

CORRIGENDUM -1 TO TENDER SPECIFICATION BHEL PSSR SCT 1576 - TEST PILE, TEST PATCH WORK ETC. AT ENNORE SEZ,DT:05/02/2015

Some of the bidders sought clarifications vide letters or in Pre Bid discussion held on 02/02/2015 at BHEL PSSR in regard to Test Pile, Test Patch work etc. for Ennore SEZ and BHEL's clarifications are furnished below for information. Sl.No. 41 Issued by BHEL.

SL. NO	REFERENCE CLAUSE OF TENDER DOCUMENT	EXISTING PROVISION	BIDDER'S QUERY	BHEL'S CLARIFICATION
1	NIT Annexure-3, Cl.no.1, Qualification criteria.	Piling and stone column works of specific value is mentioned	Please clarify whether separate completion certificate for piling work for one project and separate completion certificate for another project for stone column work can be submitted. Further, sector other than power/ industrial projects such as port works, container terminal projects etc. shall be admissible.	Revised PQR is as follows: Technical QR : 1.1 The bidder should have executed the following in india in the last seven years preceding the latest due date of bid submission : 1.1.1 One (1) civil work of value not less than Rs 2.1 Crore (OR) 1.1.2 Two (2) civil works each of value not less than Rs 1.3 Crore (OR) 1.1.3 Three (3) civil works each of value not less than Rs 1 Crore (AND) 1.2 Also bidder should have executed stone column and piling work in same or in different contract in any project in the last seven years preceding the latest due date of bid submission. <u>Note</u> : The work "Executed" in the above QR means; the value/quantum of work specific should have been completed in the said work irrespective of completion of the work.
2	Tender Notification	Last date of submission of bid is scheduled on 07.02.2015	Considering the scope of work / clarifications required, we earnestly request you to extend the due date for submission of tender bids by atleast 10 days after receiving of last addendum / clarification / errata.	Due date & Time of Offer Submission :- Date:-11/02/2015 Time:1500Hrs Opening of Tender :- Date:- 11/02/2015 Time:1530Hrs
3	NIT Annexure-2, Check list	Sl.no.20. Submission of analysis of unit rates, forms and procedures - form no.F-26 (Rev 00)	Unit rates will be quoted by the tenderer under respective items in the BOQ. Breakup details as required in Form-26 cannot be assessed since it is difficult to separate the cost into various components as asked for.	Unit rates to be quoted as per Form F26 - (Rev 00) provided in GCC
4	NIT Annexure-8	Certificate by Chartered Accountant on letter head.	Since our Company is a Limited Company and listed in stock exchange, this certificate may not be required to be produced by us. Kindly confirm.	Annexure-8 applicable only for MSME registered vendors.

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5	Technical Conditions of Contract, Volume 1A, Part 1, Chapter III Facilities and consumables in the scope of Contractor - Scope matrix Cl.1.3.1.1.1	Canteen facilities by bidders	Since our scope of work is less it is not possible to provide canteen facilities. Please clarify.	No it is in the scope of the bidder
6	Technical Conditions of Contract Cl.1.3.10	Dewatering/ work area and approach/ access roads - free from accumulation of water.	It is presumed that the piling / ground improvement works (for compaction piles, stone columns, etc.) shall be commenced only after completion of site grading / filling works. Accordingly, we presume that the entire work site duly filled, compacted and levelled condition free from any surface, subsurface and overhead obstructions shall be handed over to us prior to start of mobilisation.	Site is filled with ash and levelled to some extent. As such no filling envisaged. Bidder to take care for movement of rigs.
7	Technical Conditions of Contract Volume 1A part 1 Chapter VI, Time schedule Cl.1.6.1.2	Completion time shall be 2 months from the date of commencement of work.	Considering the scope of work as mentioned in the BOQ, the minimum period of 28 after pile installation for conducting load tests on piles and the number of load tests to be conducted please revise the completion time to atleast four months from the date of commencement of work. Further, the date of commencement of work shall be 10 days from the date of issue of LOI. Please confirm.	Start of work can be 7 days from the date of award. Completion period to be maintained as 2 months.
8	Technical Conditions of Contract Volume 1A Chapter VII cl.1.7.2	Advance for mobilisation - not applicable	We request you to give interest free mobilisation advance of 10% of the contract value against Bank Guarantee from any scheduled bank and recovery of the same shall be done from 2nd Running Account Bill.	No advance is envisaged for this work.

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9	Technical Conditions of Contract Volume 1A part 1 Chapter VII, Terms of payment cl.1.7.4.1/ Other terms of payment in SCC Cl.10.0	NIT - 50% on completion of piling and stone column, 40% after entire work and 10% on submission of final report SCC - 95% within 30 days from the date of submission of monthly Running Account bill and 5% retention	We request you to release atleast 90% of Running Account Bill within 20 calendar days of submission of bill and balance 10% after submission of final report and acceptance of the same by BHEL.	NIT clause stands.
10	Technical Conditions of Contract Volume 1A, Part 1, Chapter VIII, Taxes and other Duties.	VAT and other taxes/ levies; SEZ mentioned in name of the work	Please clarify whether this project comes under SEZ and if SEZ please confirm the tax benefits/ exemptions against this project.	No tax benefits, as envisaged in 'SEZ' is applicable.
11a	Specific Technical Requirement of driven cast-in-situ piles 30.02.00/ 30.03.00	Design of piles based on soil report to be submitted by tenderer along with the tender document.	Soil report is not furnished with the tender document. Please furnish the same. Further, we presume that design is not in the scope of tenderer since BOQ mentions the pile size, length of pile and steel reinforcement in piles, etc. Please confirm.	Design of pile foundation is on the scope of BHEL. Geotechnical investigation is in progress, how ever a few bore holes data recived from M/s TANGEDCO is enclosed.
b	Specific Technical Requirement of Bored cast-in-situ piles .30.02.00/ 30.03.00			
c	Cl.no.2.06.00/cl.2.07.00 of Technical Specification for bored cast-in-situ piles			
12	Specific Requirement Driven cast-in-situ piles/ Bored cast-in-situ piles cl.no.30.07.00 m and cl.no. 30.07.00 h	Dynamic cone penetration test to be done for each pile group	This is not practically possible and this will result in delays in the execution of the work. Further, since these tests are required to be carried out under item no.3014, Ground Improvement Work, we request that this clause may please be deleted.	Not accepted. Work shall be done as per specification.

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13	Specific Requirement Driven cast-in-situ piles/ Bored cast-in- situ piles cl.no.30.08.00	Lateral load test at cut off level and also vertical/ pull out tests	Since the appropriate length of empty boring is expected to 3.5m, load tests shall be conducted only at working ground level and suitable allowance shall be made in the interpretation of test results / test load in terms of Clause No. 6.4 & 6.4.1 of IS 2911 (Part 4) : 2013. Accordingly, at the time of concreting the test piles can be cast upto the working ground level and payment for the same shall be made as per relevant quoted rates in the Bill of Quantities together with steel reinforcement thereof.	Not accepted. Work shall be done as per specification.

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SL. NO	REFERENCE CLAUSE OF TENDER DOCUMENT	EXISTING PROVISION	BIDDER'S QUERY	BHEL'S CLARIFICATION
14	ST No.3011 to 3015 of BOQ	Various tests to be conducted in soil - Standard specification for geotechnical investigation mentions various types of tests which are not mentioned in BOQ.	We have quoted our rates only for the tests indicated in the BOQ. If any tests, other than those mentioned in the BOQ are required to be conducted, the same shall be considered as an extra item of work and payable extra.	item inclusive, bidder to quote as per BOQ
15a	Standard specification for geotechnical investigation.	As per Cl.no.1.1 it is mentioned that load intensities for various structures expected to be between 50KN per sq.m. and 500KN per sq.m.	Please indicate the bearing capacity requirement upto which the existing ground level is to be improved in each category/ case. Whether design responsibility for compaction piles/ stone columns will be with BHEL.	Design of compaction pile/stone columns shall be by BHEL. The improved parameters of sub strata after improvement shall be indicating in the drawing during detailed engineering
b	ST 3002 & 3004 of BOQ	Compaction piles of 14m long, 550mm dia. / stone column of 550mm dia 14m long.	Please confirm that indicated basic lengths are applicable for lengths measured from working ground level upto bottom tip of the pile	Accepted
c	ST 3004	Filling material in stone column shall comprise of 1 sand : 2 stone aggregate.	The filling material for stone column under item no. 3004 / A 3004 under Package-1 civil works (main work) is only 40m downsize stone aggregate, whereas in the BOQ for test piling works, the filling material is a mixture of sand and stone aggregate in 1:2 proportion. Please clarify the type of back fill material to be used for stone column for test piling work.	The fill materials shall confirm to Technical specifications

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16	Technical Specification for bored cast-in-situ piles Cl.4.02.00 installation criteria SPT/ UCS tests and others to be determined the founding level.	Determination of founding level - SPT / UCS etc., tests.	SPT cannot be done inside the pile bores, as the SPT values will not be realistic and further it is a time consuming process and will cause delays in execution of work.	SPT is not required to conduct within the pile bore hole to determine the founding level
17	Technical Specification for installation and testing of bored cast-in-situ piles/ driven cast-in-situ piles. Cl.no.8.01.14	Low strain integrity test..	All the 18 nos. of integrity tests indicated in the BOQ shall be done in a single visit by the specialist agency	Work shall be done as per specification.
18	ST No.2503/2503A of BOQ	Type of cement - as per Specific Technical Requirement cl.no.1.01.01 SRC cement is specified. Technical condition of contract - cl. No. 1.3.6.2 OPC cement for all except foundations / UG structures, Technical specification for driven cast-in-situ piles cl. No. 3.02.02 SRC Cement is specified	Please confirm the type of cement to be used for both bored cast-in-situ piles and driven cast-in-situ piles.	OPC with C3A content limited to 5% to 8% as per IS shall be used.

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19	ST No.2503/2503A of BOQ	Grade of concrete is M30 in BOQ whereas as per Specific Technical Requirement Annexure-A for bored cast-in-situ piles, grade of concrete is mentioned as M25. As per technical specification for driven cast-in-situ piles Annexure -A, grade of concrete is mentioned as M30.	Please clarify whether M30 grade concrete is applicable for both bored cast-in-situ piles as well as driven cast-in-situ piles.	M30 grade concrete is applicable for both bored cast-in-situ piles as well as driven cast-in-situ piles
20	ST No.2503/2503A of BOQ	Length of pile measured for payment will be from pile cut off level to the bottom of pile. Further empty boring from working ground level to pile cut off level shall be included in the quoted rate. As per technical specification for driven cast-in-situ pile Annexure -A length of empty boring is mentioned as approximately 3.5m	Please clarify that empty boring length of 3.5m measured from working ground level to pile cut off level mentioned for driven cast-in-situ piles is applicable for bored cast-in-situ piles also.	Cut-off level varies from 3 to 4m and is applicable for both bored cast-in-situ piles as well as driven cast-in-situ piles
			Since it is not possible to conduct load test at cut off level (3.5m below working ground level) length of pile measured for payment shall be from working ground level upto bottom tip of the pile. Accordingly, these item nos. shall be revised. Please confirm	Work shall be done as per specification

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21	ST No.A2504, A2505 of BOQ	Extra / rebate for pile lengths more/ less than the specified length of ST no.A2503	The item no. should be 2503A instead of A2503.	Please read S.T No.2503A as A2503
22	ST No.2507 of BOQ	Initial load test shall be conducted upto a maximum test load of 3 times the safe load capacity. Technical specification for bored cast-in-situ piles (Annexure-A) cl. no. 2.04.00 and 2.05.00 guarantee on pile capacities	As per clause 5.1.2 of IS 2911(Part 4):2013 initial test for piles shall be conducted upto 2.5 times the estimated safe load carrying capacity. Please confirm	Not accepted. Work shall be done as per specification.
			Annexure-A not furnished. Please specify the safe axial, lateral and uplift capacity for 550mm dia driven cast-in-situ piles and 600mm/ 760mm bored cast-in-situ piles.	The approximate safe load carrying capacities for various diameters of piles are as follows. However actual safe load carrying capacities for various diameters of piles shall be furnished during detailed Engineering. 1) Dia of pile- 550mm (Driven cast-in situ) a) safe load carrying capacity in vertical compression = 115MT b) safe load carrying capacity in uplift = 50MT c) safe load carrying capacity in Lateral = 7MT 2) Dia of pile- 600mm(Bored cast-in situ) a) safe load carrying capacity in vertical compression = 150MT b) safe load carrying capacity in uplift = 50MT c) safe load carrying capacity in Lateral = 7MT 3) Dia of pile- 760mm(Bored cast-in situ) a) safe load carrying capacity in vertical compression = 250MT b) safe load carrying capacity in uplift = 70MT c) safe load carrying capacity in Lateral = 10MT

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23	ST No.2510 of BOQ	Steel reinforcement as per Cl.no.1.01.02 of Specific Technical Requirement of bored cast-in-situ piles and cl.no.3.03.01 of Technical Specification for driven cast-in-situ piles - Fusion bonded epoxy coated reinforcement steel is mentioned.	In the absence of any item in BOQ for epoxy coating on steel reinforcement, we presume that no coating is required. Please confirm.	bidder to quote as per BOQ
24	ST No.3003 of BOQ	Stone column by vibro displacement dry method.	It is observed that the sub soil water table is around 1.2m to 1.5m below existing ground level and the proposed dry method may not be possible/ feasible. Accordingly, please inform whether installation of stone column by driving technique (similar to the method of installation of compaction piles) can be adopted in lieu of the proposed vibro displacement method.	Not accepted. Work shall be done as per specification.
26	ST No.3015(d) of BOQ	Triaxial shear test	Please specify the quantity of test to be done.	Triaxial test is not required.
26	BOQ 3002 cl.2.04.00 Technical Specification for Stone Column	Detachable MS shoe (Flat/ conical)	The description under these item nos. refers to a detachable MS shoe (flat/ conical at the bottom) to be used for installation of compaction piles. Please confirm that the Bidder can use or adopt an openable/ reusable MS shoe/ valve instead of a detachable/ disposable shoe.	Not accepted. Work shall be done as per specification.

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27	BOQ for test piling work / main piling work	Geotechnical investigation / ground improvement work	BOQ for both test piling works and main piling works contain items for geotechnical investigation works/ testing of geotechnical investigation works. As these items are repeated, kindly clarify whether it will be deleted in main piling work.	This tender is for Test Piling, Geotechnical Investigation to be carried out in line with BOQ. Main piling work will be dealt in separate tender.
28	--	Cement	Please provide us the vendor list for procurement of cement	OPC with C3A content limited to 5% to 8% as per IS shall be used.
29	BOQ	Test Piles	We presume that 3 nos. of test piles shall be installed in a particular location and load tests are conducted on all these test piles such as 1 no. vertical load test, 1 no. lateral load test and 1 no. uplift load test. We presume the adjacent piles among the above will be considered as reaction piles. No extra piles shall be installed. Please clarify.	Accepted. Yes, No extra pile is required.
30	General	Bored cast-in-situ piles as per your bid	Considering our extensive exposure in the field of piling in all types of soil, we are of the opinion that Precast Segmental piling technique will be technically far superior in quality and speedier for execution. It is also likely to be substantially cheaper compared to bored cast-in-situ piles. We may therefore be permitted to quote for Precast Segmental piling technique as an alternative to bored cast-in-situ piles for your consideration.	Not accepted. Work shall be done as per specification.

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31	General	Driven cast-in-situ RCC Piling Rigs	We shall deploy our standard Simplex type standard driven piling rig with standard accessories such as drop hammer only for installation of compaction pile and driven cast-in-situ piles.	Work shall be done as per specification.
32	ST 3001 & ST 3003	No of rigs for stone column works	No of rigs required to mobilize for stone column installation works seems high. We feel only one rig for each method is sufficient for scope of works. Please consider and confirm	bidder to quote as per BOQ
33	ST 3004	Backfill material for stone column installation	Tender BoQ says backfill material required for vibro displacement method (Dry method) is 1 (sand) : 2 (stone) – sand stone mix. However, 40mm down aggregate is mentioned in main tender works. Request you check and confirm the same.	The fill materials shall confirm to Technical specifications
34	ST 3002 & ST 3004	No of Stone columns for tests	No. of stone columns proposed for initial testing looks on higher side. Kindly re-look into testing requirement (no. of tests) accordingly stone column quantities can be reduced .	item given in the BOQ prevail.
35		Pile capacities	Pile capacities are not provided for initial test piles. Please confirm the same.	refer SI No. 22

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36	Technical Conditions of Contract	Time schedule for scope of works	We understand that time schedule for completion of total scope of works is 2 months from commencement of works. We request you to extend the mobilization period up to 3 weeks from the date of award of work.	bidder to quote as per BOQ
37		Separate BoQ for Working Platform	As this is an initial activity for this project, we feel that proper working platform for movement of heavy machineries is required. Request you to provide separate item in BoQ for preparation of working platform.	bidder to quote as per BOQ
38	PQ requirements	annexure-3	the bidder should have executed piling & stone column work in power/industrial projects. In this regard it is submitted that we have not executed any stone column however Bore castin stiu RCC piles in NCTPS and CPCL Manali. Whether our experience in RCC piling alone can be acceptable	Refer SI No. 1
39	ST3013		In BOQ item No.3013 fo conducting plate load test please specify the design load	refer SI No. 22
40			It is requested that the submission date of bid may please be extended upto 13.02.15	Refer SI No. 2

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41	VOLUME-IA PART – I CHAPTER-VII - TERMS OF PAYMENT; Note:- Sl No. (V) of point no. 02	Payment for the first running bill will be released only on production of the following. (V) Security Deposit as per GCC		In the event of not submitting, Security Deposit (SD) shall be recovered from 1st Running Bill. The SD amount shall be returned on completion of work along with final bill. The above shall be applicable for Additional Security Deposit (ASD) too.

All other Terms & Conditions remain unchanged.

Encl. Geotechnical Investigation Report from M/s TANGEDCO

GEO MARINE CONSULTANTS (P) LTD.,

11, 2nd Main Road, Kannappa Nagar Ext,
Kottivakkam, Chennai – 600 041.

Ph. No. 044 - 24481485 & 24480305.

Email: geotech@geomarineindia.com / geomarineindia@gmail.com.

PROJECT

PROPOSED CONSTRUCTION OF 2X800 MW SUPERCRITICAL THERMAL POWER PLANTS IN ASH POND, ATHIPATTU PUDU NAGAR, NORTH CHENNAI.



CLIENT

NORTH CHENNAI THERMAL POWER STATION

NCTPS-Stage-II, CHENNAI-6000 120

TITLE

GEOTECHNICAL INVESTIGATION REPORT

VOLUME-I

GEOTECHNICAL MODEL OF THE SITE, ANALYSIS & RECOMMENDATION

GMC-NCTPS-STAGE-II-JC-GT-218

DATE	REV. ON	DESCRIPTION		PREPARED BY	REVIEWED BY	APPROVED BY
05/05/2012		SUBMISSION FOR DESIGN OF FOUNDATIONS	SIGN			
			DATE	05/05/2012	05/05/2012	05/05/2012
			DESIGNATION	GEOLOGIST	GEOLOGIST	TEAM LEADER
			NAME	S.N. KARTHIKEYAN	NOBLE PHILIP	K. RAMALINGAM

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REPORT TEXT

INTRODUCTION

1.0 Preamble

North Chennai Thermal Power Station-Stage-II awarded the responsibility of carrying out the detailed geotechnical investigation for the construction of proposed 2x800MW Stage- II of Super Critical Thermal Power Plant at Ash Pond North Chennai for Tamil Nadu Electricity Board, Chennai.

A comprehensive geotechnical investigation planning was furnished by PEM department of NCTPS-Chennai and the same was executed under the supervision of Engineer in charge of Projects division of TANGEDCO, Chennai.

The investigation report is presented in two volumes as listed below:

- ◆ **Volume-I:** Geotechnical Model of the Site, Analysis & Recommendation
- ◆ **Volume-II:** Geotechnical Field and Laboratory Data

This part of report is **Volume-I: Geotechnical Model of the Site, Analysis & Recommendations**

1.1 General Scope of Work

1.1.1 Field Work

The Scope of work is as follows.

- ❖ Making Standard soil investigation bore holes of 150 mm diameter up to 30m/40m depth as per the Geotechnical Investigation Layout drawing.
- ❖ Core drilling in rock, if rock is encountered.
- ❖ Conducting Standard Penetration Test.as per IS:2131-1981
- ❖ Conduction Static Cone Penetration Test-23 Nos.as per IS: 4968 (Part-3) 1976
- ❖ Conducting Electrical Resistivity Test.-05 Nos.as per IS:3043-1987

1.1.2 Laboratory Work

On Soil Samples

- a. Bulk Density and Natural Moisture Content
- b. Atterberg's limits
- c. Grain Size Analysis
- d. Hydrometer Analysis
- e. Unconfined Compressive Strength
- f. One Dimensional Consolidation Test
- g. Direct Shear Test
- h. Triaxial Shear Test- Unconsolidated Undrained Test & Consolidated Undrained Test
- i. Specific Gravity
- j. Chemical Analysis

On Water Samples

- I. Sulphate
- II. Chloride
- III. pH

1.2 Structure of the Report

- ❖ Geology-Sub-Surface Stratification & Design Geotechnical Model
- ❖ Foundation Systems
- ❖ Recommendations
- ❖ Annexure (Design Computations)

GEOLOGY - SUB SURFACE STRATIFICATION & DESIGN GEOTECHNICAL MODEL

2.0 Preamble:

Geotechnical investigation carried out at a specific site provides location specific sub surface characteristics based on which the design of sub structures/foundations is generally carried out. However, the macro-level understanding of the sub surface is also needed for a comprehensive understanding of the sub structure/foundation response to naturally super imposed loads like earthquake forces etc., The macro level understanding of the sub surface is better provided through the knowledge of the Geology of the region. Since, it is beyond the scope of the present study to carry out geological investigation to establish the geology of the study region; published data are presented below along with the sub surface stratification observed through the direct borehole investigation carried out at the specified locations.

2.1 Geology:

Geologically, the present site is located in a coastal region with sub surface consisting of sedimentary deposits. The top sedimentary deposit is under laid by upper Gondwana system, particularly lower stage of Sriperumpudur (Sripermatpur). The formation mechanism of the sediments is chiefly due to transportation of surface water and marine deposition.

The above geological characteristics are also observed in the direct bore hole investigation, which confirms that the present site does not depict any surprising geological features that are different from that of the region.

2.2 Sub-Surface Stratification with Respect to Foundation Design:

Sub Surface Stratification (Macro Level):

In the Ash Pond Region:

In this region, the sub surface strata are:

- ❖ From existing ground level (Ash level) to an average depth of 4.0m and maximum depth of 6.0m recent fill of very loose fly ash. This fly ash is filled in the form of slurry received from the existing power plant.
- ❖ From 4.0m to 10.0m V.loose clayey silty sand/ V.Soft to soft sandy silty Clay
- ❖ From 10.0m to 14.0m M.Dense clayey silty Sand
- ❖ From 14.0m to 18.0m M.Dense silty Sand
- ❖ From 18.0m to 22.0m Dense clayey silty Sand
- ❖ From 22.0m to 27.40m V.Dense silty Sand
- ❖ From 27.40m to 30.0m Hard Compacted Clay(Shale)

In the Coal Conveyor Area:

- ❖ From existing ground level to 11.0m V.soft silty clay
- ❖ From 11.0m to 13.50m M.Dense silty Sand
- ❖ From 13.50m to 27.50m V.Dense silty Sand
- ❖ From 27.50m to 30.50m Hard Compacted Clay(Shale)

The sub geological surface stratification provides macro level insight into the formation characteristics based on the formation mechanism with respect to time history.

However, for the design of foundations, the location specific sub surface stratification with respect to relevant engineering parameters is needed. This is achieved by direct bore hole investigation, in which correlation of visually observed soil samples collected along with their derived engineering parameters reveals the in-situ strength of strata.

- For Coarse Grained Material, Ref. IS: 6403 to estimate Angle of Shearing Resistance (Reproduced and shown in Fig.A1)
- For Fine Grained Material, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength (Reproduced and shown in Fig.A2)
- Based on the above, the field data are analysed facility wise, and the geotechnical stratification of sub surface for each investigation location is presented below:

2.3 Switch Yard Area (Ref.BH-15,17)

REFERENCE BORE HOLE-BH:				15	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	γ kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	2.90	2.90	Fly Ash	Grey	0	Very Loose	-	12	-	19.6
2	2.90	8.00	5.10	Clayey Silty Sand	Grey	4	Very Loose	-	13.5	-	20.2
3	8.00	10.00	2.00	Silty Sand	Grey	7	Loose	-	14.5	-	29.4
4	10.00	14.00	4.00	Silty Sand	Grey	25	Medium Dense	-	18.5	-	34.5
5	14.00	18.00	4.00	Silty Clay with Sand Pockets	Grey	43	-	Hard	21	287	39.4
6	18.00	22.00	4.00	Sandy Silty Clay	Greyish Brown	50	-	Hard	21	333	-
7	22.00	30.40	8.40	Silty Sand with Clay Binder	Brownish Grey	>100	Very Dense	-	21	-	42.5

REFERENCE BORE HOLE-BH:				17	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	(γ) kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	4.20	4.20	Fly Ash	Grey	9	Loose	-	14.5	-	29.8
2	4.20	6.00	1.80	Silty Clay	Grey	1	-	Very Soft	13.5	7	-
3	6.00	10.00	4.00	Clayey Silty Sand	Grey	2	Very Loose	-	13	-	19.9
4	10.00	11.70	1.70	Clayey Silty Sand	Grey	17	Medium Dense	-	18	-	32.1
5	11.70	18.00	6.30	Silty Sand	Grey	23	Medium Dense	-	18.5	-	33.9
6	18.00	21.60	3.60	Silty Clay	Grey	56	-	Hard	21	373	42.5
7	21.60	27.80	6.20	Silty Sand	Grey	60	Very Dense	-	20.5	-	42.5
8	27.80	30.30	2.50	Compacted Clay (Shale)	Grey	>100	-	Hard	22	400	-

2.4 Transformer Yard Area (Ref.BH-18)

REFERENCE BORE HOLE-BH:				18	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	γ kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	4.00	4.00	Fly Ash	Grey	1	Very Loose	-	12	-	19.8
2	4.00	10.00	6.00	Clayey Silty Sand	Grey	3	Very Loose	-	13	-	20.1
3	10.00	13.50	3.50	Clayey Silty Sand	Grey	22	Medium Dense	-	18.5	-	33.6
4	13.50	16.50	3.00	Silty Sand	Grey	21	Medium Dense	-	18.5	-	33.3
5	16.50	20.00	3.50	Sandy Silty Clay	Grey	71	-	Hard	22	400	-
6	20.00	22.00	2.00	Clayey Silty Sand	Grey	>100	Very Dense	-	21	-	42.5
7	22.00	24.50	2.50	Silty Sand	Greyish, Yellow	89	Very Dense	-	21	-	42.5
8	24.50	30.50	6.00	Compacted Clay (Shale)	Brownish, Grey	>100	-	Hard	22	400	-

2.5 Boiler/Auxiliary Boiler Area (Ref.BH-21,28)

REFERENCE BORE HOLE-BH:				21	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	(γ) kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	3.00	3.00	Fly Ash	Grey	5	Loose	-	14	-	20.4
2	3.00	10.30	7.30	Clayey Silty Sand	Grey	1	Very Loose	-	12	-	19.8
3	10.30	12.00	1.70	Clayey Silty Sand	Grey	11	Medium Dense	-	15.5	-	30.3
4	12.00	15.00	3.00	Silty Sand	Grey	15	Medium Dense	-	17.5	-	31.5
5	15.00	19.60	4.60	Silty Sand	Grey	44	Dense	-	20	-	39.7
6	19.60	20.00	0.40	Silty Clay	Grey	47	-	Hard	21	313	-
7	20.00	21.40	1.40	Clayey Silty Sand	Grey	57	Very Dense	-	20.5	-	42.1
8	21.40	25.80	4.40	Silty Sand	Grey	>100	Very Dense	-	21	-	42.5
9	25.80	30.50	4.70	Compacted Clay (Shale)	Greyish Yellow	95	-	Hard	22	400	-

REFERENCE BORE HOLE-BH:				28	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	(γ) kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	3.00	3.00	Fly Ash	Grey	13	-	-	-	-	-
2	3.00	10.00	7.00	Clayey Silty Sand	Grey	1	Very Loose	-	12	-	19.8
3	10.00	12.00	2.00	Clayey Silty Sand	Grey	25	Medium Dense	-	18.5	-	34.5
4	12.00	16.50	4.50	Silty Sand	Grey	31	Dense	-	19.5	-	36.3
5	16.50	20.50	4.00	Clayey Silty Sand	Grey	68	Very Dense	-	21	-	42.5
6	20.50	30.30	9.80	Silty Sand	Grey	>100	Very Dense	-	21	-	42.5

2.6 Chimney Area (Ref.BH-23)

REFERENCE BORE HOLE-BH:				23	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	γ kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	3.40	3.40	Fly Ash	Grey	4	Very Loose	-	13.5	-	20.2
2	3.40	7.50	4.10	Clayey Silty Sand	Yellowish Grey	1	Very Loose	-	12	-	19.8
3	7.50	9.00	1.50	Sandy Silty Clay	Black	UDS	-	-	-	-	-
4	9.00	10.50	1.50	Silty Clay	Black	3	-	Soft	14	20	-
5	10.50	13.00	2.50	Clayey Silty Sand	Greyish Green	15	Medium Dense	-	17.5	-	31.5
6	13.00	20.00	7.00	Silty Sand	Greenish Grey	27	Medium Dense	-	19	-	35.1
7	20.00	24.00	4.00	Clayey Silty Sand	Greenish Yellow	48	Dense	-	20	-	40.6
8	24.00	30.30	6.30	Silty Sand	Greyish Brown	>100	Very Dense	-	21	-	42.5

2.7 T.G Building/DG House Area (Ref.BH-20,27)

REFERENCE BORE HOLE-BH:				20	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	γ kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	4.00	4.00	Fly Ash	Grey	3	Very Loose	-	13	-	20.1
2	4.00	9.00	5.00	Clayey Silty Sand	Grey	1	Very Loose	-	12	-	19.8
3	9.00	13.00	4.00	Clayey Silty Sand	Grey	10	Loose	-	15	-	30
4	13.00	20.00	7.00	Silty Sand	Greyish Brown, Yellow Green	35	Dense	-	19.5	-	37.4
5	20.00	20.50	0.50	Silty Clay	Brownish Grey	63	-	Hard	21	400	42.5
6	20.50	26.80	6.30	Silty Sand	Brown	63	Very Dense	-	21	-	42.5
7	26.80	30.20	3.40	Compacted Clay (Shale)	Yellowish, Green	>100	-	Hard	22	400	-

REFERENCE BORE HOLE-BH:				27	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	γ kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	3.50	3.50	Fly Ash	Grey	5	Loose	-	14	-	20.4
2	3.50	12.00	8.50	Clayey Silty Sand	Brownish Grey	3	Very Loose	-	13	-	20.1
3	12.00	13.50	1.50	Silty Sand	Grey	13	Medium Dense	-	16.5	-	30.9
4	13.50	20.00	6.50	Silty Sand	Grey	42	Dense	-	20	-	39.2
5	20.00	23.00	3.00	Silty Clay	Grey	47	-	Hard	21	313	-
6	23.00	27.00	4.00	Silty Sand	Brown	65	Very Dense	-	21	-	42.5
7	27.00	30.50	3.50	Compacted Clay (Shale)	Yellowish Green	95	-	Hard	22	400	-

2.8 ESP Control Room Area (Ref.BH-29)

REFERENCE BORE HOLE-BH:				29	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	(γ) kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	6.00	6.00	Fly Ash	Grey	1	-	-	-	-	-
2	6.00	9.00	3.00	Sandy Silty Clay	Dark Grey	1	-	Very Soft	13.5	7	-
3	9.00	10.50	1.50	Clayey Silty Sand	Grey	3	Very Loose	-	13	-	20.1
4	10.50	13.50	3.00	Silty Sand	Greyish Green	4	Very Loose	-	13.5	-	20.2
5	13.50	16.50	3.00	Silty Sand	Greyish Green	17	Medium Dense	-	18	-	32.1
6	16.50	20.00	3.50	Sandy Silty Clay	Yellowish Grey	53	-	Hard	22	353	-
7	20.00	30.30	10.30	Silty Sand	Greyish Brown	70	Very Dense	-	21	-	42.5

2.9 Cooling Tower/Tower Pump House Area (Ref.BH-3,4,8,9)

REFERENCE BORE HOLE-BH:				3	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	(γ) kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	3.70	3.70	Fly Ash	Grey	1	Very Loose	-	12	-	19.8
2	3.70	13.50	9.80	Clayey Silty Sand	Brownish Grey	3	Very Loose	-	13	-	20.1
3	13.50	15.00	1.50	Silty Sand	Yellowish Grey	43	Dense	-	20	-	39.4
4	15.00	24.50	9.50	Silty Sand	Brownish Grey	81	Very Dense	-	21	-	42.5
5	24.50	30.30	5.80	Compacted Clay (Shale)	Yellowish Grey	88	-	Hard	22	400	-

REFERENCE BORE HOLE-BH:				4	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	(γ) kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	3.00	3.00	Fly Ash	Grey	1	Very Loose	-	12	-	19.8
2	3.00	10.00	7.00	Clayey Silty Sand	Dark Grey	3	Very Loose	-	13	-	20.1
3	10.00	13.00	3.00	Clayey Silty Sand	Greyish Yellow	19	Medium Dense	-	18	-	32.7
4	13.00	18.00	5.00	Silty Sand	Yellowish Green	55	Very Dense	-	20.5	-	41.8
5	18.00	20.00	2.00	Clayey Silty Sand	Greyish Brown	68	Very Dense	-	21	-	42.5
6	20.00	24.00	4.00	Silty Sand	Greyish Brown	>100	Very Dense	-	21	-	42.5
7	24.00	26.00	2.00	Clayey Silty Sand	Brownish Grey	>100	Very Dense	-	21	-	42.5
8	26.00	30.30	4.30	Compacted Clay (Shale)	Greenish Yellow	>100	-	Hard	21	400	-

REFERENCE BORE HOLE-BH:				8	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	(γ) kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	3.00	3.00	Fly Ash	Grey	0	Very Loose	-	12	-	19.6
2	3.00	8.00	5.00	Clayey Silty Sand	Brownish Grey	2	Very Loose	-	13	-	19.9
3	8.00	15.50	7.50	Silty Sand	Grey	21	Medium Dense	-	18.5	-	33.3
4	15.50	20.00	4.50	Clayey Silty Sand	Grey	65	Very Dense	-	21	-	42.5
5	20.00	22.00	2.00	Clayey Silty Sand	Greyish Yellow	34	Dense	-	19.5	-	37.1
6	22.00	28.00	6.00	Silty Sand	Brownish Grey	>100	Very Dense	-	21	-	42.5
7	28.00	30.42	2.42	Compacted Clay (Shale)	Grey	>100	-	Hard	22	400	-

REFERENCE BORE HOLE-BH:				9	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	γ kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	2.80	2.80	Fly Ash	Grey	0	Very Loose	-	12	-	19.6
2	2.80	9.00	6.20	Clayey Silty Sand	Brownish Grey	2	Very Loose	-	13	-	19.9
3	9.00	12.00	3.00	Clayey Silty Sand	Grey	11	Medium Dense	-	15.5	-	30.3
4	12.00	16.00	4.00	Silty Sand	Grey	19	Medium Dense	-	18	-	32.7
5	16.00	17.00	1.00	Silty Sand	Brownish Grey	61	Very Dense	-	21	-	42.5
6	17.00	20.00	3.00	Clayey Silty Sand	Grey	>100	Very Dense	-	22	-	42.5
7	20.00	28.00	8.00	Silty Sand	Brownish Grey	>100	Very Dense	-	22	-	42.5
8	28.00	30.40	2.40	Compacted Clay (Shale)	Yellowish Grey	>100	-	Hard	22	400	-

2.10 Water Treatment Plant Area (Ref.BH-5,6,7)

REFERENCE BORE HOLE-BH:				5	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	(γ) kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	3.00	3.00	Fly Ash	Grey	1	Very Loose	-	12	-	19.8
2	3.00	4.90	1.90	Sandy Silty Clay	Grey	6	-	Medium Stiff	15.5	40	-
3	4.90	8.00	3.10	Clayey Silty Sand	Grey	1	Very Loose	-	12	-	19.8
4	8.00	15.00	7.00	Silty Sand	Grey	18	Medium Dense	-	18	-	32.4
5	15.00	16.50	1.50	Silty Sand	Greenish Grey	62	Very Dense	-	21	-	42.5
6	16.50	19.00	2.50	Silty Sand	Greenish Grey	38	Dense	-	19.5	-	38.2
7	19.00	22.00	3.00	Silty Sand	Brownish Grey	47	Dense	-	20	-	40.3
8	22.00	26.00	4.00	Silty Sand	Brownish Grey	77	Very Dense	-	21	-	42.5
9	26.00	30.25	4.25	Compacted Clay (Shale)	Greenish Brown	95	-	Hard	22	400	-

REFERENCE BORE HOLE-BH:				6	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	(γ) kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	4.50	4.50	Fly Ash	Grey	5	Loose	-	14	-	20.4
2	4.50	12.00	7.50	Clayey Silty Sand	Brownish Grey	4	Very Loose	-	13.5	-	20.2
3	12.00	15.00	3.00	Sandy Silty Clay	Yellowish Grey	27	-	Very Stiff	20.5	180	-
4	15.00	16.50	1.50	Silty Sand	Greenish Yellow	35	Dense	-	19.5	-	37.4
5	16.50	20.00	3.50	Clayey Silty Sand	Yellowish Grey	63	Very Dense	-	21	-	42.5
6	20.00	22.00	2.00	Silty Sand	Greenish Yellow	87	Very Dense	-	21	-	42.5
7	22.00	25.00	3.00	Clayey Silty Sand	Greenish Yellow	>100	Very Dense	-	21	-	42.5
8	25.00	30.50	5.50	Compacted Clay (Shale)	Greenish Yellow	>100	-	Hard	21	400	-

REFERENCE BORE HOLE-BH:				7	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	(γ) kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	3.90	3.90	Fly Ash	Grey	4	Very Loose	-	13.5	-	20.2
2	3.90	10.00	6.10	Clayey Silty Sand	Grey	1	Very Loose	-	12	-	19.8
3	10.00	12.00	2.00	Clayey Silty Sand	Grey	26	Medium Dense	-	19	-	34.8
4	12.00	15.00	3.00	Silty Sand	Grey	23	Medium Dense	-	18.5	-	33.9
5	15.00	27.50	12.50	Silty Sand	Grey	88	Very Dense	-	21	-	42.5
6	27.50	30.42	2.92	Compacted Clay (Shale)	Grey	>100	-	Hard	21	400	-

2.11 Crushed Coal Stock Pile Area (Ref.BH-25,26,31)

REFERENCE BORE HOLE-BH:				25	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	(γ) kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	2.80	2.80	Fly Ash	Grey	4	Very Loose	-	13.5	-	20.2
2	2.80	6.00	3.20	Sandy Silty Clay	Grey	10	-	Stiff	17.5	67	-
3	6.00	7.50	1.50	Sandy Silty Clay	Grey	1	-	Very Soft	13.5	7	-
4	7.50	15.00	7.50	Silty Sand	Grey	4	Very Loose	-	13.5	-	20.2
5	15.00	16.50	1.50	Silty Sand	Grey	32	Dense	-	19.5	-	36.6
6	16.50	22.60	6.10	Silty Sand	Grey	64	Very Dense	-	21	-	42.5
7	22.60	30.00	7.40	Clayey Silty Sand	Grey	>100	Very Dense	-	21	-	42.5

REFERENCE BORE HOLE-BH:				26	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	(γ) kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	4.50	4.50	Sandy Silty Clay	Greyish Green	7	-	Medium Stiff	16	47	-
2	4.50	7.50	3.00	Clayey Silty Sand	Dark Grey	4	Very Loose	-	13.5	-	20.2
3	7.50	10.50	3.00	Sandy Silty Clay	Dark Grey	2	-	Very Soft	14	13	-
4	10.50	13.00	2.50	Clayey Silty Sand	Yellowish Green	10	Loose	-	15	-	30
5	13.00	16.50	3.50	Silty Sand	Greenish Yellow	20	Medium Dense	-	18	-	33
6	16.50	19.00	2.50	Silty Sand	Greenish Yellow	62	Very Dense	-	21	-	42.5
7	19.00	23.00	4.00	Sandy Silty Clay	Greenish Yellow	85	-	Hard	22	400	-
8	23.00	30.20	7.20	Silty Sand	Greenish Yellow	>100	Very Dense	-	21	-	42.5

REFERENCE BORE HOLE-BH:				31	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	(γ) kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	6.00	6.00	Silty Clay	Brownish Black	11	-	Stiff	18	73	-
2	6.00	9.00	3.00	Silty Clay	Black	2	-	Very Soft	14	13	-
3	9.00	12.00	3.00	Silty Clay	Black	2	-	Very Soft	14	13	-
4	12.00	16.50	4.50	Silty Sand	Yellowish Grey	28	Medium Dense	-	19	-	35.4
5	16.50	21.00	4.50	Clayey Silty Sand	Yellowish Grey	85	Very Dense	-	21	-	42.5
6	21.00	24.00	3.00	Sandy Silty Clay	Greenish Yellow	83	-	Hard	22	400	-
7	24.00	27.50	3.50	Silty Sand	Yellowish Green	>100	Very Dense	-	21	-	42.5
8	27.50	30.50	3.00	Compacted Clay (Shale)	Yellowish Grey	95	-	Hard	22	400	-

2.12 Administrative Building/Security Room Area (Ref.BH-02)

REFERENCE BORE HOLE-BH:				2	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	(γ) kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	3.00	3.00	Fly Ash	Grey	4	Very Loose	-	13.5	-	20.2
2	3.00	4.50	1.50	Clayey Silty Sand	Grey	21	Medium Dense	-	18.5	-	33.3
3	4.50	12.00	7.50	Silty Sand	Grey	3	Very Loose	-	13	-	20.1
4	12.00	14.20	2.20	Sandy Silty Clay	Grey	40	-	Hard	21	267	-
5	14.20	17.80	3.60	Silty Sand	Grey	54	Very Dense	-	20.5	-	41.6
6	17.80	22.60	4.80	Clayey Silty Sand	Grey	>100	Very Dense	-	21	-	42.5
7	22.60	28.00	5.40	Silty Sand	Grey	>100	Very Dense	-	21	-	42.5
8	28.00	30.41	2.41	Compacted Clay (Shale)	Brownish Green	>100	-	Hard	21	400	-

2.13 Balance Plant Area (Ref: BH: 1, BH-10 to 14, BH-16, BH-19, BH-22, BH-24, BH-30 & BH-32 to 50)

REFERENCE BORE HOLE-BH:				1	Ref R.L. of G.L. (m):				0.00		
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	(γ) kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	3.50	3.50	Fly Ash	Grey	1	Very Loose	-	12	-	19.8
2	3.50	5.00	1.50	Silty Sand	Yellowish Grey	0	Very Loose	-	12	-	19.6
3	5.00	10.50	5.50	Clayey Silty Sand	Grey	3	Very Loose	-	13	-	20.1
4	10.50	13.00	2.50	Silty Sand	Greenish Grey	18	Medium Dense	-	18	-	32.4
5	13.00	28.00	15.00	Silty Sand	Greenish Grey	61	Very Dense	-	21	-	42.5
6	28.00	30.43	2.43	Compacted Clay (Shale)	Greyish Yellow	90	-	Hard	22	400	-

REFERENCE BORE HOLE-BH:				10	Ref R.L. of G.L. (m):				0.00		
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	(γ) kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	3.50	3.50	Fly Ash	Grey	0	Very Loose	-	12	-	19.6
2	3.50	9.00	5.50	Clayey Silty Sand	Brownish Grey	2	Very Loose	-	13	-	19.9
3	9.00	15.00	6.00	Clayey Silty Sand	Grey	20	Medium Dense	-	18	-	33
4	15.00	24.50	9.50	Silty Sand	Grey	>100	Very Dense	-	22	-	42.5
5	24.50	30.40	5.90	Compacted Clay (Shale)	Grey	>100	-	Hard	22	400	-

REFERENCE BORE HOLE-BH:				11	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	(γ) kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	4.00	4.00	Fly Ash	Grey	1	Very Loose	-	12	-	19.8
2	4.00	9.00	5.00	Clayey Silty Sand	Brownish Black	2	Very Loose	-	13	-	19.9
3	9.00	12.00	3.00	Silty Sand	Dark Grey	9	Loose	-	14.5	-	29.8
4	12.00	15.00	3.00	Clayey Silty Sand	Greyish Green	19	Medium Dense	-	18	-	32.7
5	15.00	16.50	1.50	Silty Sand	Yellowish Green	38	Dense	-	19.5	-	38.2
6	16.50	26.60	10.10	Silty Sand	Greyish Brown	87.5	Very Dense	-	21	-	42.5
7	26.60	30.40	3.80	Compacted Clay (Shale)	Greyish Yellow	95	-	Hard	22	400	-

REFERENCE BORE HOLE-BH:				12	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	(γ) kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	4.50	4.50	Fly Ash	Grey	2	Very Loose	-	13	-	19.9
2	4.50	7.50	3.00	Clayey Silty Sand	Grey, Brown	4	Very Loose	-	13.5	-	20.2
3	7.50	10.00	2.50	Sandy Silty Clay	Dark Grey	3	-	Soft	14	20	-
4	10.00	13.50	3.50	Clayey Silty Sand	Yellowish Grey	8	Loose	-	14.5	-	29.6
5	13.50	16.50	3.00	Silty Sand with Binder	Yellowish Grey	24	Medium Dense	-	18.5	-	34.2
6	16.50	18.00	1.50	Silty Sand with Binder	Yellowish Grey	69	Very Dense	-	21	-	42.5
7	18.00	20.00	2.00	Sandy Silty Clay	Yellowish Grey	60	-	Hard	21	400	42.5
8	20.00	22.00	2.00	Clayey Silty Sand	Yellowish Grey	>100	Very Dense	-	21	-	42.5
9	22.00	27.20	5.20	Silty Sand	>100	>100	Very Dense	-	21	-	42.5
10	27.20	30.00	2.80	Compacted Clay (Shale)	Grey	>100	-	Hard	21	400	-

REFERENCE BORE HOLE-BH:				13	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	γ kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	4.00	4.00	Fly Ash	Grey	0	Very Loose	-	12	-	19.6
2	4.00	10.50	6.50	Clayey Silty Sand	Brownish Grey	4	Very Loose	-	13.5	-	20.2
3	10.50	15.00	4.50	Silty Sand	Greenish Grey	19	Medium Dense	-	18	-	32.7
4	4.00	19.70	15.70	Silty Sand	Greenish Grey	58	Very Dense	-	20.5	-	42.2
5	19.70	22.00	2.30	Sandy Silty Clay	Greyish Green	56	-	Hard	22	373	-
6	22.00	24.00	2.00	Silty Sand	Greenish Grey	76	Very Dense	-	21	-	42.5
7	24.00	27.50	3.50	Clayey Silty Sand	Grey, Greyish Red	56	Very Dense	-	20.5	-	41.9
8	27.50	30.00	2.50	Compacted Clay (Shale)	Greyish Green	100	-	Hard	22	400	-
9	30.00	30.40	0.40	Compacted Clay (Shale)	Greyish Green	>100	-	Hard	22	400	-

REFERENCE BORE HOLE-BH:				14	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	(γ) kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	3.00	3.00	Fly Ash	Grey	4	Very Loose	-	13.5	-	20.2
2	3.00	4.50	1.50	Silty Clay	Grey	20	-	Very Stiff	20	133	-
3	4.50	6.00	1.50	Clayey Silty Sand	Grey	11	Medium Dense	-	15.5	-	30.3
4	6.00	9.00	3.00	Clayey Silty Sand	Grey	2	Very Loose	-	13	-	19.9
5	9.00	13.50	4.50	Clayey Silty Sand	Grey	6	Loose	-	14.5	-	29.2
6	13.50	15.00	1.50	Clayey Silty Sand	Greyish Green	14	Medium Dense	-	17	-	31.2
7	15.00	18.00	3.00	Silty Sand	Greyish Green	45	Dense	-	20	-	39.9
8	18.00	20.00	2.00	Silty Sand	Greyish Green	74	Very Dense	-	21	-	42.5
9	20.00	24.50	4.50	Sandy Silty Clay	Greyish Green	77	-	Hard	22	400	-
10	24.50	28.60	4.10	Silty Sand	Greyish Green	>100	Very Dense	-	21	-	42.5
11	28.60	30.00	1.40	Compacted Clay (Shale)	Greyish Green	>100	-	Hard	22	400	-

REFERENCE BORE HOLE-BH:				16	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	(γ) kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	3.50	3.50	Fly Ash	Grey	2	Very Loose	-	13	-	19.9
2	3.50	10.00	6.50	Clayey Silty Sand	Greyish, Yellow	2	Very Loose	-	13	-	19.9
3	10.00	15.00	5.00	Clayey Silty Sand	Grey	8	Loose	-	14.5	-	29.6
4	15.00	20.00	5.00	Silty Sand	Grey	43	Dense	-	20	-	39.4
5	20.00	24.00	4.00	Silty Sand	Grey	83	-	Hard	21	287	42.5
6	24.00	27.20	3.20	Clayey Silty Sand	Grey	>100	Very Dense	-	21	-	42.5
7	27.20	30.50	3.30	Compacted Clay (Shale)	Greyish, Green	>100	-	Hard	22	400	-

REFERENCE BORE HOLE-BH:				19	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	(γ) kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	4.30	4.30	Fly Ash	Grey	0	Very Loose	-	12	-	19.6
2	4.30	10.00	5.70	Clayey Silty Sand	Grey	3	Very Loose	-	13	-	20.1
3	10.00	11.00	1.00	Clayey Silty Sand	Grey	11	Medium Dense	-	15.5	-	30.3
4	11.00	12.50	1.50	Clayey Silty Sand	Grey	4	Very Loose	-	13.5	-	20.2
5	12.50	15.50	3.00	Silty Sand	Grey	49	Dense	-	20	-	40.8
6	15.50	18.50	3.00	Clayey Silty Sand	Grey	>100	Very Dense	-	21	-	42.5
7	18.50	26.70	8.20	Clayey Silty Sand	Greyish, Green	>100	Very Dense	-	21	-	42.5
8	26.70	30.50	3.80	Compacted Clay (Shale)	Greyish, Green	>100	-	Hard	22	400	-

REFERENCE BORE HOLE-BH:				22	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	(γ) kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	3.00	3.00	Fly Ash	Grey	5	Loose	-	14	-	20.4
2	3.00	10.30	7.30	Clayey Silty Sand	Grey	1	Very Loose	-	12	-	19.8
3	10.30	12.00	1.70	Clayey Silty Sand	Grey	11	Medium Dense	-	15.5	-	30.3
4	12.00	15.00	3.00	Silty Sand	Grey	15	Medium Dense	-	17.5	-	31.5
5	15.00	19.60	4.60	Silty Sand	Grey	44	Dense	-	20	-	39.7
6	19.60	20.00	0.40	Silty Clay	Grey	47	-	Hard	21	313	-
7	20.00	21.40	1.40	Clayey Silty Sand	Grey	57	Very Dense	-	20.5	-	42.1
8	21.40	25.80	4.40	Silty Sand	Grey	>100	Very Dense	-	21	-	42.5
9	25.80	30.50	4.70	Compacted Clay (Shale)	Greyish Yellow	95	-	Hard	22	400	-

REFERENCE BORE HOLE-BH:				24	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	(γ) kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	3.00	3.00	Fly Ash	Grey	5	Loose	-	14	-	20.4
2	3.00	6.00	3.00	Sandy Silty Clay	Greyish Yellow	3	-	Soft	14	20	-
3	6.00	7.50	1.50	Clayey Silty Sand	Greyish Yellow	2	Very Loose	-	13	-	19.9
4	7.50	10.30	2.80	Sandy Silty Clay	Greyish Yellow	7	-	Medium Stiff	16	47	-
5	10.30	12.00	1.70	Clayey Silty Sand	Greyish Green	16	Medium Dense	-	18	-	31.8
6	12.00	14.60	2.60	Sandy Silty Clay	Greyish Green	18	-	Very Stiff	20	120	-
7	14.60	19.80	5.20	Silty Sand	Greyish Green	37	Dense	-	19.5	-	37.9
8	19.80	22.00	2.20	Sandy Silty Clay	Greyish Green	52	-	Hard	21	347	-
9	22.00	27.70	5.70	Silty Sand	Greyish Green	75	Very Dense	-	21	-	42.5
10	27.70	30.40	2.70	Compacted Clay (Shale)	Greyish Green	100	-	Hard	21	400	-

REFERENCE BORE HOLE-BH:				30	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	(γ) kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	3.00	3.00	Fly Ash	Grey	5	-	-	-	-	-
2	3.00	4.50	1.50	Silty Clay	Grey	3	-	Soft	14	20	-
3	4.50	10.00	5.50	Clayey Silty Sand	Grey	2	Very Loose	-	13	-	19.9
4	10.00	12.00	2.00	Clayey Silty Sand	Greenish Grey	12	Medium Dense	-	16	-	30.6
5	12.00	13.50	1.50	Clayey Silty Sand	Greyish Green	9	Loose	-	14.5	-	29.8
6	13.50	18.00	4.50	Silty Sand	Greenish Grey	18	Medium Dense	-	18	-	32.4
7	18.00	20.00	2.00	Clayey Silty Sand	Greenish Grey	54	Very Dense	-	20.5	-	41.6
8	20.00	22.00	2.00	Silty Clay	Greyish Green	52	-	Hard	22	347	-
9	22.00	27.40	5.40	Silty Sand	Greenish Grey	65	Very Dense	-	21	-	42.5
10	27.40	30.50	3.10	Compacted Clay (Shale)	Greenish Grey	90	-	Hard	22	400	-

REFERENCE BORE HOLE-BH:				32	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	γ kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	6.00	6.00	Fly Ash	Grey	0	-	-	-	-	-
2	6.00	9.00	3.00	Sandy Silty Clay	Brownish Grey	0	-	Very Soft	13	4	-
3	9.00	10.50	1.50	Clayey Silty Sand	Dark Grey	1	Very Loose	-	12	-	19.8
4	10.50	13.50	3.00	Clayey Silty Sand	Greenish Grey	22	Medium Dense	-	18.5	-	33.6
5	13.50	18.00	4.50	Silty Sand	Brownish Grey	65	Very Dense	-	21	-	42.5
6	18.00	20.00	2.00	Clayey Silty Sand	Greyish Green	>100	Very Dense	-	21	-	42.5
7	20.00	30.40	10.40	Silty Sand	Brown	80	Very Dense	-	21	-	42.5
REFERENCE BORE HOLE-BH:				33	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	γ kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	7.00	7.00	Fly Ash	Grey	7	-	-	-	-	-
2	7.00	10.50	3.50	Silty Clay	Grey	4	-	Soft	14.5	27	-
3	10.50	15.00	4.50	Silty Sand	Grey	10	Loose	-	15	-	30
5	15.00	16.50	1.50	Clayey Silty Sand	Greyish Green	37	Dense	-	19.5	-	37.9
6	16.50	20.00	3.50	Clayey Silty Sand	Greyish Green	80	Very Dense	-	21	-	42.5
7	20.00	27.50	7.50	Silty Sand	Brownish Grey	76	Very Dense	-	21	-	42.5
8	27.50	30.40	2.90	Compacted Clay	Brown	>100	-	Hard	22	400	-

REFERENCE BORE HOLE-BH:				34	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	γ kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	5.00	5.00	Fly Ash	Grey	0	-	-	-	-	-
2	5.00	8.00	3.00	Silty Clay	Dark Grey	0	-	Very Soft	13	4	-
3	8.00	9.00	1.00	Clayey Silty Sand	Dark Grey	1	Very Loose	-	12	-	19.8
4	9.00	10.00	1.00	Silty Clay	Dark Grey	3	-	Soft	14	20	-
5	10.00	11.50	1.50	Clayey Silty Sand	Dark Green	11	Medium Dense	-	15.5	-	30.3
6	11.50	13.00	1.50	Clayey Silty Sand	Dark Green	4	Very Loose	-	13.5	-	20.2
7	13.00	14.50	1.50	Clayey Silty Sand	Dark Green	26	Medium Dense	-	19	-	34.8
8	14.50	17.50	3.00	Silty Sand	Greenish Grey	39	Dense	-	21	-	-
9	17.50	19.00	1.50	Silty Sand	Greenish Grey	57	Very Dense	-	20.5	-	42.1
10	19.00	21.00	2.00	Silty Clay	Greyish Green	48	-	Hard	21	320	-
11	21.00	27.00	6.00	Silty Sand	Greyish Yellow	63	Very Dense	-	21	-	42.5
12	27.00	32.00	5.00	Compacted Clay (Shale)	Greenish Yellow	65	-	Hard	21	400	-
13	32.00	40.00	8.00	Silty Sand	Greenish Yellow	>100	Very Dense	-	21.5	-	42.5

REFERENCE BORE HOLE-BH:				35	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	γ kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	3.00	3.00	Sandy Silty Clay	Yellowish Grey	5	-	Medium Stiff	15	33	-
2	3.00	7.50	4.50	Silty Clay	Yellowish Grey	8	-	Medium Stiff	16.5	53	-
3	7.50	9.00	1.50	Silty Clay	Black	2	-	Very Soft	14	13	-
4	9.00	10.00	1.00	Clayey Silty Sand	Black	1	Very Loose	-	12	-	19.8
5	10.00	13.00	3.00	Silty Clay	Black	1	-	Very Soft	13.5	7	-
6	13.00	15.60	2.60	Clayey Silty Sand	Black	14	Medium Dense	-	17	-	31.2
7	15.60	27.50	11.90	Silty Sand	Greenish Yellow	75	Very Dense	-	21	-	42.5
8	27.50	30.20	2.70	Compacted Clay (Shale)	Yellowish Grey	>100	-	Hard	22	400	-

REFERENCE BORE HOLE-BH:				36	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	γ kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	5.00	5.00	Fly Ash	Grey	0	-	-	-	-	-
2	5.00	6.00	1.00	Silty Clay	Grey	0	-	Very Soft	13	4	-
3	6.00	8.00	2.00	Clayey Silty Sand	Dark Grey	0	Very Loose	-	12	-	19.6
4	8.00	9.00	1.00	Silty Clay	Dark Grey	3	-	Soft	14	20	-
5	9.00	10.00	1.00	Clayey Silty Sand	Grey	8	Loose	-	14.5	-	29.6
6	10.00	11.50	1.50	Clayey Silty Sand	Brownish Grey	13	Medium Dense	-	16.5	-	30.9
7	11.50	16.00	4.50	Silty Sand	Greenish Grey	17	Medium Dense	-	18	-	32.1
8	16.00	19.00	3.00	Silty Sand	Greenish Grey	68	Very Dense	-	21	-	42.5
9	19.00	20.50	1.50	Silty Clay	Greenish Grey	59	-	Hard	22	393	-
10	20.50	22.00	1.50	Clayey Silty Sand	Greyish Yellow	>100	Very Dense	-	21	-	42.5
11	22.00	26.00	4.00	Silty Sand	Greyish Yellow	>100	Very Dense	-	21	-	42.5
12	26.00	27.00	1.00	Compacted Clay (Shale)	Brown	>100	-	Hard	22	400	-
13	27.00	30.40	3.40	Compacted Clay (Shale)	Brown	>100	-	Hard	22	400	-

REFERENCE BORE HOLE-BH:				37	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	(γ) kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	4.00	4.00	Fly Ash	Grey	0	-	-	-	-	-
2	4.00	10.50	6.50	Clayey Silty Sand	Brownish Grey	4	Very Loose	-	13.5	-	20.2
3	10.50	18.00	7.50	Silty Sand	Grey	26	Medium Dense	-	19	-	34.8
4	18.00	19.00	1.00	Silty Sand	Grey	56	Very Dense	-	20.5	-	41.9
5	19.00	22.00	3.00	Sandy Silty Clay	Greyish Yellow	63	-	Hard	22	400	-
6	22.00	29.00	7.00	Silty Sand	Greyish Yellow	72	Very Dense	-	21	-	42.5
7	29.00	30.50	1.50	Compacted Clay (Shale)	Yellowish Grey	>100	-	Hard	22	400	-

REFERENCE BORE HOLE-BH:				38	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	(γ) kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	3.00	3.00	Silty Clay	Grey	1	-	Very Soft	13.5	7	-
2	3.00	6.00	3.00	Clayey Silty Sand	Grey	2	Very Loose	-	13	-	19.9
3	6.00	9.00	3.00	Silty Clay	Dark Grey	4	-	Soft	14.5	27	-
4	9.00	12.00	3.00	Clayey Silty Sand	Greyish Green	20	Medium Dense	-	18	-	33
5	12.00	13.50	1.50	Silty Sand	Greyish Green	45	Dense	-	20	-	39.9
6	13.50	18.00	4.50	Silty Sand	Greyish Green	59	Very Dense	-	20.5	-	42.4
7	18.00	21.60	3.60	Clayey Silty Sand	Greyish Green	95	Very Dense	-	21	-	42.5
8	21.60	26.00	4.40	Clayey Silty Sand (Cemented Sand)	Greyish Green	>100	Very Dense	-	21	-	42.5
9	26.00	27.00	1.00	Compacted Clay (Shale)	Greyish Green	>100	-	Hard	22	400	-
10	27.00	30.00	3.00	Compacted Clay (Shale)	Greyish Green	>100	-	Hard	22	400	-

REFERENCE BORE HOLE-BH:				39	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	γ kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	7.50	7.50	Clayey Silty Sand	Grey	3	Very Loose	-	13	-	20.1
2	7.50	10.00	2.50	Clayey Silty Sand	Grey	8	Loose	-	14.5	-	29.6
3	10.00	12.00	2.00	Silty Sand	Grey	14	Medium Dense	-	17	-	31.2
4	12.00	20.00	8.00	Silty Sand	Grey	52	Very Dense	-	20.5	-	41.3
5	20.00	23.80	3.80	Silty Sand	Grey	>100	Very Dense	-	21	-	42.5
7	23.80	30.50	6.70	Compacted Clay (Shale)	Greyish Green	95	-	Hard	22	400	-

REFERENCE BORE HOLE-BH:				40	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	γ kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	7.50	7.50	Clayey Silty Sand	Brownish Grey	2	Very Loose	-	13	-	19.9
2	7.50	10.00	2.50	Silty Sand	Brownish Grey	17	Medium Dense	-	18	-	32.1
3	10.00	16.50	6.50	Silty Sand	Brownish Grey	42	Dense	-	20	-	39.2
4	16.50	26.50	10.00	Silty Sand	Brownish Grey	77	Very Dense	-	21	-	42.5
5	26.50	30.50	4.00	Compacted Clay (Shale)	Yellowish Grey	70	-	Hard	22	400	-

REFERENCE BORE HOLE-BH:				41	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	(γ) kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	7.50	7.50	Silty Clay	Dark Grey	1	-	Very Soft	13.5	7	-
2	7.50	9.00	1.50	Silty Clay	Dark Grey	3	-	Soft	14	20	-
3	9.00	11.00	2.00	Silty Clay	Dark Grey	4	-	Soft	14.5	27	-
4	11.00	13.50	2.50	Silty Sand	Greyish Green	47	Dense	-	20	-	40.3
5	13.50	27.50	14.00	Silty Sand	Greyish Green	87	Very Dense	-	21	-	42.5
6	27.50	30.50	3.00	Compacted Clay (Shale)	Greyish Green	96	-	Hard	22	400	-

REFERENCE BORE HOLE-BH:				42	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	(γ) kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	4.50	4.50	Sandy Silty Clay	Dark Grey	1	-	Very Soft	13.5	7	-
2	4.50	7.50	3.00	Sandy Silty Clay	Dark Grey	1	-	Very Soft	13.5	7	-
3	7.50	10.50	3.00	Calvee Silty Sand	Dark Grey	1	Very Loose	-	12	-	19.8
4	10.50	18.00	7.50	Silty Sand	Greyish Green	34	Dense	-	19.5	-	37.1
5	18.00	28.00	10.00	Silty Sand	Greyish Green	86	Very Dense	-	21	-	42.5
6	28.00	30.50	2.50	Compacted Clay (Shale)	Greyish Green	93	-	Hard	22	400	-

REFERENCE BORE HOLE-BH:				43	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	(γ) kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	4.50	4.50	Silty Clay	Black	4	-	Soft	14.5	27	-
2	4.50	8.50	4.00	Silty Clay	Black	1	-	Very Soft	13.5	7	-
3	8.50	12.00	3.50	Silty Sand	Greenish Yellow	40	Dense	-	20	-	38.8
4	12.00	17.50	5.50	Silty Sand	Greenish Yellow	68	Very Dense	-	21	-	42.5
5	17.50	18.50	1.00	Silty Clay	Greenish Yellow	54	-	Hard	22	360	-
6	18.50	23.50	5.00	Clayey Silty Sand (Cemented Sand)	Yellowish Red	90	Very Dense	-	21	-	42.5
7	23.50	30.50	7.00	Silty Sand	Greyish Brown	87	Very Dense	-	21	-	42.5

REFERENCE BORE HOLE-BH:				44	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	(γ) kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	10.00	10.00	Clayey Silty Sand	Dark Grey	1	Very Loose	-	12	-	19.8
2	10.00	12.50	2.50	Clayey Silty Sand	Greyish Green	50	Dense	-	20.5	-	41
3	12.50	22.00	9.50	Silty Sand	Greyish Green	92	Very Dense	-	21	-	42.5
4	22.00	30.50	8.50	Compacted Clay (Shale)	Greyish Green	87	-	Hard	22	400	-

REFERENCE BORE HOLE-BH:				45	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	γ kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	6.00	6.00	Clayey Silty Sand	Dark Grey	1	Very Loose	-	12	-	19.8
2	6.00	7.50	1.50	Silty Clay	Dark Grey	2	-	Very Soft	14	13	-
3	7.50	9.00	1.50	Silty Clay	Dark Grey	3	-	Soft	14	20	-
4	9.00	10.50	1.50	Silty Clay	Dark Grey	6	-	Medium Stiff	15.5	40	-
5	10.50	13.50	3.00	Clayey Silty Sand	Greyish Green	45	Dense	-	20	-	39.9
6	13.50	15.00	1.50	Silty Sand	Greyish Green	32	Dense	-	19.5	-	36.6
7	15.00	28.00	13.00	Silty Sand	Greyish Green	65	Very Dense	-	21	-	42.5
8	28.00	30.50	2.50	Clayey Silty Sand	Greyish Green	90	Very Dense	-	21	-	42.5

REFERENCE BORE HOLE-BH:				46	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	γ kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	4.50	4.50	Silty Sand	Grey	8	Loose	-	14.5	-	29.6
2	4.50	10.00	5.50	Silty Sand	Grey	3	Very Loose	-	13	-	20.1
3	10.00	15.00	5.00	Silty Sand	Greyish Green	23	Medium Dense	-	18.5	-	33.9
4	15.00	22.00	7.00	Silty Sand	Greyish Green	53	Very Dense	-	20.5	-	41.5
5	22.00	24.00	2.00	Sandy Silty Clay	Greyish Green	62	-	Hard	22	400	-
6	24.00	27.50	3.50	Clayey Silty Sand (Cemented Sand)	Greyish Green	86	Very Dense	-	21	-	42.5
7	27.50	30.30	2.80	Silty Sand	Greyish Green	>100	Very Dense	-	21	-	42.5

REFERENCE BORE HOLE-BH:				47	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	γ kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	7.50	7.50	Silty Sand	Greyish Brown	3	Very Loose	-	13	-	20.1
2	7.50	12.00	4.50	Silty Sand	Greyish Brown	9	Loose	-	14.5	-	29.8
3	12.00	15.00	3.00	Silty Sand	Greyish Green	34	Dense	-	19.5	-	37.1
4	15.00	20.00	5.00	Silty Sand	Greyish Brown	59	Very Dense	-	20.5	-	42.4
5	20.00	30.10	10.10	Silty Sand	Brown	90	Very Dense	-	21	-	42.5

REFERENCE BORE HOLE-BH:				48	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	γ kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	5.20	5.20	Silty Clay	Grey	1	-	Very Soft	13.5	7	-
2	5.20	9.00	3.80	Clayey Silty Sand	Grey	3	Very Loose	-	13	-	20.1
3	9.00	10.00	1.00	Clayey Silty Sand	Greyish Green	21	Medium Dense	-	18.5	-	33.3
4	10.00	15.00	5.00	Silty Sand	Greyish Green	18	Medium Dense	-	18	-	32.4
5	15.00	18.00	3.00	Silty Sand	Greyish Green	75	Very Dense	-	21	-	42.5
6	18.00	20.00	2.00	Silty Sand	Greyish Green	35	Dense	-	19.5	-	37.4
7	20.00	30.20	10.20	Silty Sand	Greyish Green	84	Very Dense	-	21	-	42.5

REFERENCE BORE HOLE-BH:				49	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	(γ) kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	6.00	6.00	Silty Sand	Brownish Black	27	Medium Dense	-	19	-	35.1
2	6.00	8.50	2.50	Silty Sand	Brownish Grey	63	Very Dense	-	21	-	42.5
3	8.50	10.00	1.50	Clayey Silty Sand	Black	0	Very Loose	-	12	-	19.6
4	10.00	12.00	2.00	Clayey Silty Sand	Black	6	Loose	-	14.5	-	29.2
5	12.00	14.00	2.00	Clayey Silty Sand	Greyish Brown	21	Medium Dense	-	18.5	-	33.3
6	14.00	24.00	10.00	Silty Sand	Greenish Yellow	27	Medium Dense	-	21	-	42.5
7	24.00	28.00	4.00	Silty Sand	Greyish Yellow	63	Very Dense	-	21	-	42.5
8	28.00	29.00	1.00	Compacted Clay (Shale)	Brownish Grey	83	-	Hard	22	400	-
9	29.00	30.30	1.30	Silty Sand	Greyish Brown	>100	Very Dense	-	21	-	42.5

REFERENCE BORE HOLE-BH:				50	Ref R.L. of G.L. (m):			0.00			
Layer No.	Layer Thk. (m)			Type of Strata	Colour	Ave. Design SPT	Relative Density	Consistency	(γ) kN/m ³	Shear Parameters	
	Top. R.L.	Bot. R.L.	Thickness							(C _u) kPa	(ϕ) Deg.
1	0.00	4.00	4.00	Silty Sand	Yellowish Brown	24	Medium Dense	-	18.5	-	34.2
2	4.00	7.00	3.00	Silty Clay	Dark Brown	2	-	Very Soft	14	13	-
3	7.00	9.00	2.00	Clayey Silty Sand	Brownish Green	0	Very Loose	-	12	-	19.6
4	9.00	10.00	1.00	Clayey Silty Sand	Brownish Green	9	Loose	-	14.5	-	29.8
5	10.00	13.00	3.00	Clayey Silty Sand	Greyish Brown	22	Medium Dense	-	18.5	-	33.6
6	13.00	15.00	2.00	Clayey Silty Sand	Greyish Yellow	40	Dense	-	20	-	38.8
7	15.00	16.50	1.50	Clayey Silty Sand	Greyish Yellow	61	Very Dense	-	21	-	42.5
8	16.50	20.00	3.50	Silty Sand	Greyish Green	75	Very Dense	-	21	-	42.5
9	20.00	24.00	4.00	Clayey Silty Sand	Greyish Green	36	Dense	-	19.5	-	37.7
10	24.00	25.80	1.80	Clayey Silty Sand	Greyish Green	>100	Very Dense	-	21	-	42.5
11	25.80	28.00	2.20	Compacted Clay (Shale)	Yellowish Green	91	-	Hard	22	400	-
12	28.00	30.10	2.10	Silty Sand	Greyish Green	>100	Very Dense	-	21	-	42.5

- ◆ A combination of weak soil characteristics among the bore holes located at each facility is considered in described the design strata for a specified depth.

Based on the above approach, the **Design Geotechnical Models** for different areas are presented below:

Table-2.1 Design Soil Profile for Switch Yard Area

Sl. No	Depth Below E.G.L. (m)			Description	DGN. "N" Value	ϕ (Deg.)	Cu (kPa)
	From	To	Thk				
1	0	4.2	4.2	Fly Ash	9	-	-
2	4.2	6	1.8	V.Soft Silty Clay	1	0	6.67
3	6	10	4	V.Loose to Loose Clayey Silty Sand	2	28.4	0
4	10	11.7	1.7	M.Dense Clayey Silty Sand	17	32.1	0
5	11.7	18.0	6.3	M.Dense Silty Sand	23	33.9	0
6	18.0	21.6	3.6	Hard Silty Clay	56	0	373.33
7	21.6	27.8	6.2	V.Dense Silty Sand	>100	42.5	0
8	27.8	30.0	2.2	Hard Compacted Clay(Shale)	>100	0	400*

Table-2.2 Design Soil Profile for Transformer Yard Area

Sl. No	Depth Below E.G.L. (m)			Description	DGN. "N" Value	ϕ (Deg.)	Cu (kPa)
	From	To	Thk				
1	0	4.0	4.0	Fly Ash	1	-	-
2	4.0	10	6.0	V.Loose to Loose Clayey Silty Sand	3	28.6	0
3	10	13.5	3.5	M.Dense Clayey Silty Sand	22	33.6	0
4	13.5	16.5	3.0	M.Dense Silty Sand	21	33.3	0
5	16.5	20.0	3.5	Hard Silty Clay	71	0	400*
6	20.0	22.0	2.0	V.Dense Clayey Silty Sand	>100	42.5	0
7	22.0	24.5	2.5	V.Dense Silty Sand	>100	42.5	0
8	24.5	30.0	5.0	Hard Compacted Clay(Shale)	>100	0	400*

Table-2.3 Design Soil Profile for Boiler/Auxiliary Boiler Area

Sl. No	Depth Below E.G.L. (m)			Description	DGN. "N" Value	ϕ (Deg.)	Cu (kPa)
	From	To	Thk				
1	0	3.0	3.0	Fly Ash	5	-	-
2	3.0	10.3	7.3	V.Loose to Loose Clayey Silty Sand	1	28.0	0
3	10.3	12.0	1.7	M.Dense Clayey Silty Sand	11	30.3	0
4	12.0	15.0	3.0	M.Dense Silty Sand	15	31.5	0
5	15.0	18.0	3.0	Dense Silty Sand	44	39.7	0
6	18.0	20.0	2.0	Hard Sandy Silty Clay	47	0	313.33
7	20.0	21.40	1.4	V.Dense Silty Sand	57	42.1	0
8	21.4	25.8	4.4	V.Dense Silty Sand	>100	42.5	0
9	25.8	30.5	4.7	Hard Compacted Clay(Shale)	95	0	400*

Table-2.4 Design Soil Profile for Chimney Area

Sl. No	Depth Below E.G.L. (m)			Description	DGN. "N" Value	ϕ (Deg.)	Cu (kPa)
	From	To	Thk				
1	0	3.4	3.4	Fly Ash	4	-	-
2	3.4	9.0	5.6	V.Loose to Loose Clayey Silty Sand	1	28.0	0
3	9.0	10.5	1.5	V.Soft Silty Clay	3	0	6.67
4	10.5	13.0	2.5	M.Dense Clayey Silty Sand	15	31.5	0
5	13.0	20.0	7.0	M.Dense to Dense Silty Sand	27	37.9	0
6	20.0	24.0	4.0	V.Dense Clayey Silty Sand	48	40.6	0
7	24.0	30.0	6.0	V.Dense Silty Sand	>100	42.5	0

Table-2.5 Design Soil Profile for T.G Building Area

Sl. No	Depth Below E.G.L. (m)			Description	DGN. "N" Value	ϕ (Deg.)	Cu (kPa)
	From	To	Thk				
1	0	3.5	3.5	Fly Ash	5	-	-
2	3.5	12.0	8.5	V.Loose to Loose Clayey Silty Sand	6	29.2	0
3	12.0	20.0	8.0	M.Dense to Dense Silty Sand	36	37.7	0
4	20.0	23.0	3.0	Hard Sand Silty Clay	47	0	313.33
5	23.0	27.0	4.0	V.Dense Silty Sand	65	42.5	0
6	27.0	30.0	23.0	Hard Compacted Clay(Shale)	>100	0	400*

Table-2.6 Design Soil Profile for ESP Control Room Area

Sl. No	Depth Below E.G.L. (m)			Description	DGN. "N" Value	ϕ (Deg.)	Cu (kPa)
	From	To	Thk				
1	0	6.0	6.0	Fly Ash	1	-	-
2	6.0	9.0	3.0	V.Soft Sandy Silty Clay	1	0	6.67
3	9.0	10.5	1.5	V.Loose Clayey Silty Sand	3	28.6	0
4	10.5	13.5	3.0	M.Dense Silty Sand	4	28.8	0
5	13.5	16.5	3.0	M.Dense Silty Sand	17	32.1	0
6	16.5	20.0	3.5	Hard Sandy Silty Clay	53	0	353.33
7	20.0	30.0	10.0	V.Dense Silty Sand	>100	42.5	0

Table-2.7 Design Soil Profile for Cooling Tower/Tower Pump House Area

Sl. No	Depth Below E.G.L. (m)			Description	DGN. "N" Value	ϕ (Deg.)	Cu (kPa)
	From	To	Thk				
1	0	3.7	3.7	Fly Ash	1	-	-
2	3.7	13.5	9.8	V.Loose to Loose Clayey Silty Sand	4	28.8	0
3	13.5	15.0	1.5	Dense Silty Sand	43	39.4	0
4	15.0	24.5	9.5	V.Dense Silty Sand	60	42.5	0
5	24.5	30.0	3.0	Hard Compacted Clay(Shale)	>100	0	400*

Table-2.8 Design Soil Profile for Water Treatment Plant Area

Sl. No	Depth Below E.G.L. (m)			Description	DGN. "N" Value	ϕ (Deg.)	Cu (kPa)
	From	To	Thk				
1	0	4.5	4.5	Fly Ash	1	-	-
2	4.5	12.0	7.5	V.Loose to Loose Clayey Silty Sand	4	28.8	0
3	12.0	15.0	3.0	V.Stiff Sandy Silty Clay	27	0	180
4	15.0	16.5	1.5	Dense Silty Sand	35	37.4	0
5	16.5	20.0	3.5	V.Dense Clayey Silty Sand	63	42.5	0
6	20.0	22.0	2.0	V.Dense Silty Sand	87	42.5	0
7	22.0	25.0	3.0	V.Dense Clayey Silty Sand	>100	42.5	0
8	25.0	30.0	5.0	Hard Compacted Clay(Shale)	>100	0	400*

Table-2.9 Design Soil Profile for Crushed Coal Stock Pile/Crusher House Area

Sl. No	Depth Below E.G.L. (m)			Description	DGN. "N" Value	φ(Deg.)	Cu (kPa)
	From	To	Thk				
1	0	4.5	4.5	Sandy Silty Clay	7	-	46.67
2	4.5	7.5	3.0	V.Loose to Loose Clayey Silty Sand	4	28.8	0
3	7.5	10.5	3.0	V.Stiff Sandy Silty Clay	2	0	13.37
4	10.5	13.0	7.5	Loose Clayey Silty Sand	10	30	0
5	13.0	16.5	3.5	M.Dense Silty Sand	20	33.0	0
6	16.5	19.0	2.5	V.Dense Silty Sand	68	42.5	0
7	19.0	23.0	4.0	Hard Sandy Silty Clay	>100	0	400*
8	23.0	30.0	7.0	V.Dense Silty Sand	>100	42.5	0

Table-2.10 Design Soil Profile for Administrative Building/Security Room Area

Sl. No	Depth Below E.G.L. (m)			Description	DGN. "N" Value	φ(Deg.)	Cu (kPa)
	From	To	Thk				
1	0	3.0	3.0	Fly Ash	4	-	-
2	3.0	4.5	1.5	M.Dense Clayey Silty Sand	21	33.3	0
3	4.5	12.0	7.5	V.Loose to Loose Silty Sand	5	29.0	0
4	12.0	14.2	2.2	Hard Sandy Silty Clay	40	0	266.67
5	14.2	17.8	3.6	V.Dense Silty Sand	54	41.6	0
6	17.8	22.6	4.8	V.Dense Clayey Silty Sand	60	42.5	0
7	22.6	28.0	5.4	V.Dense Silty Sand	>100	42.5	0
8	28.0	30.0	2.0	Hard Compacted Clay(Shale)	>100	0	400*

*Undrained Shear Strength in Shale is restricted to 400 kPa to account for stress reversal due to swelling.

□

FOUNDATION SYSTEM

FOUNDATION SYSTEM

3.0 Preamble:

In the design of foundation system, the stress-strain compatibility of the super structure, sub structure and the bearing strata should be satisfied both individually and as a combined system. In view of this, the following data are needed for the design of foundation system:

- The super structure characteristics along with the loading pattern on the sub structure.
- The sub soil characteristics – These will provide in sight in to the type of sub structure that safely transfer the super structure loads to the bearing strata.

Considering the above aspects of the foundation design, the suitable type of foundation system for the proposed structures is presented below.

3.1 Proposed Structures:

The proposed structures consists of:

- Switch Yard
- Transformer Yard
- Boiler/Auxiliary Boiler
- Chimney
- T.G Building/DG House
- ESP Control Room
- Cooling Tower/Cooling Water Pump House
- Crushed coal stock pile/Crusher House
- Water Treatment Plant
- Administrative Building/Security Room
- Balance Plant Structures
- Coal Conveyor Belt Structures

All the above structures are located in Ash Pond Area, except the coal conveyor belt corridor. In view of this, the entire investigation is considered to comprise of two zones, zone-I is Ash pond area and Zone-II is the coal conveyor belt structures. With respect to the sub soil conditions in Ash pond, the design approach is described below. However, for coal conveyor belt, the average weakest sub soil encountered among the bore holes made in the corridor is considered.

3.2 Subsurface Strata and Load Transfer Mechanism in Ash Pond Region (Design Basis):

In Fly ash, by virtue of very small particle size, the drainage conditions are very poor and as a result, dissipation of pore water pressure will also be very poor. In addition, the specific weight of fly ash is also very low (in the order of 1.1 to 1.2). The castigating effect of poor drainage coupled with very low specific weight, results in the formation of under consolidated deposit. The problem is further complicated due to super saturated condition that is effected due to slurry deposition.

In the present case, the under consolidated nature is reflected in the form of very low SPT-values (in the range of 0 to 2) even at deeper depths. Apart from the fly ash, the stratum below fly ash for a thickness of about 6-8 metres is also an under consolidated stratum with N values ranging from 2-6.

Apart from the deposit characteristics, the present site needs grading for a minimum thickness of 2.5m to 3.0m (assumed in the absence of factual data at the time of preparing this report) and this grade fill will further increases the pore water pressure in under consolidated deposits.

Hence, considering the under consolidated nature of such deep deposit of fly ash / soft clays (about 10.0m to 12.0 thickness), no efficient foundation system is possible without any effort to consolidate the deposit by improving the drainage path, which intern releases excess pore water pressure. This process of ground improvement is also needed even to achieve proper compaction of the grade fill which is otherwise adversely affected by the built-up of pore water pressure due to compaction process in the underlying under consolidated deposits.

Apart from the above, without ground improvement, it would be highly uneconomical to design substructures for power plants primarily from subsoil liquefaction consideration of such large thickness of under consolidated deposits.

In the absence of ground improvement, the substructures need to be designed not only considering the liquefaction, but also to withstand lateral soil flow forces whose estimation is very complex and cannot be quantified without physical modal studies.

Thus, for an efficient super structure load transfer to the bearing strata through the sub-structure, it is by default that “Implementation of Ground Improvement Techniques and Post Improvement evaluation of sub surface properties up to 15.0m below the Existing Ground Level” is a part of foundation design.

However, no improvement in the strength parameters of top under consolidated deposits are assumed for load carrying capacity estimates, but at the same time no “Negative Drag” is considered,

Similarly, no lateral load carrying estimates are made, as the lateral load carrying capacity depends upon the sub soil properties in shallow depth (within 10 to 15 times

the diameter of pile). As thumb rule, 5% of the vertical load carrying capacity is indicated as guide line for carrying out pre-tender designs.

The theoretical lateral load carrying capacity shall be estimated only after ground improvement operations and post improvement evaluation of soil properties are completed, and shall be confirmed by conducting lateral load test to arrive at design value.

3.3 Main Plant Structures:

3.3.1 In Ash Pond Area:

For heavily loaded installations, structures and facilities in Main Plant Structures, it is recommended to provide deep pile foundations. The safe load carrying capacities of different diameters of piles and lengths are worked out as per IS: 2911, Part-1 (Sec.2) and presented in Table-3.1.

Typical computations are presented in Annexure.

3.3.2 Balance Plant Area:

For the kind of sub soil conditions, it is not possible to adopt open foundation system from settlement considerations. Hence, it is recommended to provide deep pile foundations. The safe load carrying capacities of different diameters of piles and lengths are worked out as per IS: 2911, Part-1 (Sec.2) and presented in Table-3.1.

3.3.3 Coal Conveyor Belt Area:

Vicinity of BH-38 to 50:

For the kind of sub soil conditions, it is not possible to adopt open foundation system from settlement considerations. Hence, it is recommended to provide deep pile foundations. The safe load carrying capacities of different diameters of piles and lengths are worked out as per IS: 2911, Part-1 (Sec.2) and presented in Table-3.1.

TABLES

Table-3.1: Recommended Safe Load Carrying Capacities of Bored Cast in Situ Piles

Considered Cut off below E.G.L. = 3.0m

Sl.No.	Location	Length of Pile below E.G.L (m)	Length of Pile below Cut off (m)	Dia.Of Pile (mm)	Safe Load Carrying Capacities (kN)		
					Vertical	Pull Out	*Horizontal
1	Main Plant (Ash Pond Area)	30	27	500	1000	260	50
2				600	1100	340	55
3				700	1500	400	75
4				800	1600	420	80
5				900	1900	500	95
6	Balance Plant Area	30	27	500	1000	260	50
7				600	1100	340	55
8				700	1500	400	75
9				800	1600	420	80
10				900	1900	500	95
11	Coal Conveyor Belt Area	30	27	500	1000	260	50
12				600	1100	340	55
13				700	1500	400	75
14				800	1600	420	80
15				900	1900	500	95

* Horizontal Capacity is consider as 5% of Vertical compression load.

Note:- The above load carrying capacities are valid only if ground improvement technique is adopted and post improvement properties are estimated to validate the improvement.

Table-3.2: Recommendations of the Type of Cement used for the Construction of Substructure along with extract of permissible limits as per IS:456-2000

Concentration of Sulphates expressed as SO ₃				Type of Cement	Cement Content (kg/m ³)	Max. Water-Cement Ratio	Recommended Cement
In 2:1 water Soil		In Ground Water					
g/l	ppm	g/l	ppm				
<1	<1000	<0.3	<300	OPC/PPC/PSC	280	0.55	
1 to 1.9	1000-1900	0.3-1.2	300-1200	OPC/PPC/PSC	330	0.5	
				SSC/SRPC	310	0.5	
1.9 to 3.1	1900-3100	1.2-2.5	1200-2500	SSC/SRPC	330	0.5	
				PPC/PSC	350	0.45	
3.1-5	3100-5000	2.5-5	2500-5000	SSC/SRPC	370	0.45	
>5	>5000	>5	>5000	SSC/SRPC	400	0.4	Recommended

OPC Ordinary Port Land Cement
 PPC Portland Pozzolana Cement
 PSC Portland Slag Cement

SSC Supersulphated Cement
 SRPC Sulphate Resistant Port Land Cement

NOTES:

However, the structural consultant shall refer the notes below Table-4, page-19 of IS:456-2000 for any required additional information on the use of cement for the construction of substructure.

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RECOMMENDATIONS

RECOMMENDATIONS

Mandatory:

Due to existence of large under consolidated liquefiable deposits of thickness 10-12 m with an anticipated surcharge thickness of 2.5 – 3.0m, it is a primary requisite to implement effective ground improvement and monitoring mechanism not only for efficient substructure designs, but also to contain probable liquefaction and subsurface soil flow problems that can be triggered during earth quakes.

Recommendations for Foundations:

- ◆ No shallow foundation is feasible for main plant and B.O.P (Balance of Plant)
- ◆ The theoretical load carrying capacity estimates presented in Chapter-3 do not consider negative drag forces. This is in line with the mandatory recommendations mentioned above with respect to ground improvement.
- ◆ The recommended load carrying capacities do not consider any beneficial strength improvement in the top under consolidated deposits due to the implementation of ground improvement technique.

Recommendations for Shallow Foundations

- ◆ As it is a pre-requisite to implement ground improvement technique and monitoring the same including post-improvement evaluation of subsoil properties depending upon the degree of improvement and on the super structure loads, appropriate shallow foundation systems may be viable for the construction of light load structures.
- ◆ In order to provide a unified foundation construction foundations, a combination of critical soil parameters from different boreholes are considered and arrived at as **Design Geotechnical Model for the facility.**
- ◆ Bored Cast in Situ pile with Direct Mud Circulation shall be adopted. The mud used shall be made out of sodium bentonite.
- ◆ Since, the compacted hard clay has swelling nature, on boring and removing the overburden, there will be a stress reversal due to swelling and as a result the shear strength will reduce. It is not possible to quantify the reduction but no credit to the “N-Value” shall be given in such strata beyond an N-value of 60 and the same is considered in the design. This assumption restricts the behaviour of clay to very stiff to hard consistency.
- ◆ The theoretical load carrying capacity estimates presented in Table-3.1 shall be considered as provisional design loads, as the load carrying capacity of the piles not only depends up on the soil strength parameters but also on execution care and experience. In view of this, the theoretical load carrying capacity estimates shall be confirmed by conducting pile load tests as per the guide lines laid down in IS:2911-Part-IV.

- ◆ The pile concreting shall be carried out within one to two hours after completing the boring operation to minimize the softening of the hard compacted clay. Care shall be taken to clean the bottom of the bore before concreting.

Recommendations for Foundation Concrete:

- ◆ The Chloride content in ground water is much higher than the permissible limits. This could be due to the mixing of fly ash with sea water to facilitate settling to create the ash pond. In view of this, it is recommended to use corrosion resistant steel or steel with epoxy based on anticorrosion paint for construction.
- ◆ Since Sulphates are much more than the permissible limits as per IS.456-2000 (Table-19), sulphates resistant cement shall be used in all sub structure constructions.

Recommendations for Earthing Design:

- ◆ The Soil Resistance values obtained from Electrical Resistivity Survey are reported in Volume-I of this report and the same can be used for the design of earthing system.

For Geo Marine Consultants (P) Ltd., Chennai.

(Dr.Venkata Prasad Chintaluri)

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ANNEXURE

ESTIMATION OF SAFE LOAD CARRYING CAPACITY OF VERTICAL PILE DESIGN																
Ref.Bore Hole-17			Bored	Diameter of Pile	Length of Pile below G.L. (m)			30	IS:2911-Par-I(Sec.2)							
Type of Pile					500	mm	Surcharge Pressure		10	kPa						
Layer No.	Layer Thk. (m)			Type of Strata	Ave. SPT	(γ) kN/m ³		Shear Parameters		Effective Overburden Pressure (kPa)			Adhesion Factor (α)	Earth Pressure Coef. (k)	Skin Friction (Q _f) kN	
	Top. R.L.	Bot. R.L.	Thickness			of Layer	Ave. upto Layer	(C _u) kPa	(ϕ) Deg.	At top of Layer	At Bot. of Layer	At Mid. of Layer			Positive	Negative
1	0	3	Cutoff Zone													
2	3	4.2	1.2	Fly Ash	0	12	12	-	19.6	16.0	12.4	14.2	-	1	qf ₂	-9.535
3	4.2	6	1.8	clay	1	13.5	12.75	7	-	12.4	18.7	25.6	0.7	-	qf ₃	-13.854
4	6	10	4	sand	2	13	13.25	-	19.9	18.7	30.7	34.7	-	1	qf ₄	-78.984
5	10	18	8	sand	22	18.5	18.5	-	33.6	30.7	98.7	74.7	-	1.2	qf ₅	748.411
6	18	21.6	3.6	clay	50	21	21	333	-	98.7	138.3	128.5	0.3	-	qf ₆	564.921
7	21.6	27.8	6.2	sand	50	20.5	20.75	-	41	138.3	203.4	180.9	-	2	qf ₇	3062.127
8	27.8	30	2.2	clay	50	21	20.75	333	-	203.4	227.6	225.5	0.3	-	qf ₈	345.230

Ultimate Positive Skin Resistance Q_f 4618.31 kN

Negative Skin Resistance -Q_f -102.374 "

Computation of End Bearing Resistance

SPT	N _q	N _c	C _u	Efc.Ht.of Overburden (20*dia.of pile)	10	m
			(kPa)	Effective Overburden Pressure		
Bearing Stratum	clay	60	-	9	400	70.7
						Q _p 706.8583 kN
						Ultimate Safe Vertical Load Carrying Capacity Q _u =Q _f +Q _p 5325.173 "
						Safe Load Carrying Capacity (Q _{safe}) Q _u /2.5 2130.07 "
						Allowable Safe Load Carrying Capacity Q _{A-safe} (-Q _f) 2027.70 "
						Allowable Safe Pull out Capacity Q _{A-pull} 1231.551 "

NOTE:

Skin Resistance in Clay Layers is: $\pi d^*T_1*C_u*\alpha$ d= Dia. Of Pile T₁= Thickness of Layer
C_u= Undrained Shear Strength of Clay α = Adhesion Factor

Skin Resistance in Sand Layers is: $\pi d^*T_1*q_1*K*\tan(\phi)$ ϕ = Angle of Shearing Resistance
K= Coef. Earth Pressure at Rest
q₁= Effective Overburden Pressure at the middle of Layer

End Bearing Resistance in Clay is: $\pi d^2/4*C_u*N_c$ N_c= Bearing Capacity Factor = 9

End Bearing Resistance in Sand is: $\pi d^2/4*Q*N_q$ N_q= Bearing Capacity Factor, Ref. Fig.1 of IS: Code Referred above
Q= Effective Overburden Pressure at the tip of Pile (Restricted to a Maximum Value equal to Soil Height = 20 times the Diameter of Pile)

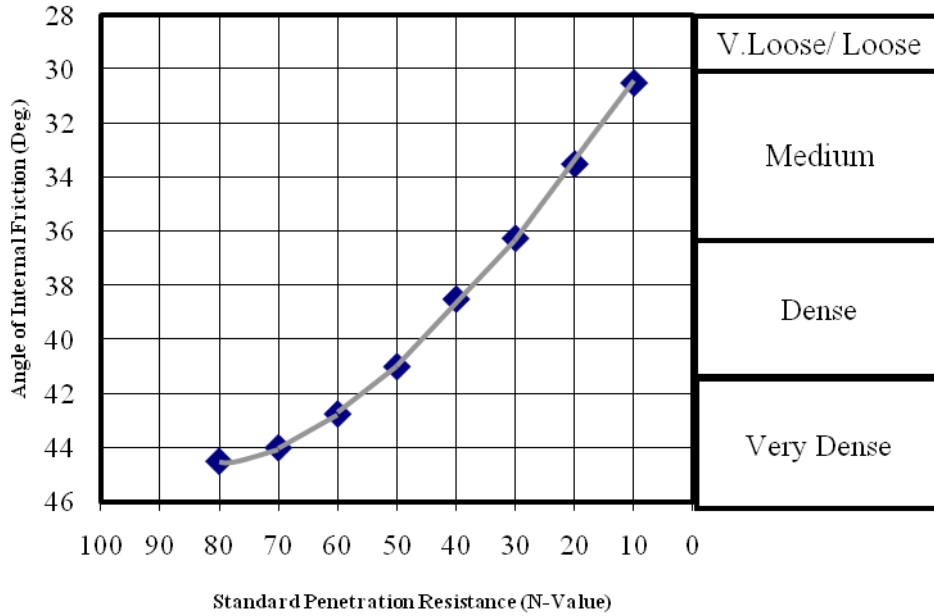


FIG. A1 Relation Ship between Angle of Internal Friction & N-value (Reproduced from IS:6403-1981)

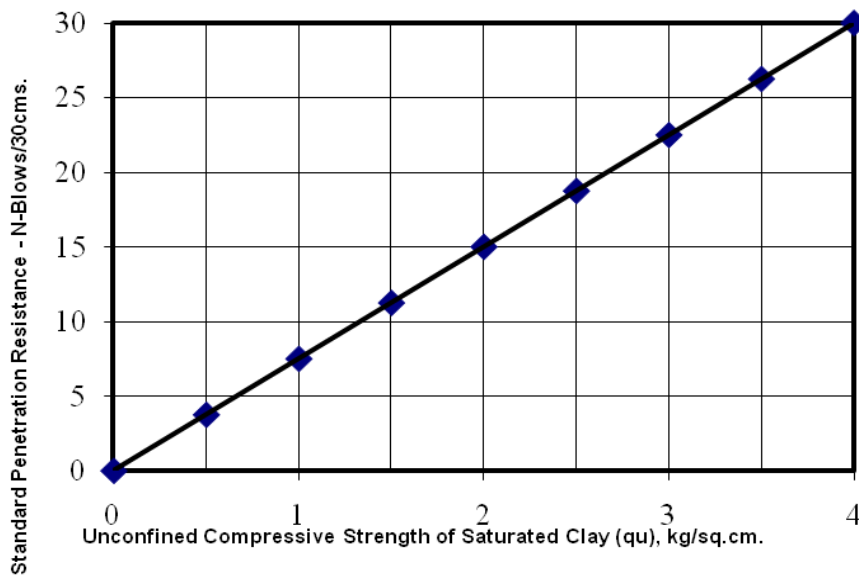


FIG. A2 : Relationship between UCC & SPT-Value (N) of Saturated Clay (After Terzhagi & Peck, 1948)