, stratigraphy and tectonics, core recovery and rock quality designation (RD/DD/QD), etc.,
- d) Observations and data regarding change of course of rivers, velocity, scour depths, slit factor, etc., and history of flood details for mid stream and river bank locations;
- e) Past observations and historical data, if available, for the area or for other areas with similar soil profile, or with similar structures in the surrounding areas;
- f) Plot of Standard Penetration Test (uncorrected and corrected N values) with depth for each test site;
- g) Results of all laboratory test summarised according to Table 4.0 (i) for each sample as well as (ii) for each layer, along with all the relevant charts, tables, graphs, figures, supporting calculations, conclusions and photographs of representative rock cores,
- h) For all triaxial shear tests, stress vs. strain diagrams as well as Mohr's circle envelopes shall be furnished. If back pressure is applied for saturation, the magnitude of the same shall be indicated. The value of modulus of elasticity (E) shall be furnished for all tests along with relevant calculations;
- i) For all consolidation tests, the following curves shall be furnished
 - i. e vs. $\log p$;
 - ii. e vs. p ;
 - iii. Compression vs $\log t$ or $vs \sqrt{t}$

depending upon the shape of the plot, for proper determination of coefficient of consolidation.

The point showing the initial condition (e_0 , p_0) of the soil shall be marked on the curves;

- j) The procedure adopted for calculating the compression index from the field curve and settlement of soil strata shall be clearly specified. The time

required for 50% and 90% primary consolidation along with secondary settlements, if significant, shall also be calculated.

Table 4.0
SUMMARY OF RESULTS OF LABORATORY TESTS ON SOIL
AND WATER SAMPLES

1. Bore hole test pit. no
2. Depth (m)
3. Type of sample
4. Density(kg/m³)
 - a) Bulk
 - b) Dry.
 - c) **Submerged**
5. Water content (%)
6. Particle Size (%)
 - a) Gravel
 - b) Sand
 - c) Silt
 - d) Clay
7. Consistency properties
 - a) LL
 - b) PL
 - c) PI
 - d) LI
8. Soil
 - a) Classification -IS
 - b) Description
 - c) Specific gravity
9. Strength Test
 - a) Type
 - b) C (Cohesion)
 - c) ϕ (angle of internal friction)
 - d) **Angle of repose**
10. Consolidation Test
 - a) e_0
 - b) P_c
 - c) C_c
 - d) DP

- e) Mv
- f) Cv
- 11. Shrinkage limit(%)
- 12. Swell Test
 - a) S.Pr
 - b) FS
- 13. Relative Density (%)
- 14. Remarks

Notations:

I. For type of Sample:

DB - Disturbed bulk soil sample.

DP - Disturbed SPT soil sample

DS - Disturbed samples from cutting edge of undisturbed soil sample.

RM - Remoulded soil sample

UB - Undisturbed block soil sample

US - Undisturbed soil sample by sampler

W - Water sample

II. For Strength Test :

SCPT - Static Cone Penetration Test

UCC - Unconfined Compression Test

VST - Vane Shear Test

Tuu - Unconsolidated Undrained Triaxial Test

Note: Replace T by D for Direct Shear Test

Tod - Consolidation Drained Triaxial Test

III. For Others :

LL - Liquid Limit (%)

PL - Plastic Limit

PI - Plasticity Index

LI - Liquidity Index

C - Cohesion (kPa)

ϕ - Angle of Internal Friction (degrees)

S-Pr. - Swelling Pressure (kPa)

e_0 - Initial Void Ratio

P_c - Reconsolidation Pressure (kPa)

C_c - Compression Index

DP - Change in Pressure (kPa)

m_v - Coefficient of Volume Compressibility (m^2/KN)

C_v - Coefficient of Consolidation (m^2/hr)

IV. For Chemical Test

As per Specifications - Clause 4.8.4

4.8.3. Recommendations

4.8.3.1. Recommendations shall be provided for each tower location duly considering soil type and tower spotting data. The recommendations shall provide all design parameters and considerations required for proper selection, dimensioning and future performance of tower foundations and the following

- a) The subsurface material must provide safe bearing capacity and uplift resistance by incorporating appropriate safety factors thereby avoiding rupture under ultimate loads;
- b) Movement of the foundation, including short and long term components under transient and permanent loading, shall be strictly controlled with regard to settlement, uplift, lateral translation and rotation:
- c) Co-efficient of permeability of various sub soil and rock strata based on in-situ permeability tests.

Core resistance, total frictional resistance, relation between core resistance and Standard Penetration Test N value and settlement analysis for different sizes of foundation as specified in para 4.8.3.1 (i) based on static cone penetration test.

- d) For shallow foundation the following shall be indicated with comprehensive supporting calculations:

- i. Net Safe allowable bearing pressure for isolated square footing of sizes 4.0, 5.0, 6.0 & 7. m at three different founding depths of 1,2 and 3 & 3.5m below ground level considering both shear failure and settlement criteria giving reasons for type of shear failure adopted in the calculation.
 - ii. Net safe allowable bearing pressure for raft foundations of widths greater than 5m at 2.0, 3.0 and 4.0m below ground level considering both shear failure and settlement criteria.
 - iii. Rate and magnitude of settlement expected of the structure.
 - iv. Net safe bearing capacity for foundation sizes mentioned in para(i) above, modulus of sub grade reaction, modules of elasticity from plate load test results along with time settlement curves and load settlement curve in both natural and log graph, variation of Modulus of sub grade reaction with size, shape and depth of foundation.
- e) The stable slopes for shallow and deep excavations, active and passive earth pressure at rest and angle of repose for sandy soils shall be furnished. The loading of the foundations shall not compromise the stability of the surrounding subsurface materials and the stability of the foundation shall be ensured against sliding or overturning:-
 - f) Depending on the subsurface material, water table level and tower type, either reinforced concrete isolated pad and chimney, cast-in-situ bored pile of special foundations shall be installed at a given location.
 - g) Net Safe allowable bearing pressure and uplift resistance shall be provided for the various sizes of isolated square footings founded at various depths below ground level considering both shear failure and movement criteria; rate and magnitude of movement expected of the structure (settlement, uplift, rotation) shall also be given.
 - h) In cases where normal open cast/pile foundations appear to be impractical, special pile foundations shall be given due consideration along with the following:
 - i. Type of pile foundation and reasons for recommending the same duly considering the soil characteristics.
 - ii. Suitable founding strata for the pile:
 - iii. Estimated length of pile for 500, 750 and 1000 KN and 4500 KN capacities; end bearing and frictional resistance shall be indicated separately:
 - iv. Magnitude of negative skin friction or uplift forces due to soil swelling.

- i) Where the subsoil water and soil properties are found to be chemically aggressive. Contractor shall take suitable precautions during construction including any protective coating to be applied on the foundations; susceptibility of soil to termite action and remedial measures for the same shall be dealt with;
- j) Suitability of locally available soils at site for filling, backfilling and adequate compaction shall be investigated.
- k) If expansive soil such as black cotton soil is encountered recommendation of removal or retainment of the same shall be given in the latter case, detailed specifications of special requirements shall also be given;
- l) Susceptibility of subsoil strata to liquefaction in the event of earthquake and remedial measures, if required, shall be considered.
- m) Any other information of special significance such as dewatering schemes, etc. which may have a bearing on the design and construction shall be provided.
- n) Recommendations for additional soil investigations, beyond the scope of the present work, shall be given if Contractor considers such investigations necessary.

4.8.4. Hydrogeological Conditions

4.8.4.1. The maximum elevation of ground water table, amplitudes of its fluctuations and data on water aggressivity with regard to foundation structure materials shall be reported. While preparing ground water characteristics the following parameters should be specified for each aquifer:

- a) bicarbonate alkalinity mg-eq/(deg),
- b) pH value
- c) content of aggressive carbon dioxide, mg/l;
- d) content of magnesia salts. mg/l, recalculated in terms of ions Mg²⁺;
- e) content of ammonia salts, mg/l, recalculated in terms of ions NH₄⁺
- f) content of caustic alkalis, mg/l, recalculated in terms of ions Na⁺ and K⁺
- g) contents of chlorides,mg/l recalculated in terms of ions Cl⁻
- h) contents of sulphates, mg/l, recalculated in terms of ions SO₄²⁻
- i) aggregate content of chlorides, sulphates, nitrates, carbonates and other salts. mg/l.

4.9 Rates and Measurements

4.9.1. Rates

The contractor's quoted rates shall be inclusive of making observations, establishing the ground level and co-ordinates at the location of each borehole, test pit etc. No extra payments shall be made for conducting Standard Penetration Test, collecting, packing, transporting of all samples and cores, recording and submittal of results on approved formats.

4.10 Specific Requirements for Geotechnical Investigation at River Crossings.

4.10.1. The entire soil investigation work at river crossing locations (if required) shall be carried out in accordance with the relevant parts of the specifications for geotechnical investigation modified to the extent given below.

4.10.2. Requirements

4.10.2.1. Boreholes shall be executed to specified depth of 40m (refer clause 4.5.1.1 b). If refusal strata is reached (i.e. SPT-N value is greater than 100 continuously for 5m depth) with characteristics of rock the borehole may be terminated at shallower depth i.e. at 5m in refusal strata, with prior approval of the Owner.

4.10.2.2. Laboratory testing shall be conducted on all soil samples to determine grain size distribution, liquid limit and plastic limit of the different soil strata encountered.

4.10.2.3. Geotechnical Report must furnish the following:

- a) Geotechnical investigation scheme;
- b) Bore-logs indicating soil stratification, with IS classification, sampling details and SPI 'N' values.
- c) Soil cross-sections along various boreholes in two orthogonal directions indicating soil stratification based on field and laboratory tests;
- d) Grain size distribution curves.
- e) IS classification of soils.
- f) Shear tests (UU) to be done on saturated soil samples;
- g) Bearing capacity of soil at different levels;
- h) Highest flood level (H.F.L.);
- i) Maximum discharge, velocity etc. (from authenticated source such as CWC or appropriate State authorities)

j) Recommendations regarding type of foundation to be adopted at the location.

4.10.3. A check list for reporting results of river crossing locational details, detailed soil investigation and river values for river crossing locations is enclosed at Annexure-C.

4.11 Special Terms and conditions for Geotechnical Investigation in the River bed

4.11.1. Contractor is required to mobilise a suitable arrangement (floating pontoon, plant, equipment etc,) to carry out geotechnical investigation work in creek/river locations identified by the Owner.

4.11.2. In the event of storm or stoppage of work, etc., Contractor shall not be paid extra for mobilization / remobilisation of floating pontoon, plant, equipment, etc.

4.11.3. Contractor shall fully satisfy himself about the conditions of creek/river (depth of water, wave currents, wind conditions, etc.) prevailing in the area of proposed investigation and plan the necessary tools and plant to be deployed before quoting. Any claim resulting from lack of data collection in this respect shall not be entertained.

4.11.4. Contractor shall make his own arrangements for locating the coordinates and position of boreholes in creek/river with respect to two grid-lines indicated by Owner.

4.11.5. Boring in creek or river shall be payable only below the bed level and no payment shall be made for lowering the casing in water.

4.11.6. Contractor shall arrange for necessary transportation on water (e.g. motor boat) to facilitate the supervision of work by officials of Owner at its own cost.

4.11.7. Full details of the construction plant, proposed working method for boring and sampling in water shall be submitted along with the Tender.

4.11.8. The unit rate quoted for underwater boring shall include complete work required as per specification and no separate payment shall be made on any account.

5. STATUTORY REGULATIONS AND STANDARDS

5.1 Contractor is required to follow statutory regulations stipulated in Electricity Act 2003, Indian Electricity Rules and other local rules & regulations.

5.2 The codes and standards referred to in these specifications shall govern. In case of a conflict between such codes/standards and these specifications, the provisions of the specifications shall prevail. Such codes, standards referred to

shall mean latest revisions, amendments, changes adopted and published by relevant agencies.

5.3 Other Internationally acceptable standards which ensure equivalent or better performance than those specified shall also be acceptable.

6. FIELD QUALITY PLAN

A standard Field Quality Plan is annexed to Section IV of this document. The bidders are requested to convey their acceptance to the same along with their offer.

7. COMPLETION PERIOD

The work as detailed in this specification shall be completed in all respects within the time schedule stipulated in letter of award (LOA).