

- Deformability test (both saturated and dry samples).

d) Chemical analysis of sub soil water.

#### **4.7.3 Salient Test Requirement**

- 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;
- 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;
- Consolidation test shall have loading stages of 10, 25, 50, 75, 100, 200, 400 and 800 KPa. Rebound curve shall 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 Employer;
- Chemical analysis of subsoil shall 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 (%);
- 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 Employer's review;

- Contractor's Geotechnical engineer shall visit Employer's Office for a detailed review based on Employer'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 Employer 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  $\dot{\sigma}_t$

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.

## A) SUMMARY OF RESULTS OF LABORATORY TESTS ON SOIL

Following additional information should also be provided:

- Note: where ever undisturbed sampling is not possible, reasons must be clearly indicated and all the tests shall be conducted on re-moulded samples.

(Signature)  
Checked & Approved by  
POWERGRID Site / RHQ Engg.

**B) SUMMARY OF ULTIMATE BEARING CAPACITIES CONSIDERING MAXIMUM RISE OF WATER  
TABLE**

Location no.	Foundation Classification	Depth of footing considered for bearing capacity calculation	Size of footing considered for bearing capacity calculation	Bearing capacity*		
				Based on settlement criteria (for 40mm total settlement)	Based on settlement criteria (for 50mm total settlement)	Based on shear failure criteria
		3.0m	3.0m x 3.0m			
		3.0m	5.0m x 5.0m			
		3.0m	7.0m x 7.0m			
		3.0m	9.0m x 9.0m			
		3.5m	3.0m x 3.0m			
		3.5m	5.0m x 5.0m			
		3.5m	7.0m x 7.0m			
		3.5m	9.0m x 9.0m			

\* Detailed calculations of all the bearing capacities should be enclosed with soil investigation reports.

(Signature)	(Signature)	(Signature)
Prepared by	Checked & Reviewed by	Checked & Approved by
Soil investigator	Line Contractor	POWERGRID Site / RHQ Engg.

**C) 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:-

- 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-term 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, frictional resistance total resistance, relation between core resistance, Standard Penetration Test N value, and settlement analysis for different sizes of foundation as specified in para 4.1.8.3 (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 & 70. 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  $Mg^{+2}$ ;
- e) content of ammonia salts, mg/l, recalculated in terms of ions  $NH^{4+}$
- 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  $SO_4^{-2}$
- 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 Employer.

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
- c) SPI 'N' values;



- d) Soil cross-sections along various boreholes in two orthogonal directions indicating soil stratification based on field and laboratory tests;
  - e) Grain size distribution curves;
  - f) IS classification of soils;
  - g) Shear tests (UU), to be done on saturated soil samples;
  - h) Bearing capacity of soil at different levels;
  - i) Highest flood level (HFL);
  - j) Maximum discharge, velocity etc. (from authenticated source such as CWC or appropriate State authorities);
  - k) 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 Employer.
- 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 Employer.
- 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 Employer 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.

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## 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.