7.00.00 FOUNDATION SYSTEM AND GEOTECHNICAL DATA

7.01.00 Soil Data

The owner has carried out detailed geotechnical investigation at the project site. Bore logs data and Bearing capacity for design of foundations are given at Annexure - C of this specification. The detailed geotechnical investigation report comprising of Boreholes, Laboratory tests, Chemical analysis, etc for the sub-strata prevailing at site would be made available for the Bidder's study at the Owner's consultant office, if required. The onus of correct assessment / interpretation and understanding of the existing subsoil condition / data lies with the Bidder. **In case, bidder feels that the available data is inadequate, he may carry out his own geotechnical investigation. Further, if there is any change in layout or for any area not covered in the provided geotechnical data, the bidder has to carry out geotechnical investigation in the area at no cost to the Owner.** Geotechnical investigation work shall get executed by the Contractor through the agencies as mentioned in Clause No. 7.07.00. However, no time extension shall be given on account of the soil investigation carried out by the Bidder. The geotechnical investigation report shall be prepared with detailed recommendations regarding type of foundation and allowable bearing pressure for various structures/ facilities and other soil parameters. Net allowable bearing pressure shall be limited to Table-1 of Annexure-C. The report shall be submitted for Owner's approval prior to commencement of design of foundation.

Bidder may refer enclosed topographical survey drawing and general layout plan along with borelogs for variation in existing ground level (EGL) / natural ground level (NGL) and finished ground level (FGL). For variation in Natural ground level, topographical survey drawing and borelog data may be referred. Further, wherever ash/coal deposit/brickbats etc. is found the same shall be treated as filled up soil.

7.01.01 **The furnished borelog details are specific to the co-ordinates where the boreholes have been carried out and are provided for bidder's information only. The soil profile in the proposed area may vary with respect to the borelogs enclosed for bidder's information. The bidder has to consider all such variations in his estimation, over the extent of the work to be carried out. The Bidder should note that nothing extra whatsoever on account of variation between soil data collected by Owner and that found by the Bidder during geotechnical investigation by him or during execution of works, shall be Payable.**

7.01.02 Tank Foundations

a) The tanks shall rest on flexible tank pad foundation, resting on sand with concrete ring wall to retain sand. The base of the concrete ring wall shall not rest on the expansive soil, if any.
b) Entire loose/ soft soil inside the concrete ring wall shall be removed and shall be filled with natural sand/ sand manufactured from other than natural sources as specified elsewhere in the technical specification. Sand for filling shall be clean and well graded conforming to IS 383 with grading Zone I to III.
c) Natural sand/ sand manufactured from other than natural sources as specified elsewhere in the technical specification shall be spread in layers not exceeding 30cm compacted thickness over the area. Each layer shall be uniformly compacted by mechanical means like plate vibrators, small vibratory rollers, etc to achieve a relative density of not less than 80%.
d) Other requirements of tank foundations shall be as per IS 803 and as specified elsewhere in the specifications.

7.02.00 **Foundation System**

The requirements for the foundation system to be adopted are as given in subsequent clauses. Depending upon the depth of competent strata/stratum, type of structures, functional requirement of facility, extent of cutting / filling, suitable foundation, open or pile

shall be adopted with approval of owner's consultant.

7.02.01 General Requirements

a) All structures/equipment shall be supported on suitable open foundations (isolated, combined, raft) or pile foundation depending on type of structures/facilities, sub-strata, topography etc.

b) The roads, ground floor slabs, trenches, pipe pedestals (except thrust blocks), channels/drains and staircase foundation with foundation loading intensity less than 4 T / M2 may be supported on open / shallow foundations resting on virgin / controlled compacted filled up soil.

c) No other foundation (other than as mentioned in (b) above and (g) below) shall rest on the filled-up ground / soil.

d) All foundations shall be designed in accordance with relevant parts of the latest revisions of Indian Standards.

e) The water table for design purpose shall be considered at Finished Ground Level.

f) A combination of open and pile foundations shall not be permitted under the same equipment / structure / building.

g) Foundation for equipments on ground floor

For equipments of static weight upto 1.5 T, the equipment may be supported on the ground floor slab by locally thickening the slab. Thickening of the ground floor slab shall be done upto an extent of about 0.6 m beyond the plan area of the equipment on all the sides. Further, the load intensity below the equipment shall be limited to 4T/m2. Other requirements of floor slab and compaction below the floor slab shall be adhered, as specified elsewhere in the specifications.

For equipment's of static weight between 1.5 T and 20 T, the equipment may be supported on compacted sand filling from Natural Ground Level (NGL) or excavation level of nearby footing whichever is deeper with the load intensity below the equipment limited to 4T/m2. The minimum depth of foundation is 1.0m below FFL. Other requirements of sand compaction below the foundation shall be adhered, as specified elsewhere in the specifications.

For equipment of static weight more than 20 T, the equipment foundation shall be taken to the founding level or shall be built up with PCC from the level as mentioned in Table 1. The pedestal of equipment foundation or the foundation Block shall be isolated from the adjoining floor slab by providing bitumen impregnated fiber board of minimum 50 mm thick, conforming to IS: 1838 all around the equipment pedestal for the full depth of the floor slab.

7.02.02 Open Foundations

In case open foundations are adopted, the following shall be adhered to.

a) The minimum width of the foundation shall be 1.0 m.

b) The minimum founding level shall be 1.0m below Finished ground level (FGL) or, 1.0m below Natural ground level (NGL) whichever is lower.

For meeting the bearing capacity and /or functional requirement lower depth to be adopted based on requirement.

c) It shall be ensured that all foundations of a particular structure/ buildings/ facility shall rest on one bearing stratum.

d) Wherever the intended bearing sub-strata is virgin soil stratum but the actual stratum encountered during foundation excavation consists of filled up soil at founding level, under such cases either the foundation shall be lowered completely into the virgin

stratum or the filled up soil upto the virgin layers shall be removed and built up through PCC M7.5 up to designed foundation level.

e) The last layer of about 300 mm before reaching the founding level shall be excavated carefully by such equipment so that soil / rock at the required level will be left in its natural condition.

f) Wherever the new facilities (excluding roads, ground floor slabs, trenches, pipe pedestals, channels/drains and staircase foundation) are to be constructed after dismantling existing facilities; it is to be ensured that the new foundations shall be taken at least 0.5m below the existing founding depth of the dismantled structures.

7.03.00 Pile Foundations – In case piles are adopted, following shall be adhered to:

i) The pile foundation shall be of RCC, Cast-in-situ bored piles as per IS:2911. Pile boring shall be done using Self erecting Crawler mounted Rotary Hydraulic Rigs. Two stages flushing of pile bore shall be ensured by airlift technique duly approved by the Employer.

ii) If required, temporary or permanent MS liner may be provided for piling.

The allowable load capacity of the pile in different modes (vertical compression, Lateral and pullout) shall be least of below three i.e.

a) design value based on borelog along with lab test data furnished in Annexure-C, AND

b) pile capacity achieved in pile load tests AND

c) the values furnished in following table:

Dia. (mm)	Structures/ Facilities	Cut off Level	Min. Pile Length below COL (m)	Vertical compression capacity (T)	Uplift capacity (T)	Lateral capacity (T)
600	Except Stacker area, Crusher, Silo, Biomass area (BH139-BH161)	2.0m below NGL	*Rock Socketed Pile	140	80	9.0
		4.0m below NGL		140	80	11.0
		7.0m below NGL		140	80	13.0
760		2.0m below NGL		240	130	13.0
		4.0m below NGL		240	130	14.0
		7.0m below NGL		240	130	16.0
1000		3.0m below NGL		410	240	17.0
		4.0m below NGL		410	240	18.0
		7.0m below NGL		410	240	20.0
600	Stacker area, Crusher, Silo, Biomass area (BH139-BH161)	2.0m below FGL	18	70	40	10.0
		2.0m below FGL	24	80	50	10.0
		2.0m below FGL	28	100	60	10.0
760		2.0m below FGL	24	120	80	14.0
		2.0m below FGL	28	140	90	14.0
1000		2.0m below FGL	24	210	120	19.0
		2.0m below FGL	28	230	150	19.0

*The pile shall be socketed 5d (minimum) into rock. Where d is the diameter of pile.

iii) Only straight shaft piles shall be used. Minimum cast length of pile above cutoff level shall be 1.0 m.

iv) The contractor shall furnish design of piles (in terms of rated capacity, length, diameter, termination criteria to locate the founding level for construction of pile in terms of measurable parameter, reinforcement for job as well as test piles, pile load test arrangement, locations of initial test piles etc.) for Engineer's approval.

v) The piling work shall be carried out in accordance with IS:2911 (Relevant part) and accepted construction methodology. The construction methodology shall be submitted by the Contractor for Engineer's approval.

vi) Number of initial load tests to be performed for each diameter and rated capacity of pile shall be subject to minimum as under.

Vertical

Lateral Minimum of 2 Nos. in each mode.

Uplift

vii) The initial pile load test shall be conducted with test load three times the pile capacity. In case of vertical compression test (initial test) the method of loading shall be cyclic as per IS:2911 (relevant part).

viii) The load test shall be conducted at pile Cut-off Level (COL). If the water table is above the COL the test pit shall be kept dry throughout the test period by suitable de-watering methods. Alternatively, the vertical load test may be conducted at a level higher than COL. In such a case, an annular space shall be created to remove the effect of skin friction above COL by providing an outer casing of suitable diameter larger than the pile diameter.

ix) Number of routine pile load tests to be performed for each diameter/allowable capacity of pile shall be as under:

i) Vertical: 0.5% of the total number of piles provided.

ii) Lateral: 0.5% of the total number of piles provided.

x) The routine tests on piles shall be conducted test load of one and half times the allowable pile capacity. Piles for routine load tests shall be approved by the Employer.

xi) In case, routine pile load test shows that the pile has not achieved the desired capacity or pile(s) have been rejected due to any other reason, then the Contractor shall install additional pile(s) as required and the pile cap design shall accordingly be reviewed and modified, if required.

xii) Testing of piles and interpretation of pile load test results shall be carried out as per IS:2911 (Part-4). The contractor shall ensure that all the measuring equipment and instruments are properly calibrated at a reputed laboratory / institute prior to their use. Settlement / movement of the pile top shall be made by Linear Variable Differential Transducers (LVDT) having a least count of 0.01mm.

xiii) The test load on initial test piles shall be applied by means of Kentledge with concrete blocks / reaction from anchor piles / rock anchors alone or combination of anchor piles / rock anchors and kentledge with concrete blocks.

xiv) The Low Strain Pile Integrity test shall be conducted on all test piles and job piles. This test shall be used to identify the routine load test and not intended to replace the use of static load test. This test is limited to assess the imperfection of the pile shaft and shall be undertaken by an independent specialist agency to be approved by Engineering department of owner's consultant. The test equipment shall be of TNO or PDI make or equivalent. The process shall confirm to ASTM.

xv) Routine pile load tests to be performed on 0.5% of the total number of piles provided for each diameter/allowable capacity. High Strain dynamic load test may be carried out for routine load testing of working piles. However, at least two numbers of static routine vertical load tests shall be carried out on pile on which high strain dynamic load test has already been carried out for establishing the correlation between the two tests. In case of discrepancy if any between dynamic and static vertical load tests, then additional static routine vertical load tests shall be conducted as decided by the Engineer and the results of static routine vertical load shall prevail. Number of routine vertical pile load tests as per clause 7.03.00 (ix) shall be total of static routine vertical load test and high strain dynamic load tests.

In case agency wish to carry out only static routine vertical load test on 0.5% of total number of piles, he may adopt the same.

The procedure to carry out the test shall be submitted to the Engineer. The test and equipment shall conform to ASTM D4945-00. The test shall be conducted by an experienced independent test agency approved by the owner's consultant. Field data shall be submitted to the site engineer and shall include force velocity curves, pile capacity, simulated static load test curve, net and total pile displacement, pile integrity. A (Case pile wave analysis) CAPWAP or equivalent software analysis shall be conducted on the field data for correct capacity estimation and to evaluate end bearing and skin friction components of the pile.

xvi) From load considerations, single pile may be used under a column/tower. In that case, pile shall be connected with tie beams at pile cut off level in both directions.

xvii) Contribution of frictional resistance of filled up soil if any, shall not be considered for computation of frictional resistance of piles.

xviii) Reinforcement for job piles shall be designed as following:

(a) Compression + bending piles: For these piles, the allowable safe pile capacities in compression and bending shall be considered.

(b) Tension + bending piles: For these piles, the actual pile forces to be considered. However, maximum 3 types of combinations for varying percentage of tension capacity + bending case may be designed & adopted by contractor for the entire scope of work under this package.

7.05.00 Excavation, Filling and Dewatering

7.05.01 For excavation works, comprehensive dewatering with well point or deep wells arrangement, if required, shall be adopted. Scheme for dewatering and design with all computations and back up data for dewatering shall be submitted for the owner's consultant information. The water table shall be maintained at 0.5m below the founding depth.

7.05.02 Excavation for shallow foundations shall be covered with PCC immediately after reaching the founding level. In case of any local loosening of soil or any loose pockets are encountered at founding level during excavation the same shall be removed and compensated by PCC M7.5. The final layer of about 300 mm thickness above the founding level shall be excavated by suitable means, so as to avoid disturbance to the founding stratum.

7.05.03 **Backfilling in Powerhouse & Boiler Area**

Backfilling around foundations, trenches, sumps, pits, plinths, etc. shall be carried out with natural sand/ sand manufactured from other than natural sources as specified elsewhere in the technical specification in layers not exceeding 300 mm compacted thickness and each layer shall be compacted to minimum 80% of relative density. **Controlled Low Strength Material (CLSM) as specified elsewhere in technical specification may also be used for backfilling in Powerhouse and Boiler area.**

Backfilling in other area

Backfilling around foundations, pipes, trenches, sumps, pits, plinths, etc. shall be carried out with approved material in layers not exceeding 300 mm compacted thickness (higher thickness of layers upto 500mm with heavy mechanical compacting equipment) and each layer shall be compacted to 90% of standard proctor density for cohesive soils and to 80% of relative density for non-cohesive soils.

7.05.04 Founding level for trenches/channels shall be decided as per functional requirement. The bottom of excavation shall be properly compacted prior to casting of bottom slab of trenches / channels.

7.05.05 CBR tests for pavement/road design shall be carried out by the Contractor after earth filling (if applicable) has been completed upto the formation level.

7.05.06 The contractor shall take all necessary measures during excavation to prevent the hazards of falling or sliding of material or article from any bank or side of such excavation which is more than one and a half meter above the footing by providing adequate piling, shoring, bracing etc. against such bank or sides.

Adequate and suitable warning signs shall be put up at conspicuous places at the excavation work to prevent any persons or vehicles falling into the excavation trench. No worker should be allowed to work where he may be stuck or endangered by excavation machinery or collapse of excavations or trenches.

7.06.00 Sheeting & Shoring

The contractor shall ascertain for himself the nature of materials to be excavated and difficulties, if any, likely to be encountered in excavation while executing the work. Sheet piling, sheeting and shoring, bracing and maintaining suitable slopes, drainage, etc. shall be provided and installed by the Contractor, to the satisfaction of the Engineer.

7.07.00 **Geotechnical investigation work shall be got executed by the Contractor through the following agencies**

1. C.E. TESTING COMPANY Pvt. Ltd, Kolkata

2. Cengrs Geotechnica Pvt. Ltd, New Delhi
3. KCT Consultancy Services, Ahmedabad
4. M.K. Soil Testing Laboratory, Ahmedabad
5. Secon Private Limited, Bangalore
6. Soil Engineering Consultants, New Delhi
7. CEG Test House and Research Centre Private Limited, Jaipur
8. Geomarine Consultants Pvt Ltd., Chennai
9. Soiltech India Private Limited, Pune

Annexure-C

SOIL DATA AND FOUNDATION SYSTEM

The employer has carried out geotechnical investigation in the proposed area. Logs of boreholes of proposed area are enclosed with this Annexure.

a) The minimum founding level and the corresponding net allowable bearing pressure shall be as given in Table – 1 below.

Table-1

Structure	Depth of Foundation	Width of Foundation	Net Allowable Bearing Capacity (t/sqm)		
			S=25mm(soil)	S=40mm(soil)	S=75mm(soil)
Boiler, Main Powerhouse, ID Fan, FD & PA Fan, Mill reject silo	1.5m below NGL	1m to 3m	11	18	-
		3m to 6m	6	10	-
		>6m	7	-	13
	2.5m below NGL	1m to 3m	12	20	-
		3m to 6m	07	11	-
		>6m	07	-	13
	3.5m below NGL	1m to 3m	13	21	-
		3m to 6m	08	12	-
		>6m	08	-	14
	4.5 or more than 4.5m below NGL	1m to 3m	14	22	-
		3m to 6m	09	13	-
		>6m	09	-	15

Structure	Founding Depth/ Stratum	Net Allowable Bearing Pressure T/m2		
		Isolated / Strip Foundation S=40mm		Rafts (width > 6m) S=75mm
		Width upto 3.0m	width >3 to 6m	

Fire Water PH area (BH42, BH43)	1.5m below NGL	18	13	15
	2.5m below NGL	22	15	17
	3.5m below NGL	25	16	19
	>=5.0m below NGL	28	17	20
NDCT (BH04-BH06, BH10-BH13)	2.0m below FGL	20	12	16
	3.0m below FGL	21	13	18
	4.0m below FGL	22	15	20
	6.0m below FGL	28	18	20
	>=7.0m below FGL	32	18	21
NDCT, LHP, GHP (BH15-BH21, BH25-BH29, BH84, BH118)	1.0m below FGL	20	11	13
	2.0m below FGL	22	12	14
	3.0m below FGL	24	13	15
	6.0m below FGL	28	18	21
	>=7.0m below FGL	30	19	22
H2 Plant area, O&M Store, Worker rest room (BH02, BH03, BH07-BH09)	1.0m below NGL	15	12	13
	2.0m below NGL	20	13	15
	3.0m below NGL	24	15	17
	>=4.0m below NGL	27	16	19
Switch yard area (BH01, BH175-BH183)	1.0m below FGL	14	08	10
	2.0m below FGL	18	10	13
	3.0m below FGL	20	11	13
	>=4.0m below FGL	21	12	14
WTP area (BH76, BH184-BH195)	1.0m below NGL	14	08	10
	2.0m below NGL	20	12	15
	3.0m below NGL	26	15	18
	>=4.0m below NGL	30	18	20
Safety Control room, Gate Complex area (BH196, BH197)	1.0m below NGL	14	08	10
	2.0m below NGL	20	11	14
	3.0m below NGL	23	13	15
	>=4.0m below NGL	25	15	17
AWPH, TAC, CAC, SUMP AWPH, HCSD PH, FOPH, FOUPH, FO Tank, AHP Clarifier (BH102-BH109, BH129-BH132, BH138)	1.0m below NGL	12	08	09
	2.0m below NGL	18	10	13
	3.0m below NGL	20	12	14
	>=4.0m below NGL	21	13	15
ESP, ASPH, ESP Control room, (BH82, BH83, BH85, BH86, BH88, BH91, BH94-BH97, BH99, BH111, BH112, BH127)	1.0m below NGL	10	07	08
	2.0m below NGL	14	08	09
	3.0m below NGL	16	10	11
	4.0m below NGL	18	12	14
	>=5.0m below NGL	26	15	18
Con43, Con45, Con46, CPU Reg, DSPH1, FWBPH, TP25 to TP29 (BH67, BH68, BH74, BH77, BH79, BH81, BH87, BH89, BH98, BH100, BH101)	1.0m below NGL	12	08	09
	2.0m below NGL	18	10	13
	3.0m below NGL	20	11	13
	>=4.0m below NGL	21	12	14
	1.0m below NGL	14	10	12

CWPH, CW Chem Plant, SSF Sump (BH22, BH23, BH30, BH33)	2.0m below NGL	24	12	16
	3.0m below NGL	28	15	18
	4.0m below NGL	32	20	22
	>=5.0m below NGL	34	22	25
GT, Air Comp House, Service Bldg. (BH34, BH35, BH37-BH41, BH45, BH47, BH62, BH73)	1.0m below NGL	14	09	10
	2.0m below NGL	24	12	16
	3.0m below NGL	28	15	18
	>=4.0m below NGL	30	18	20
Chimney, FGD area (BH115-BH117, BH135, BH136 BH119-BH126)	1.5m below FGL	18	10	13
	2.5m below FGL	20	11	13
	3.5m below FGL	21	12	14
	>=4.5m below FGL	25	15	17
Silo, Utility bldg., Stacker, Con 53, TP34, Biomass area, Stacker, Crusher House, TP32, Con 51, TP31, Con 48, Con49, TP33, TP34, Con53, CSSP, Track Hopper (BH139-BH161)	1.0m below FGL	16	10	12
	2.0m below FGL	22	12	14
	3.0m below FGL	23	14	16
	4.0m below FGL	25	16	18
	6.0m below FGL	30	18	20
	>=11.0m below FGL	30	25	24
TP24, Con41(except between BH163 to BH165), Con42 (BH75, BH162, BH163)	1.5m below NGL	12	07	08
	2.5m below NGL	14	07	08
	3.5m below NGL	15	08	08
	>=4.5m below NGL	20	09	09
Reclaim Hopper, TP30, Con 47(except between BH167 to BH170) (BH165, BH167, BH170- BH173)	1.5m below NGL	20	11	14
	2.5m below NGL	22	13	15
	3.5m below NGL	23	15	17
	>=4.5m below NGL	28	17	19
TP21, TP22, TP23, Con 39, Con40, Con41 between BH163 to BH165, Con 47 between BH167 and BH170 (BH164, BH168)	1.5m below NGL	06	04	08
	2.5m below NGL	08	06	09
	3.5m below NGL	10	07	11
	>=5.5m below NGL	24	14	18
RWPH, MCC SWGR near RWPH (BH212, BH213)	1.5m below NGL	09	08	12
	2.5m below NGL	14	09	17
	3.5m below NGL	20	11	20
	>=4.5m below NGL	24	15	24
RW Pipeline (BH206 to BH211, BH195, BH198, BH199)	1.5m below NGL	08	05	07
	2.5m below NGL	10	06	07
	3.5m below NGL	14	08	09
	>=4.5m below NGL	17	09	09
Transmission line Corridor (BH200 to BH205)	1.5m below NGL	20	10	14
	2.5m below NGL	22	13	15
	3.5m below NGL	25	15	17
	>=4.5m below NGL	27	17	20
Ash Dyke area (BHAD01 & BHAD02)	1.5m below NGL	15	12	14
	2.5m below NGL	17	16	15
	3.5m below NGL	24	22	22

	>=4.0m below NGL	25	25	25
Ash Dyke area (BHAD02)	1.5m below NGL	25	25	25
	>=2.5m below NGL	40	40	40
Ash Dyke area (BHAD03)	1.5m below NGL	04	04	07
	2.5m below NGL	07	05	08
	3.5m below NGL	10	06	10
	>=7.5m below NGL	20	15	18
Any other structure/facilities not mentioned above	1.5m below NGL	08	06	08
	2.5m below NGL	10	08	10
	3.5m below NGL	14	10	14
	>=4.0m below NGL	18	14	18

For Finished ground level (FGL) refer General layout plan (GLP)

To determine the Natural Ground Level (NGL), tender drawings titled "TOPGRAPHICAL SURVEY" shall be referred. Further the above tender drawings shall also be referred in conjunction with borelog data attached at Annexure to this chapter.

The NGL for any particular structure/facility shall be the lowest of all the NGLs mentioned in the extent of the building/facility.

The NGL of any point shall be the lowest of the levels at (a) TOPGRAPHICAL SURVEY and (b) Borelog data attached at Annexure to this chapter.

In case any loose/soft pockets are encountered at founding level, the same shall be removed completely upto the hard strata and filled up with PCC M7.5.

The net allowable bearing pressure higher than above mentioned values shall not be permitted. At intermediate levels the bearing capacity shall be same as the net allowable bearing pressure corresponding to the immediate shallower level mentioned above.

For the new facilities to be constructed after dismantling existing facilities; founding level of new facilities shall be taken at least 0.5m below the existing founding depth of the dismantled structures.

For open foundations, the total permissible settlement shall be governed by IS: 1904 / IS: 13063 and from functional requirements whichever is more stringent. However, total settlement shall be restricted to the following:

Isolated & Raft (Main powerhouse, TG Area Footings, Boiler, Mill, Bunker Footings & Fans) resting on soil	25 mm
Isolated & Strip (other than Main powerhouse, TG Area Footings, Boiler, Mill, Bunker Footings & Fans) resting on soil	40 mm
Raft (other than Main powerhouse, TG Area Footings, Boiler, Mill, Bunker Footings & Fans) resting on soil	75 mm

In case the total permissible settlement is to be restricted to less than as above specified from functional requirements, then the net allowable bearing pressure shall be reduced after review in consultation with Engineer.

Special Requirements:

i) Chemicals in ground water and subsoil, as observed during investigation are:

Chemical	Sulphates	Chlorides	pH
Ground Water	60-180 mg/l	20-82 mg/l	6.7-7.4
Sub-soil	< 0.05%	0.008-0.014%	4.7-6.6

D-1-12(E)

Annexure-(E)

CRITERIA FOR EARTHQUAKE RESISTANT DESIGN OF STRUCTURES AND EQUIPMENT

All structures and equipment shall be designed for seismic forces adopting the site specific seismic information provided in this document and using the other provisions in accordance with IS:1893 (Part 1 to Part 4). Pending finalization of Parts 5 of IS:1893, provisions of part 1 shall be read along with the relevant clauses of IS:1893:1984, for embankments.

A site specific seismic study has been conducted for the project site. The peak ground horizontal acceleration for the project site, the site specific acceleration spectral coefficients (in units of gravity acceleration 'g') in the horizontal direction for the various damping values and the multiplying factor (to be used over the spectral coefficients) for evaluating the design acceleration spectra are as given at Annexure-I.

Vertical acceleration spectral values shall be taken as 2/3rd of the corresponding horizontal values.

The site specific design acceleration spectra specified shall be used in place of the response acceleration spectra, given at figure-2 in IS:1893 (Part 1) and Annex B of IS:1893 (Part 4). The site specific acceleration spectra along with multiplying factors specified in Annexure-I includes the effect of the seismic environment of the site, the importance factor related to the structures and the response reduction factor. Hence, the design spectra do not require any further consideration of the zone factor (Z), the importance factor (I) and response reduction factor (R) as used in the IS:1893 (Part 1 and Part 4).

Damping in Structures

The damping factor (as a percentage of critical damping) to be adopted shall not be more than as indicated below for:

a)	Steel structures	:	2%
b)	Reinforced Concrete structures	:	5%
c)	Reinforced Concrete Stacks	:	3%
d)	Steel stacks	:	2%

Method of Analysis

Since most structures in a power plant are irregular in shape and have irregular distribution of mass and stiffness, dynamic analysis for obtaining the design seismic forces shall be carried out using the response spectrum method. The number of vibration modes used in the analysis should be such that the sum total of modal masses of all modes considered is at least 90 percent of the total seismic mass and shall also meet requirements of IS:1893 (Part 1). Modal combination of the peak response quantities shall be performed as per Complete Quadratic Combination (CQC) method or by an acceptable alternative as per IS:1893 (Part 1).

In general, seismic analysis shall be performed for the three orthogonal (two principal horizontal and one vertical) components of earthquake motion. The seismic response from the three components shall be combined as specified in IS:1893.

The spectral acceleration coefficient shall get restricted to the peak spectral value if the fundamental natural period of the structure falls to the left of the peak in the spectral acceleration curve.

For buildings, if the design base shear (V_B) obtained from modal combination is less than the base shear ($\bar{V}_B$) computed using the approximate fundamental period (T_a) given in IS:1893:Part 1 and using site specific acceleration spectra with appropriate multiplying factor specified at Annexure-I, the response quantities (e.g. member forces, displacements, storey forces, storey shears and base reactions) shall be enhanced in the ratio of $\bar{V}_B$/ V_B. However, no reduction is permitted if $\bar{V}_B$ is less than V_B.

Design/Detailing for Ductility for Structures

The site specific design acceleration spectra is a reduced spectra and has an in-built allowance for ductility. Structures shall be engineered and detailed in accordance with relevant Indian/International standards to achieve ductility.

ANNEXURE – I

SITE SPECIFIC SEISMIC PARAMETERS FOR DESIGN OF STRUCTURES AND EQUIPMENT

The various site specific seismic parameters for the project site shall be as follows:

1) Peak ground horizontal acceleration (MCE) : 0.204g

2) Multiplying factor to be applied to the site specific horizontal acceleration spectral coefficients (in units of gravity acceleration 'g') to obtain the design acceleration spectra

a) for special moment resisting steel building frames designed and detailed as per IS:800 : 0.051

b) for special concentrically braced steel building frames designed and detailed as per IS:800 : 0.038

c) For special moment resisting RC building frames designed and detailed as per IS:456 and IS:13920 : 0.031

d) for RCC chimney, RCC Natural Draft Cooling Tower : 0.102

e) for Anchored base liquid retaining steel tanks (ground supported) : 0.061

f) for Unanchored base liquid retaining steel tanks (ground supported) : 0.102

g) for steel chimney, Absorber tower, Vessels : 0.077

3) Multiplying factor to be applied to the site specific horizontal acceleration spectral coefficients (in units of gravity acceleration 'g') for design of equipment and structures where inelastic action is not relevant or not permitted : 0.102

Note: g = Acceleration due to gravity

The horizontal seismic acceleration spectral coefficients are furnished in subsequent pages.

Annexure – I

HORIZONTAL SEISMIC ACCELERATION SPECTRAL COEFFICIENTS
(In units of 'g')

Time Period	Damping Factor (as a percentage of critical damping)		
(Sec)	5 %	3 %	2 %
0.000	1.000	1.000	1.000
0.010	1.000	1.000	1.000
0.020	1.167	1.236	1.300
0.030	1.333	1.472	1.600
0.040	1.500	1.708	1.900
0.050	1.667	1.944	2.200
0.055	1.750	2.063	2.350
0.060	1.833	2.181	2.500
0.080	2.167	2.653	3.100
0.090	2.333	2.889	3.400
0.100	2.500	3.125	3.700
0.103	2.550	3.196	3.790
0.120	2.550	3.210	4.150
0.140	2.550	3.210	4.150
0.160	2.550	3.210	4.150
0.180	2.550	3.210	4.150
0.200	2.550	3.210	4.150
0.220	2.550	3.210	4.150
0.240	2.550	3.210	4.150
0.260	2.550	3.210	4.150
0.280	2.550	3.210	4.150
0.300	2.550	3.210	4.150

Annexure – I

HORIZONTAL SEISMIC ACCELERATION SPECTRAL COEFFICIENTS
(In units of 'g')

Time Period	Damping Factor (as a percentage of critical damping)		
(Sec)	5 %	3 %	2 %
0.320	2.550	3.210	4.150
0.340	2.550	3.210	4.150
0.360	2.550	3.210	4.150
0.380	2.550	3.210	4.150
0.400	2.550	3.210	4.150
0.420	2.550	3.210	4.150
0.440	2.550	3.210	4.150
0.460	2.550	3.210	4.150
0.480	2.550	3.210	4.150
0.500	2.550	3.210	4.150
0.520	2.550	3.210	4.150
0.540	2.550	3.210	4.150
0.550	2.550	3.210	4.150
0.560	2.550	3.210	4.150
0.580	2.550	3.210	4.150
0.600	2.550	3.210	4.150
0.620	2.550	3.210	4.150
0.640	2.550	3.210	4.150
0.660	2.550	3.210	4.150
0.670	2.550	3.210	4.150
0.680	2.550	3.210	4.118
0.700	2.550	3.210	4.000
0.720	2.550	3.210	3.889
0.740	2.550	3.210	3.784
0.760	2.550	3.210	3.684
0.780	2.550	3.210	3.590

Annexure – I

HORIZONTAL SEISMIC ACCELERATION SPECTRAL COEFFICIENTS
(In units of 'g')

Time Period	Damping Factor (as a percentage of critical damping)		
(Sec)	5 %	3 %	2 %
0.800	2.500	3.125	3.500
0.820	2.439	3.049	3.415
0.840	2.381	2.976	3.333
0.860	2.326	2.907	3.256
0.880	2.273	2.841	3.182
0.900	2.222	2.778	3.111
0.920	2.174	2.717	3.043
0.940	2.128	2.660	2.979
0.960	2.083	2.604	2.917
0.980	2.041	2.551	2.857
1.000	2.000	2.500	2.800
1.020	1.961	2.451	2.745
1.040	1.923	2.404	2.692
1.060	1.887	2.358	2.642
1.080	1.852	2.315	2.593
1.100	1.818	2.273	2.545
1.120	1.786	2.232	2.500
1.140	1.754	2.193	2.456
1.160	1.724	2.155	2.414
1.180	1.695	2.119	2.373
1.200	1.667	2.083	2.333
1.220	1.639	2.049	2.295
1.240	1.613	2.016	2.258
1.260	1.587	1.984	2.222
1.280	1.563	1.953	2.188
1.300	1.538	1.923	2.154

Annexure – I

HORIZONTAL SEISMIC ACCELERATION SPECTRAL COEFFICIENTS
(In units of 'g')

Time Period	Damping Factor (as a percentage of critical damping)		
(Sec)	5 %	3 %	2 %
1.320	1.515	1.894	2.121
1.340	1.493	1.866	2.090
1.360	1.471	1.838	2.059
1.380	1.449	1.812	2.029
1.400	1.429	1.786	2.000
1.420	1.408	1.761	1.972
1.440	1.389	1.736	1.944
1.460	1.370	1.712	1.918
1.480	1.351	1.689	1.892
1.500	1.333	1.667	1.867
1.520	1.316	1.645	1.842
1.540	1.299	1.623	1.818
1.560	1.282	1.603	1.795
1.580	1.266	1.582	1.772
1.600	1.250	1.563	1.750
1.620	1.235	1.543	1.728
1.640	1.220	1.524	1.707
1.660	1.205	1.506	1.687
1.680	1.190	1.488	1.667
1.700	1.176	1.471	1.647
1.720	1.163	1.453	1.628
1.740	1.149	1.437	1.609
1.760	1.136	1.420	1.591
1.780	1.124	1.404	1.573
1.800	1.111	1.389	1.556
1.820	1.099	1.374	1.538

Annexure – I

HORIZONTAL SEISMIC ACCELERATION SPECTRAL COEFFICIENTS
(In units of 'g')

Time Period	Damping Factor (as a percentage of critical damping)		
(Sec)	5 %	3 %	2 %
1.840	1.087	1.359	1.522
1.860	1.075	1.344	1.505
1.880	1.064	1.330	1.489
1.900	1.053	1.316	1.474
1.920	1.042	1.302	1.458
1.940	1.031	1.289	1.443
1.960	1.020	1.276	1.429
1.980	1.010	1.263	1.414
2.000	1.000	1.250	1.400
2.020	0.990	1.238	1.386
2.040	0.980	1.225	1.373
2.060	0.971	1.214	1.359
2.080	0.962	1.202	1.346
2.100	0.952	1.190	1.333
2.150	0.930	1.163	1.302
2.200	0.909	1.136	1.273
2.250	0.889	1.111	1.244
2.300	0.870	1.087	1.217
2.350	0.851	1.064	1.191
2.400	0.833	1.042	1.167
2.450	0.816	1.020	1.143
2.500	0.800	1.000	1.120
2.550	0.784	0.980	1.098
2.600	0.769	0.962	1.077
2.650	0.755	0.943	1.057
2.700	0.741	0.926	1.037

Annexure – I

HORIZONTAL SEISMIC ACCELERATION SPECTRAL COEFFICIENTS
(In units of 'g')

Time Period	Damping Factor (as a percentage of critical damping)		
(Sec)	5 %	3 %	2 %
2.750	0.727	0.909	1.018
2.800	0.714	0.893	1.000
2.850	0.702	0.877	0.982
2.900	0.690	0.862	0.966
2.950	0.678	0.847	0.949
3.000	0.667	0.833	0.933
3.050	0.656	0.820	0.918
3.100	0.645	0.806	0.903
3.150	0.635	0.794	0.889
3.200	0.625	0.781	0.875
3.250	0.615	0.769	0.862
3.300	0.606	0.758	0.848
3.350	0.597	0.746	0.836
3.400	0.588	0.735	0.824
3.450	0.580	0.725	0.812
3.500	0.571	0.714	0.800
3.550	0.563	0.704	0.789
3.600	0.556	0.694	0.778
3.650	0.548	0.685	0.767
3.700	0.541	0.676	0.757
3.750	0.533	0.667	0.747
3.800	0.526	0.658	0.737
3.850	0.519	0.649	0.727
3.900	0.513	0.641	0.718
3.950	0.506	0.633	0.709
4.000	0.500	0.625	0.700