GEO-TECHNICAL INVESTIGATION REPORT

(FINAL)

Project:

New Building in BHEL complex at
Plot No.-25, Sector-16-A, Noida (U.P.)

Project Ref.:13022215

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Report submitted to:

M/s Space Combine
New Delhi

CONSULTANT

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BRIEF SUMMARY AND RECOMMENDATIONS

S. N.	DESCRIPTION	RESULTS
1.	**Name of Project**	**New Building of BHEL**
2.	**Location**	BHEL Complex, Plot No.-25,Sector-16-A, Noida (U.P.)
3.	**No. of Boreholes & Depth**	3 nos. of 40m depth, 2 nos. of 30m depth, 1 no. of 20m depth and 2 DCPT up to 10m depth below EGL or refusal
4.	**Seismic Zone**	*Zone IV*
5.	**Findings of the investigation:**	

5.1 - Sub soil Strata

Layer No.	Depth below EGL (m)	Strata Description
Layer - 1	0.00-1.00	Sandy Silt (ML-CL)
Layer - 2	2.00-4.00	Silty Sand (SM)
Layer - 3	4.00-28.00	Fine Sand with Gravel (SP)
Layer - 4	28.00-35.00	Sandy Silt with Gravel (ML-CL)
Layer - 5	35.00-40.00	Silty Sand with Gravel (SM)

5.2 – SPT values at different depth

Depth Below EGL	BH-1		BH-2		BH-3		BH-4		BH-5		BH-6		BH-7	
	N_r	N_c	N_r	N_c	N_r	N_c	N_r	N_c	N_r	N_c	N_r	N_c	N_r	N_c
1.50 m	10	15	11	16	6	9	8	12	11	16	9	13	6	9
3.00 m	9	11	9	11	8	10	7	9	8	10	8	10	14	17
4.50 m	11	12	11	12	13	14	16	17	10	11	13	14	21	23
6.00 m	37	37	13	13	17	17	30	30	17	17	22	22	22	22
7.50 m	39	36	24	22	20	18	41	38	21	19	22	20	25	23
9.00 m	59	50	29	25	18	15	27	23	26	22	27	23	28	23
10.50 m	31	25	27	22	18	14	39	31	30	24	28	23	-	-
12.00 m	34	26	33	25	63	48	63	48	36	27	33	25	-	-
13.50 m	28	20	23	17	19	14	36	26	17	12	65	47	-	-
15.00 m	37	21	20	14	27	17	42	22	40	22	21	15	-	-
18.00 m	48	24	34	19	42	22	46	23	38	20	30	18	-	-
21.00 m	47	23	43	21	50	24	57	26	52	24	58	27	-	-
24.00 m	49	23	48	23	45	22	56	25	48	23	-	-	-	-
27.00 m	59	25	29	16	50	23	27	16	56	24	-	-	-	-
30.00 m	52	23	47	21	48	21	36	18	57	24	-	-	-	-
33.00 m	29	16	-	-	72	28	-	-	60	24	-	-	-	-
36.00 m	66	25	-	-	54	22	-	-	70	27	-	-	-	-
40.00 m	78	28	-	-	63	24	-	-	85	30	-	-	-	-

5.3 - Water Table: Water table was found at 15m depth below EGL.

5.4 - Liquefaction Potential: After carrying out assessment of liquefaction potential of subsoil strata by simplified approach proposed by Seed & Idriss (1983 – 1985) from the SPT data and peak ground acceleration likely to occur at the site during earthquake, it is found that the soil strata up to the explored depth i.e., 40.0 m below ground level is **not susceptible** to liquefaction.

6.

6.1 Design soil Parameters:

Depth of Foundation below EGL	Soil Type	Bulk Density t/m³	Foundation Size	Weighted average value of N*		Parameters adopted for analysis		
				For Shear	For Settlement	N	C t/m²	ϕ
1.50 m	Silty Sand (SM)	1.72	2.0m	12	12	12	0	30°
			2.5m	12	13	13	0	30°
			3.0m	12	13	13	0	30°
			25.0m	19	20	15	0	30°
14.50 m	Fine Sand with Gravel (SP)	1.78	25.0m	22	22	22	0	31°
			30.0m	22	22	22	0	31°
			35.0m	22	22	22	0	31°
15.00 m	Fine Sand with Gravel (SP)	1.79	25.0m	22	22	22	0	31°
			30.0m	22	22	22	0	31°
			35.0m	22	22	22	0	31°
15.50 m	Fine Sand with Gravel (SP)	1.80	25.0m	23	23	23	0	31°
			30.0m	23	23	23	0	31°
			35.0m	23	23	23	0	31°
16.00 m	Fine Sand with Gravel (SP)	1.82	25.0m	23	23	23	0	31°
			30.0m	23	23	23	0	31°
			35.0m	23	23	23	0	31°

***** For shear criteria the weighted average value of SPT has been taken up to a depth equal to least dimension of the foundation below the depth of foundation, while for settlement criteria the influence zone has been taken as twice the least dimension of the foundation below the depth of foundation. In case of influence zone below the depth of investigation it has been suitably assumed that the strata are similar as observed in deeper boreholes.

6.2 Allowable total settlement taken for safe bearing pressure :

For Isolated footing: 50 mm, For raft footing: 75mm

7. Recommendations:

7.1 Type of Foundation : Isolated / Raft Foundation

Depth of Foundation below EGL	Thickness of Foundation	Type of Foundation	Size of Foundation	$q_{allowable}$ (t/m^2)	Modulus of Subgrade Reaction (k) in KN/m^3
1.50m (Buildings without basement Floor)	1.50m	Isolated Strip	2.0m	10.50	-
			2.5m	11.00	-
		Isolated Square	2.5mX2.5m	11.75	-
			3.0m X3.0m	12.00	-
		Raft	25.0mX25.0m	20.75	2,760
14.50 m (Buildings with three basement Floors)	1.50m	Raft	25.0mX25.0m	47.00	6,260
			30.0mX30.0m	45.25	6,030
			35.0mX35.0m	44.75	5,960
15.00 m (Buildings with three basement Floors)	1.50m	Raft	25.0mX25.0m	47.50	6,330
			30.0mX30.0m	45.75	6,100
			35.0mX35.0m	45.25	6,030
15.50 m (Buildings with three basement Floors)	1.50m	Raft	25.0mX25.0m	51.50	6,860
			30.0mX30.0m	51.25	6,830
			35.0mX35.0m	50.75	6,760
16.00 m (Buildings with three basement Floors)	1.50m	Raft	25.0mX25.0m	52.00	6,930
			30.0mX30.0m	51.75	6,900
			35.0mX35.0m	51.25	6,830

7.2 Type of Foundation : Cast in situ bored piles with M30 Grade of concrete

Dia. of Pile	Length of Pile Below Cut-off Level	Safe Axial Load Carrying Capacity (t)		Safe Lateral Load Carrying Capacity (t)		Minimum Pile length (4T)	
		Compression	Uplift	Free Head	Fixed Head	Free Head	Fixed Head
600 mm	10.0 m	55	15	4.5	11.5	8.14m	8.14m
	15.0 m*	85	30	4.5	11.5	8.14m	8.14m
	20.0 m*	120	45	4.5	11.5	8.14m	8.14m
	25.0 m	155	65	4.5	11.5	8.14m	8.14m
750 mm	10.0 m	75	20	6.0	17.0	9.73m	9.73m
	15.0 m*	135	45	6.0	17.0	9.73m	9.73m
	20.0 m*	190	70	6.0	17.0	9.73m	9.73m
	25.0 m	240	95	6.0	17.0	9.73m	9.73m

The cut off level is 15.0m below EGL.

The load capacities of piles are based on Static formulae using IS code. It is recommended to confirm the theoretical pile capacity by conducting initial pile load tests as per IS: 2911 (Part IV) on test piles before installing the working piles.

*For 0.6 m and 0.75 m pile diameter of piles, the pile length of 15 m and 20 m are actually terminated in sandy silt / clay layer which has some plasticity / compressibility. Hence settlement of piles/pile groups has to be calculated and checked for the permissible limits at working loads.

1.0 INTRODUCTION

1.1 Project Description

Bharat Heavy Electrical Limited (BHEL) is planning to construct its new building in BHEL complex at Plot no.-25, Sector-16-A, Noida (U.P.).

Architectural Consultancy of the project is being carried out by M/s Space Combine, New Delhi.

The Consultant of the project has approached us for carrying out geo-technical investigations and recommendations about the design of suitable foundation for the construction of this project.

We have carried out the investigations and testing accordingly and our final report for this project is submitted below:

1.2 Object of Investigations

To establish the parameters for the foundation design of the structure, various properties and parameters regarding the subsoil at site are required. These parameters are achieved through geo-technical investigations viz. soil profile, engineering properties & physical characteristics of the soil strata, variation in strength of soil strata etc. and can be elaborated as below:

- Sub-surface conditions which will reflect the thickness of the different soil strata
- Depth of ground water table
- Safe bearing capacity of the soil which will need the determination of various engineering properties of the soil strata at different levels
- Depth of the foundations
- Suitable type of foundations
- Requirement of any treatment needed to enhance the engineering properties of the soil beneath the footing

1.3 Scope of Investigations

For achieving the aforesaid objectives, the scope of work, as finalized by the consultant includes:

1. Making **3 nos.** bore holes up to a depth of 40m, **2 nos.** bore holes up to a depth of 30m, **1 no.** bore holes up to a depth of 20m and **1 no.** bore holes up to a depth of 10m below existing ground surface in subsoil or refusal whichever is encountered earlier on the site at locations specified by the consultant.

2. Conducting Standard Penetration Tests (S. P. T.) at 1.5 m depth interval.
3. Extracting disturbed & undisturbed soil sample at different depth interval.
4. Observing ground water table after a stabilization period of 24 hours.
5. Conducting dynamic cone penetration test at **2 nos.** locations up to a depth of 10m or refusal as per IS code.
6. Conducting laboratory tests on disturbed and undisturbed soil samples collected during the subsurface exploration.
7. Compiling and submitting report in three copies, containing field and laboratory tests results and suggestion & recommendations regarding type & depth of foundations and allowable load bearing capacity of soil and other desired parameters at various depths.

1.4 Organization of Report

This report has been primarily designed to explain the whole study in a systematic way, keeping in view the various demands of designers as well as the client. Each investigation is backed by its theoretical base and the results obtained either during the field tests or in laboratory are presented herein this report in self-explanatory tabular and/or graphical form. Calculations are shown wherever necessary before incorporating any parameter in the recommendations.

The chapter 'Introduction' describes the details of the project and various contents of this study. 'Site Reconnaissance' provides the general information regarding the site conditions, weather of the region, topography and the geology of the area. Details of various field and laboratory tests are given in the following two chapters. Findings obtained during these tests are summarized in the next chapter. 'Foundation Analysis' is an important chapter dealing with all design calculations required for the foundation selection and design. Recommendations are finalized in the concluding chapter.

Various table, figures and graphs are given in the annexure in quite an explanatory mode.

A list of Indian Standard (IS) Codes, which are referred throughout the study, is also attached at the end of this report.

2.0 SITE RECONNAISSANCE

2.1 General Geology of the Area

The present site is located at Sector-16-A, Noida. The upper strata of this area comprise the alluvium, made up predominantly of fine sand, silty sand and sandy silt with gravel. These alluviums are underlain by harder formations of the system of rocks.

2.2 General Weather

The available data about the weather and average rainfall and location of the site indicate that there may not be variation in the ground water to affect the proposed structure and its foundation system.

2.3 Site Description

The proposed building is to be constructed in the existing campus of BHEL. The building will have structures with three basement floors having founding level at 14.5m to 16.0m depth below EGL.

Hence In this report, foundation proposal has been made at founding level of 14.5m to 16.0m depth below EGL. However for other structures, foundation proposal has also been given at 1.50m depth below EGL.

3.0 FIELD INVESTIGATION

3.1 Introduction

For achieving various soil parameters, Field Investigations are carried out at site. Field Investigation comprises site reconnaissance, detailed exploration including extensive boring program and conducting specified field tests viz. Standard Penetration Test and dynamic cone penetration test.

3.2 Subsurface Exploration

Subsurface Exploration was carried out during 26th February to 19th March 2013 by using suitable boring rig. Boreholes with following designation were made on the site:

Activity	Depth of exploration	Date of start	Date of completion
BH-1	40m	14-03-2013	17-03-2013
BH-2	30m	10-03-2013	13-03-2013
BH-3	40m	07-03-2013	10-03-2013
BH-4	30m	04-03-2013	06-03-2013
BH-5	40m	28-02-2013	04-03-2013
BH-6	20m	26-02-2013	27-02-2013
BH-7	10m	19-03-2013	19-03-2013
DCPT-1	10m	18-03-2013	18-03-2013
DCPT-2	10m	18-03-2013	18-03-2013

The depth of bore- holes was taken below the existing ground surface of the plot. Disturbed and undisturbed samples were collected from bore- holes at various depths.

3.3 Standard Penetration Test

Standard Penetration Test conducted by means of the split spoon sampler furnishes data about resistance of the soils to penetration, which can be used to evaluate standard strength data, such as N values (number of blows per 30 cm of penetration using standard split spoon) of the soil.

Standard Penetration Tests were conducted in the boreholes at 1.5 m interval as per the provisions of IS 2131:1981. The tests were conducted by means of the split spoon sampler conforming to IS 9640:1980. If N values exceed 50 for 15cm penetration at any depth, it is taken as refusal depth and the bore-hole shall be terminated.

3.4 Dynamic Cone Penetration Test

Dynamic Cone Penetration Test is a test conducted for obtaining a general qualitative idea of the strata. Dynamic Cone Penetration Test were conducted at the specified locations on the site by using 50mm cone attached loosely to the driving A-rod through a cone adopter in accordance with IS: 4968(Part-I)-1976.

The number of blows (N_{cd}) as a continuous record for every 300mm of penetration was taken in the field and is presented in the appendices here. Depth of DCP's were terminated at refusal depth as defined in IS: 4968 (Part-I)-1976, i.e. Number of blows for 100mm penetration exceeds 35.

3.5 Ground Water Conditions

Water Table at this site was found at 15m depth below the existing ground surface.

4.0 LABORATORY INVESTIGATIONS

The laboratory tests to determine the physical properties, the engineering properties and the engineering characteristics of the soil were conducted in accordance with IS 2720. The tests performed are as follows.

4.1 Bulk Density and Natural Moisture Content

Undisturbed samples were collected from the boreholes in thin wall steel sample tubes by taking the dimensions and weight of these sample tubes, the bulk density of the soil is determined. Moisture content of the soil has been calculated by Oven Drying Method.

4.2 Grain Size Analysis

Grain size distribution of the soil is determined by sieving the soil sample in a set of IS sieves: 4.75 mm, 2 mm, 1 mm, 0.5 mm, 0.25 mm, 0.125 mm, 0.075 mm size. Grain Size Analysis curve has been plotted and attached in the appendices of this report for the soil samples collected from various depths of bore-holes.

4.3 Atterberg's Limits

Atterberg's Limits in the form of liquid limit, plastic limit and shrinkage limit are determined for the soil to establish its consistency. In the case of cohesionless soil, plastic limit is first determined and if it cannot be determined the soil sample is reported to be non-plastic.

4.4 Specific Gravity

Specific Gravity of the soil has been determined by Specific Gravity Bottle.

4.5 Direct Shear Test

Direct Shear Test is a strength test, which is performed on the soil sample to determine the value of angle of internal friction.

The direct shear test is generally conducted on cohesionless soil as consolidated drained (CD) test. In the present case the soil samples were prepared for various depths and were tested in the Direct Shear Apparatus under CD- condition.

4.6 Triaxial Shear Test

Triaxial Shear Test is a strength test, which is performed on the soil sample to determine the value of cohesion and angle of internal friction. Test samples are prepared from undisturbed samples and are tested in the Triaxial Apparatus.

Summary of Laboratory Tests results for all boreholes is shown in tabular form and the same is presented in the appendices of this report.

5.0 FINDINGS OF INVESTIGATIONS

Based on various field and laboratory tests, following findings are observed:

1. The general grain size distribution pattern in the bore-holes has been observed as following:

BH No.	Subsoil Layers	Soil Type	Shear Parameters	
			Cohesion c in t/m^2	Angle of Friction ϕ
BH-1	Layer – 1 (0.0m to 1.0m)	Sandy Silt (ML-CL)	-	-
	Layer – 2 (1.0m to 4.0m)	Silty Sand (SM)	0.00	30-31
	Layer – 3 (4.0m to 10.0m)	Fine Sand with Gravel (SP)	0.00	30-34
	Layer – 4 (10.0m to 13.0m)	Sandy Silt with Gravel (ML-CL)	0.25	30
	Layer – 5 (13.0m to 31.0m)	Fine Sand with Gravel (SP)	0.00	32-34
	Layer – 6 (31.0m to 38.0m)	Sandy Silt with Gravel (ML-CL)	0.27-0.30	30
	Layer – 7 (38.0m to 40.0m)	Silty Sand with Gravel (SM)	0.00	34
BH-2	Layer – 1 (0.0m to 1.0m)	Sandy Silt (ML-CL)	-	-
	Layer – 2 (1.0m to 5.0m)	Silty Sand (SM)	0.00	30-32
	Layer – 3 (5.0m to 28.0m)	Fine Sand with Gravel (SP)	0.00	31-34
	Layer – 4 (28.0m to 30.0m)	Silty Sand with Gravel (SM)	0.00	32-33
BH-3	Layer – 1 (0.0m to 1.0m)	Sandy Silt (ML-CL)	-	-
	Layer – 2 (1.0m to 4.0m)	Silty Sand (SM)	0.00	30
	Layer – 3 (4.0m to 28.0m)	Fine Sand with Gravel (SP)	0.00	30-34
	Layer – 4 (28.0m to 32.0m)	Sandy Silt with Gravel (ML-CL)	0.28-0.30	30
	Layer – 5 (32.0m to 34.0m)	Fine Sand with Gravel (SP)	0.00	34
	Layer – 6 (34.0m to 40.0m)	Sandy Silt with Gravel (ML-CL)	0.30-0.31	30
BH-4	Layer – 1 (0.0m to 4.0m)	Silty Sand (SM)	0.00	30
	Layer – 2 (4.0m to 26.0m)	Fine Sand with Gravel (SP)	0.00	30-34
	Layer – 3 (26.0m to 30.0m)	Sandy Silt with Gravel (ML-CL)	0.21	30
BH-5	Layer – 1 (0.0m to 1.0m)	Sandy Silt (ML-CL)	-	-
	Layer – 2 (1.0m to 4.0m)	Silty Sand (SM)	0.00	30-32
	Layer – 3 (4.0m to 28.0m)	Fine Sand (SP)	0.00	30-34
	Layer – 4 (28.0m to 33.0m)	Silty Sand (SM)	0.00	34
	Layer – 5 (33.0m to 36.0m)	Sandy Silt (ML-CL)	0.25	30
	Layer – 6 (36.0m to 38.0m)	Silty Sand (SM)	0.00	34
	Layer – 7 (38.0m to 40.0m)	Sandy Silt (ML-CL)	-	-

BH-6	Layer – 1 (0.0m to 1.0m)	Sandy Silt (ML-CL)	-	-
	Layer – 2 (1.0m to 4.0m)	Silty Sand (SM)	0.00	30-31
	Layer – 3 (4.0m to 20.0m)	Fine Sand with Gravel (SP)	0.00	30-34
BH-7	Layer – 1 (0.0m to 3.0m)	Silty Sand (SM)	0.00	30
	Layer – 2 (3.0m to 10.0m)	Fine Sand with Gravel (SP)	0.00	31-34

The grain size distribution pattern reveals that the subsurface strata comprises of layers of silty sand, fine sand and sandy silt with Gravel.

2. Standard Penetration Test (SPT) results show the following pattern in bore-holes in different depth range:

Depth Below EGL	BH-1		BH-2		BH-3		BH-4		BH-5		BH-6		BH-7	
	N_r	N_c	N_r	N_c	N_r	N_c	N_r	N_c	N_r	N_c	N_r	N_c	N_r	N_c
1.50 m	10	15	11	16	6	9	8	12	11	16	9	13	6	9
3.00 m	9	11	9	11	8	10	7	9	8	10	8	10	14	17
4.50 m	11	12	11	12	13	14	16	17	10	11	13	14	21	23
6.00 m	37	37	13	13	17	17	30	30	17	17	22	22	22	22
7.50 m	39	36	24	22	20	18	41	38	21	19	22	20	25	23
9.00 m	59	50	29	25	18	15	27	23	26	22	27	23	28	23
10.50 m	31	25	27	22	18	14	39	31	30	24	28	23	-	-
12.00 m	34	26	33	25	63	48	63	48	36	27	33	25	-	-
13.50 m	28	20	23	17	19	14	36	26	17	12	65	47	-	-
15.00 m	37	21	20	14	27	17	42	22	40	22	21	15	-	-
18.00 m	48	24	34	19	42	22	46	23	38	20	30	18	-	-
21.00 m	47	23	43	21	50	24	57	26	52	24	58	27	-	-
24.00 m	49	23	48	23	45	22	56	25	48	23	-	-	-	-
27.00 m	59	25	29	16	50	23	27	16	56	24	-	-	-	-
30.00 m	52	23	47	21	48	21	36	18	57	24	-	-	-	-
33.00 m	29	16	-	-	72	28	-	-	60	24	-	-	-	-
36.00 m	66	25	-	-	54	22	-	-	70	27	-	-	-	-
40.00 m	78	28	-	-	63	24	-	-	85	30	-	-	-	-

Nc, Corrected value of recorded Nr is obtained after applying correction of overburden and dilatancy.

SPT results indicate that the nature of subsoil is medium dense to dense throughout the explored depth.

3. Water table was found at 15m depth below EGL.

4. The soil throughout the explored strata is non plastic to low plastic in nature.

5. The variation of bulk density, natural moisture content and dry density for various depth ranges is found to follow the following pattern:

BH No.	Bulk Density gm/cc	Natural Moisture Content (%)	Dry Density gm/cc
BH-1	1.72-1.84	9.29-12.19	1.57-1.84
BH-2	1.71-1.82	9.85-12.06	1.56-1.63
BH-3	1.71-1.84	9.22-12.33	1.57-1.64
BH-4	1.72-1.82	10.04-12.07	1.56-1.62
BH-5	1.70-1.81	9.36-12.91	1.55-1.60
BH-6	1.72-1.81	9.95-11.88	1.56-1.62
BH-7	1.70-1.79	8.89-11.05	1.56-1.61

6. Results obtained from the Dynamic Cone Penetration Test conducted at two locations in the field, confirm the type of strata, as finalized on the basis of Standard Penetration Test.

Inference of Findings:

From the above findings it can be inferred that the subsoil strata at 1.50m depth is Silty Sand (SM) and at 14.50m to 16.00m depth below EGL, it is Fine Sand with Gravel (SP). Correction factor for overburden and dilatancy has been applied to field SPT values, for the entire explored depth. Corrected SPT value has been used for the calculation of safe bearing pressure values from the settlement criterion as per IS: 8009, Part-I. Following general design soil parameters at founding level have been taken for the analysis purpose:

Depth of Foundation below EGL	Soil Type	Bulk Density t/m^3	Foundation Size	Weighted average value of N*		Parameters adopted for analysis		
				Shear	Settlement	N	C t/m^2	ϕ
1.50 m	Silty Sand (SM)	1.72	2.0m	12	12	12	0	30°
			2.5m	12	13	13	0	30°
			3.0m	12	13	13	0	30°
			25.0m	19	20	15	0	30°
14.50 m	Fine Sand with Gravel (SP)	1.78	25.0m	22	22	22	0	31°
			30.0m	22	22	22	0	31°
			35.0m	22	22	22	0	31°
15.00 m	Fine Sand with Gravel (SP)	1.79	25.0m	22	22	22	0	31°
			30.0m	22	22	22	0	31°
			35.0m	22	22	22	0	31°
15.50 m	Fine Sand with Gravel (SP)	1.80	25.0m	23	23	23	0	31°
			30.0m	23	23	23	0	31°
			35.0m	23	23	23	0	31°
16.00 m	Fine Sand with Gravel (SP)	1.82	25.0m	23	23	23	0	31°
			30.0m	23	23	23	0	31°
			35.0m	23	23	23	0	31°

6.0 FOUNDATION ANALYSIS

6.1 Foundation Type

A Foundation is required for distributing the loads of the superstructure on a larger ground area. The dead and live load of the proposed structure are to be transferred to the underlying supporting soil through suitable foundation.

Foundation may be broadly classified into two categories: (i) Shallow Foundation and (ii) Deep Foundation.

6.2 Shallow Foundation

Shallow foundation transmits the loads to the strata at shallow depth. A shallow foundation is one the width of which is greater than its depth. Shallow Foundations are located just below the lowest part of the wall or a column, which they support.

6.3 Deep Foundation

When the soil at or near the ground surface is not capable of supporting a structure, deep foundations are required to transfer the loads to deeper strata. Deep foundations are, therefore, used when surface soil is unsuitable for shallow foundation, and a firm stratum is so deep that it cannot be reached economically by shallow foundations. The most common types of deep foundations are piles, wells and caissons.

6.4 Assessment of Liquefaction

Liquefaction is the sudden loss of shear strength of the loose fine-grained sands due to earthquake-induced vibration under saturated conditions. Liquefaction generally takes place in loose fine-grained sands (fines < 10 %, D_{60}, 0.20 mm to 1.0 mm and C_u between 2 to 5) with N value less than 15. In case of soil strata having N>15, liquefaction of soil will not take place normally.

The present site falls in seismic zone – IV. Considering the history of past earthquakes and available seismic data, an earthquake of magnitude 6.5 having peak ground acceleration a_{max} = 0.18 g is considered in the present analysis.

Preliminary assessment of liquefaction potential of foundation strata is made by simplified approach proposed by Seed & Idriss (1983 – 1985) from the SPT data and peak ground acceleration likely to occur at the site for a horizontal ground surface.

In this method, cyclic shear stress likely to be induced in the foundation strata by Design Basis Earthquake (DBE) is first evaluated. Next threshold cyclic shear stress, which is good enough to cause liquefaction, is determined from SPT data and the empirical relations. Finally, comparison of these two stresses is used in the estimation of liquefaction susceptibility of the foundation strata.

Cyclic Stress Ratio (CSR)

The equivalent average of shear stress τ_{av} likely to be induced in the foundation material due to an earthquake is calculated by using the equation

τ_{av} = $0.65 * \gamma * h * (a_{max} / g) * r_d$

τ_{av} = equivalent average of shear stress to be induced by DBE

γ = Unit weight of foundation material

h = depth at which cyclic shear stress is calculated

a_{max} = maximum surface acceleration

r_d = Stress reduction factor

= $1.0 – 0.00765 * h$ if h < 9.15 m

= $1.174 – 0.0267 * h$ if h = 9.15 m to 23 m

= $0.744 – 0.008 * h$ if h = 23.0 m to 30.0 m

= 0.50 if h > 30.0 m

If the equivalent average of shear stress τ_{av} is normalized with the initial effective overburden pressure (σ_o), the term is called seismic demand of soil layer or cyclic stress ratio (CSR).

$$CSR = 0.65 * (\sigma_o / \sigma_o') * (a_{max} / g) * r_d$$

Cyclic Resistance Ratio (CRR)

It expresses capacity of soil to resist liquefaction. CRR is determined using correlation between corrected blow count $(N_1)_{60}$ and CRR for earthquake of magnitude 6.5. $(N_1)_{60}$ is the SPT blow count corrected to an effective overburden pressure of 100 kPa and to hammer energy efficiency of 60 %.

The corrected blow count $(N_1)_{60}$ is determined as follows.

$$(N_1)_{60} = N_m C_N C_E C_B C_R C_S$$

Where, N_m = Uncorrected SPT blow count

C_E = Correction factor for hammer energy ratio = 1.00

C_B=Correction factor for borehole dia = 1.05 and 1.15 for 150 mm and 200mm dia borehole

C_R = Correction factor for rod length =0.75 for 3.0m to 4.0 m

=0.85 for 4.0 m to 6.0 m

=0.95 for 6.0 m to 10.0 m

=1.0 for 10.0 m to 30.0 m

C_S = Correction factor for standard sampler =1.0

Correction factor for effective overburden pressure (C_N) is given by the following relation.

C_N = Sqrt (P_a / σ_o') Where P_a = Atmospheric pressure

The value of SPT blow count for soil with fines content (FC) can be adjusted to the equivalent clean sand value of $(N_1)_{60CS}$ as follows:

$(N_1)_{60CS}$ = $\alpha + \beta (N_1)_{60}$

where α and β can be determined as follows.

α = 0.0 and β = 1.0 for FC <= 5.0 %

$\alpha = e_{xp} [(1.76 – (190/FC^2)]$ for 5.0 % < FC < 35.0 %

$\beta = [0.99+ (FC^{1.5}/1000)]$

α = 5.0 and β = 1.20 for FC >= 35.0 %

$CRR_{M = 7.5}$ is given by the following equation.

$CRR_{M=7.5} =[1/ (34-(N_1)_{60CS})] + [(N_1)_{60CS}/135]+[50/\{10*(N_1)_{60CS} + 45\}^2]–[1/200]$

Hence the CRR for a particular earthquake magnitude is determined as

CRR = $CRR_{M = 7.5}$ * MSF * K_σ

The MSF value is 1.50 for earthquake of magnitude 6.5. K_σ is taken as 1.

The factor of safety against liquefaction, FS_L, is given as

FS_L = CRR/CSR

The value of CSR and CRR are computed at different depth and depth susceptible to liquefaction is determined.

Liquefaction is probable when FS_L is less than 1.0.

It is found from the computations that the soil strata up to the explored depth i.e., 40.0 m below existing ground level are not susceptible to liquefaction. Computation at different depth for each borehole is given in details of Bore Hole.

6.5 Selection of Foundation

Selection of suitable type of foundation for the proposed structure depends upon the (i) intensity & type of loading to be transferred from the superstructure and (ii) the properties & behavior of sub soil.

In the present case, the proposed building is likely to transfer moderate load on the subsoil. The bearing capacity of the natural subsoil herein at required depth is adequate enough to bear the expected moderate load of the proposed structures. Hence shallow foundation can be considered as the right solution for this project.

6.6 Determination of Bearing Capacity for the Shallow Foundations

Bearing capacity of soil for foundation has been calculated in accordance with IS: 6403 –1981. Here Allowable bearing pressure has been evaluated by: (a) Shear Failure criterion and (b) Settlement criterion

(a) Shear Failure criterion

$$q_a = \frac{1}{F}[\, c\, N_c\, S_c\, d_c\, i_c + \gamma\, D_f\, (Nq-1) S_q\, d_q\, i_q + 0.5\, \gamma B N_\gamma S_\gamma d_\gamma i_\gamma W']$$

Here q_a = Allowable Bearing Capacity

F = Factor of safety, taken equal to 3.0 as per IS: 1904

c = Cohesion

γ = Unit weight of soil

W' = Water table correction factor

D_f = Depth of foundation

B = Width of foundation

N_c , N_q , N_γ = Bearing Capacity factors

S_c , Sq , S_γ = Shape Factors

d_c , dq, d_γ = Depth Factor

i_c , iq , i_γ = Inclination Factor

For various values of Df & B, calculations are done and the values for net safe bearing capacity have been obtained.

Depth of Foundation Below EGL	Thickness of Foundation	Type of Foundation	Size of Foundation	$q_{net\ safe}$ (t / m^2)
1.50 m (Buildings without basement Floor)	1.50m	Isolated Strip	2.0m	10.48
			2.5m	10.93
		Isolated Square	2.5m X 2.5m	11.74
			3.0m X 3.0m	12.10
		Raft	25.0m X 25.0m	33.50
14.50 m (Buildings with three basement Floors)	1.50m	Raft	25.0m X 25.0m	50.96
			30.0m X 30.0m	58.72
			35.0m X 35.0m	66.49
15.00 m (Buildings with three basement 5loors)	1.50m	Raft	25.0m X 25.0m	51.25
			30.0m X 30.0m	59.05
			35.0m X 35.0m	66.87
15.50 m (Buildings with three basement 6loors)	1.50m	Raft	25.0m X 25.0m	51.53
			30.0m X 30.0m	59.38
			35.0m X 35.0m	67.24
16.00 m (Buildings with three basement Floors)	1.50m	Raft	25.0m X 25.0m	52.10
			30.0m X 30.0m	60.04
			35.0m X 35.0m	67.99

(b) Settlement criterion taking SPT values.

As per IS: 8009-1976 Part-I- Clause-9.1.4, the settlement for different width has been computed. For the allowable total settlement of 50mm for isolated footing and 75mm for Raft foundation (as per IS: 1904), the safe bearing pressure is found as following:

Depth of Foundation Below EGL	Thickness of Foundation	Type of Foundation	Size of Foundation	Safe Bearing Pressure (t/m²)
1.50 m (Buildings without basement Floor)	1.50m	Isolated Strip	2.0m	12.82
			2.5m	12.82
		Isolated Square	2.5m X 2.5m	14.48
			3.0m X 3.0m	13.13
		Raft	25.0mX25.0m	20.80
14.50 m (Buildings with three basement Floors)	1.50m	Raft	25.0mX25.0m	47.06
			30.0mX30.0m	45.42
			35.0mX35.0m	44.90
15.00 m (Buildings with three basement Floors)	1.50m	Raft	25.0mX25.0m	47.64
			30.0mX30.0m	45.96
			35.0mX35.0m	45.42
15.50 m (Buildings with three basement Floors)	1.50m	Raft	25.0mX25.0m	52.61
			30.0mX30.0m	51.34
			35.0mX35.0m	50.73
16.00 m (Buildings with three basement Floors)	1.50m	Raft	25.0mX25.0m	53.27
			30.0mX30.0m	51.97
			35.0mX35.0m	51.34

Hence the values of allowable bearing capacity as chosen the minimum value (rounded off) from above two criterions are as following:

Depth of Foundation Below EGL	Thickness of Foundation	Type of Foundation	Size of Foundation	$q_{allowable}$ (t/m²)
1.50 m (Buildings without basement Floor)	1.50m	Isolated Strip	2.0m	10.50
			2.5m	11.00
		Isolated Square	2.5m X 2.5m	11.75
			3.0m X 3.0m	12.00
		Raft	25.0m X	20.75
14.50 m (Buildings with three basement Floors)	1.50m	Raft	25.0mX25.0m	47.00
			30.0mX30.0m	45.25
			35.0mX35.0m	44.75
15.00 m (Buildings with three basement Floors)	1.50m	Raft	25.0mX25.0m	47.50
			30.0mX30.0m	45.75
			35.0mX35.0m	45.25
15.50 m (Buildings with three basement Floors)	1.50m	Raft	25.0mX25.0m	51.50
			30.0mX30.0m	51.25
			35.0mX35.0m	50.75
16.00 m (Buildings with three basement Floors)	1.50m	Raft	25.0mX25.0m	52.00
			30.0mX30.0m	51.75
			35.0mX35.0m	51.25

6.7 Modulus of Subgrade Reaction

Modulus of Subgrade Reaction (k) is required for the design of Raft foundation. In the field the method for the determination of its value is conducting 'Plate Load Test' on a 30cm or 60cm plate. Values obtained from this test are corrected for the actual foundation size, which becomes unrealistic when the foundation size is too large.

As per IS : 2950 (Part 1) – 1981-clause B-4, the average modulus of subgrade reaction can be calculated as average contact pressure per unit settlement of the raft for the design of rigid raft.

6.8 Pile Capacity

Determination of safe Axial load carrying capacity (Both in compression and uplift) and lateral load carrying capacity of cast in situ bored pile has been made and the Values obtained are as following.

Dia. of Pile (mm)	Length of Pile Below Cut-off Level	Safe Axial Load Carrying Capacity (t)		Safe Lateral Load Carrying Capacity (t)		Minimum Pile Length (4T)	
		compression	Uplift	Free Head	Fixed Head	Free Head	Fixed Head
600	10.0 m	55	15	4.5	11.5	8.14m	8.14m
	15.0 m	85	30	4.5	11.5	8.14m	8.14m
	20.0 m	120	45	4.5	11.5	8.14m	8.14m
	25.0 m	155	65	4.5	11.5	8.14m	8.14m
750	10.0 m	75	20	6.0	17.0	9.73m	9.73m
	15.0 m	135	45	6.0	17.0	9.73m	9.73m
	20.0 m	190	70	6.0	17.0	9.73m	9.73m
	25.0 m	240	95	6.0	17.0	9.73m	9.73m

A cut-off length of 15.0m has been taken below EGL. For 0.6 m and 0.75 m pile diameter piles, the pile length of 15m and 20m are actually terminated in sandy silt / clay layer which has some plasticity / compressibility. Hence settlement has to be calculated and checked for the limits at working loads.

The load capacities of piles are based on Static formulae using IS code. It is recommended to confirm the theoretical pile capacity by conducting initial pile load tests as per IS: 2911 (Part IV) on test piles before installing the working piles.

7.0 RECOMMENDATIONS

In view of the these findings & results obtained during the field and laboratory investigations and the analysis carried out thereafter, following general recommendations are being made for the foundation design of the proposed new building at BHEL complex, Plot No.-25, Sector-16-A, Noida (U.P.).

1. The type of foundation depends upon the configuration of loading & loading intensity as well as characteristics & behavior of subsoil. Considering the type of loading and based on various findings of the subsoil, in the present case, the type of foundation can be adopted as Isolated or Raft Foundation.

2. Allowable Bearing Capacity shall be adopted corresponding to various parameters as following:

Depth of Foundation Below EGL	Thickness of Foundation	Type of Foundation	Size of Foundation	$q_{allowable}$ (t/m^2)	Modulus of Subgrade Reaction (k) in KN/m^3
1.50m (Buildings without basement Floor)	1.50m	Isolated Strip	2.0m	10.50	-
			2.5m	11.00	-
		Isolated Square	2.5m X 2.5m	11.75	-
			3.0m X 3.0m	12.00	-
		Raft	25.0m X 25.0m	20.75	2,760
14.50 m (Buildings with three basement Floors)	1.50m	Raft	25.0m X 25.0m	47.00	6,260
			30.0m X 30.0m	45.25	6,030
			35.0m X 35.0m	44.75	5,960
15.00 m (Buildings with three basement Floors)	1.50m	Raft	25.0m X 25.0m	47.50	6,330
			30.0m X 30.0m	45.75	6,100
			35.0m X 35.0m	45.25	6,030
15.50 m (Buildings with three basement Floors)	1.50m	Raft	25.0m X 25.0m	51.50	6,860
			30.0m X 30.0m	51.25	6,830
			35.0m X 35.0m	50.75	6,760
16.00 m (Buildings with three basement Floors)	1.50m	Raft	25.0m X 25.0m	52.00	6,930
			30.0m X 30.0m	51.75	6,900
			35.0m X 35.0m	51.25	6,830

3. If any loose pockets are observed during excavation for shallow foundation, the same shall be filled with brickbats/gravel and compacted. Foundation can subsequently be placed over this prepared surface.

4. Recommended safe vertical load carrying capacity (both in compression and uplift) and lateral load carrying capacity of cast in situ bored piles shall be adopted corresponding to various parameters as following:

Dia. of Pile (mm)	Length of Pile Below Cut-off Level	Safe Axial Load Carrying Capacity (t)		Safe Lateral Load Carrying Capacity (t)		Minimum Pile length	
		compression	Uplift	Free Head	Fixed Head	Free Head	Fixed Head
600	10.0 m	55	15	4.5	11.5	8.14m	8.14m
	15.0 m	85	30	4.5	11.5	8.14m	8.14m
	20.0 m	120	45	4.5	11.5	8.14m	8.14m
	25.0 m	155	65	4.5	11.5	8.14m	8.14m
750	10.0 m	75	20	6.0	17.0	9.73m	9.73m
	15.0 m	135	45	6.0	17.0	9.73m	9.73m
	20.0 m	190	70	6.0	17.0	9.73m	9.73m
	25.0 m	240	95	6.0	17.0	9.73m	9.73m

A cut-off length of 15.0m has been taken below the existing ground level.

The load capacities of piles are based on Static formulae using IS code. It is recommended to confirm the theoretical pile capacity by conducting initial pile load tests as per IS: 2911 (Part IV) on test piles before installing the working piles.

5. As per the analysis done for the liquefaction potential of the subsoil strata, it is found that the subsoil strata up to the explored depth are not prone to liquefaction during earthquake.

6. Our analysis and recommendations are based only on the data collected from seven bore-holes made at the site. Subsoil strata observed in these bore-holes has been assumed as the representative of the site.

For **Explore Engineering Consultants (P) Ltd.**

Date: 30/08/2013 (A.K.SINGH) (A.P.SINGH)
Place: Noida

ANNEXURES

Bore Holes Location Plan

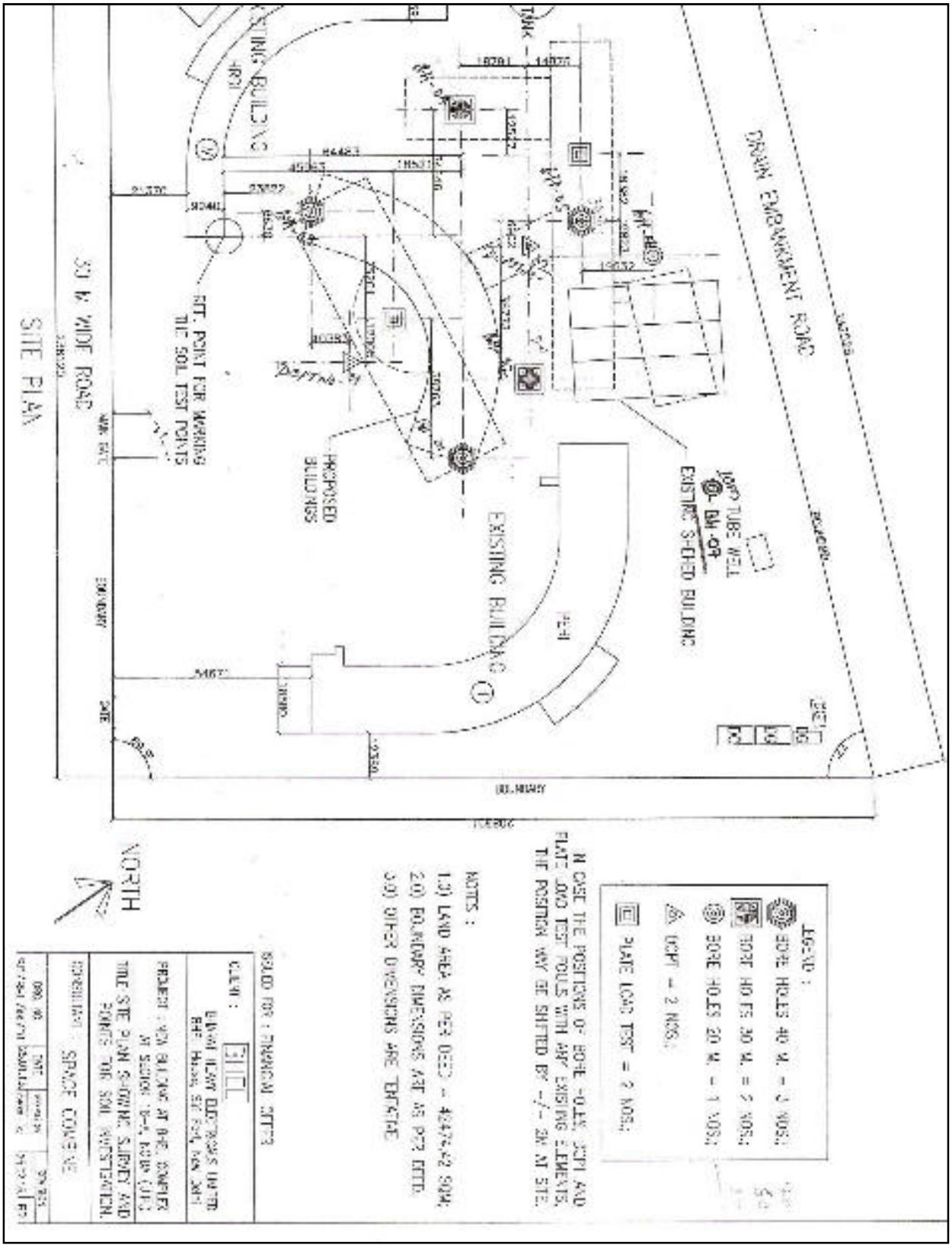


Fig.:- 1: Site plan showing test locations

Details of BH- 1

FIELD BORELOG — Table No.- 1

METHOD OF BORING	: Shell & Auger Method	BORE HOLE NO.	: 1
CASING TYPE & DEPTH	: SX-6.40m	LOCATION	: As per attached location plan
WATER TABLE	: 15.0m	DATE START	: 14-03-2013
DEPTH OF BORING	: 40 m b.g.l	DATE COMPLETION	: 17-03-2013

DEPTH(m)	DISCRIPTION OF SOIL STRATA	SOIL CLASS.	LEGEND	STRATA THICK. (m)	SAMPLES DETAILS			SPT BLOWS COUNTS				REMARKS
					TYPE	NO.	TEST DEPTH (m)	15	30	45	"N"	
1.0	SANDY SILT	ML-CL		1.00	DS	1	0.00-0.50	COLLECTED				
2.0	SILTY SAND	SM		3.00	UDS	1	1.00-1.30	COLLECTED				
					SPT	1	1.50-1.95	3	4	6	10	
3.0												
4.0					SPT	2	3.00-3.45	3	4	5	9	
5.0	FINE SAND WITH GRAVEL	SP		6.00	UDS	2	4.00-4.30	COLLECTED				
					SPT	3	4.50-4.95	4	5	6	11	
6.0												
7.0					SPT	4	6.00-6.45	4	16	21	37	
8.0					UDS	3	7.00-7.30	COLLECTED				
					SPT	5	7.50-7.95	7	15	24	39	
9.0												
10.0					SPT	6	9.00-9.45	8	27	32	59	
11.0	SANDY SILT WITH GRAVEL	ML-CL		3.00	UDS	4	10.00-10.30	COLLECTED				
					SPT	7	10.50-10.95	6	19	12	31	
12.0												
13.0					SPT	8	12.00-12.45	6	15	19	34	
14.0	FINE SAND WITH GRAVEL	SP		18.00	UDS	5	13.00-13.30	COLLECTED				
					SPT	9	13.50-13.95	7	11	17	28	
15.0												
16.0					SPT	10	15.00-15.45	8	15	22	37	
17.0					UDS	6	16.00-16.30	SLIPPED				
18.0												
19.0					SPT	11	18.00-18.45	10	21	27	48	
20.0					UDS	7	19.00-19.30	SLIPPED				
21.0												
22.0					SPT	12	21.00-21.45	8	16	31	47	
23.0					UDS	8	22.00-22.30	SLIPPED				
24.0												
25.0					SPT	13	24.00-24.45	13	20	29	49	
26.0					UDS	9	25.00-25.30	SLIPPED				
27.0												
28.0					SPT	14	27.00-27.45	15	26	33	59	
29.0					UDS	10	28.00-28.30	SLIPPED				
30.0												
31.0					SPT	15	30.00-30.45	12	25	27	52	
32.0	SANDY SILT WITH GRAVEL	ML-CL		7.00	UDS	11	31.00-31.30	COLLECTED				
33.0												
34.0					SPT	16	33.00-33.45	8	13	16	29	
35.0					UDS	12	34.00-34.30	COLLECTED				
36.0												
37.0					SPT	17	36.00-36.45	9	27	39	66	
38.0					UDS	12	37.00-37.30	COLLECTED				
39.0	SILTY SAND WITH GRAVEL	SM		2.00								
40.0					SPT	19	39.55-40.00	12	36	42	78	

LABORATORY TEST RESULTS OF BH-1

Table No.-2

DEPTH BELOW GL	TYPE / SAMPLE NO.	DEPTH OF SAMPLE	SPT VALUE 'N' OBSERVED	SPT VALUE 'N' CORRECTED	DESCRIPTION OF STRATA	LEGEND	GRAIN SIZE ANALYSIS: GRAVEL (%)	GRAIN SIZE ANALYSIS: SAND (%)	GRAIN SIZE ANALYSIS: SILT + CLAY (%)	ATTERBERG LIMIT: LIQUID LIMIT (%)	ATTERBERG LIMIT: PLASTIC LIMIT (%)	ATTERBERG LIMIT: PLASTICITY INDEX	BULK DENSITY in t/m^3	DRY DENSITY in t/m3	MOISTURE CONTENT (%)	SPECIFIC GRAVITY	SHEAR PARAMETER: COHESION 'C' in t/m^4	SHEAR PARAMETER: ANGLE of FRICTION (Φ)
1.00	DS	0.00-0.50	COLLECTED		SANDY SILT (ML-CL)		1	47	52									
2.00	UDS	1.00-1.30	COLLECTED		SILTY SAND (SM)		1	81	18	NON-PLASTIC			1.72	1.57	9.29	2.66	0.00	30
	SPT	1.50-1.95	10	15			1	82	17									31
3.00																		
4.00	SPT	3.00-3.45	9	11			1	80	19									30
5.00	UDS	4.00-4.30	COLLECTED		FINE SAND WITH GRAVEL (SP)		4	87	9	NON-PLASTIC			1.74	1.58	9.88	2.65	0.00	30
	SPT	4.50-4.95	11	12			3	86	11									30
6.00																		
7.00	SPT	6.00-6.45	37	37			2	89	9									34
8.00	UDS	7.00-7.30	COLLECTED				3	89	8				1.75	1.59	10.14	2.65	0.00	32
	SPT	7.50-7.95	39	36			4	90	6									34
9.00																		
10.00	SPT	9.00-9.45	59	50			3	93	4									34
11.00	UDS	10.00-10.30	COLLECTED		SANDY SILT WITH GRAVEL (ML-CL)		4	37	59	26	20	6	1.77	1.60	10.52	2.67	0.25	30
	SPT	10.50-10.95	31	25			3	39	58									
12.00																		
13.00	SPT	12.00-12.45	34	26			3	36	61									
14.00	UDS	13.00-13.30	COLLECTED		FINE SAND WITH GRAVEL (SP)		4	89	7	NON-PLASTIC			1.79	1.62	10.66	2.65	0.00	32
	SPT	13.50-13.95	28	20			4	89	7									33
15.00																		
16.00	SPT	15.00-15.45	37	21			2	92	6									33
17.00	UDS	16.00-16.30	SLIPPED				-	-	-				-	-	-	-	-	-
18.00																		
19.00	SPT	18.00-18.45	48	24			4	94	2									34
20.00	UDS	19.00-19.30	SLIPPED				-	-	-				-	-	-	-	-	-
21.00																		
22.00	SPT	21.00-21.45	47	23			4	93	3									34
23.00	UDS	22.00-22.30	SLIPPED				-	-	-				-	-	-	-	-	-
24.00																		
25.00	SPT	24.00-24.45	49	23			3	93	4									34
26.00	UDS	25.00-25.30	SLIPPED				-	-	-				-	-	-	-	-	-
27.00																		
28.00	SPT	27.00-27.45	59	25			3	89	8									34
29.0	UDS	28.00-28.30	SLIPPED				-	-	-				-	-	-	-	-	-
30.0																		
31.00	SPT	30.00-30.45	52	23			3	92	5									34
32.00	UDS	31.00-31.30	COLLECTED		SANDY SILT WITH GRAVEL (ML-CL)		4	39	57	26	20	6	1.81	1.63	11.32	2.67	0.27	30
33.00																		
34.00	SPT	33.00-33.45	29	16			4	41	55									
35.00	UDS	34.00-34.30	COLLECTED				3	39	58	26	20	6	1.82	1.62	12.04	2.67	0.27	30
36.00																		
37.00	SPT	36.00-36.45	66	25			4	35	61									
38.00	UDS	37.00-37.30	COLLECTED				3	35	62	27	21	6	1.84	1.64	12.19	2.67	0.30	30
39.00					SILTY SAND WITH GRAVEL (SM)													
40.00	SPT	39.55-40.00	78	28			4	62	34									34

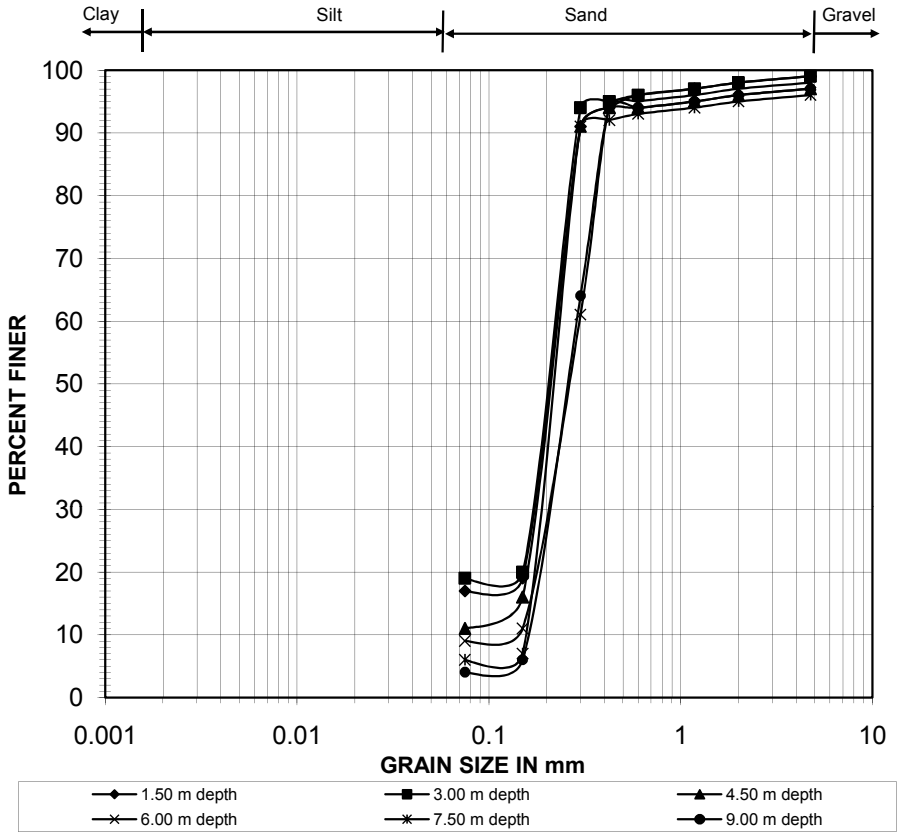
Computation of Liquefaction Potential at Different Depth by Idriss and Seed Method | **Table No.- 3**

Borehole No.	1
Borehole dia.	150 mm
Water Table (in m below EGL)	15.00

COMPUTATION DEPTH (h)	SAT. DENSITY (t/cum)	FINE CONTENT (%)	STRESS RED. RATIO (r_d)	Total overburden (σo)	Eff. overburden (σ_o)' for CSR (WT = 0)	Cyclic Stress ratio (CSR)	SPT Value (N)	Bulk Density	Eff. overburden (σ_o)' for CN (WT = Actual)	C_N	C_E	C_B	C_R	C_S	SPT Corrected $(N1)_{60}$	α	β	$(N1)_{60cs}$	$CRR_{M=7.5}$	CRR	FS_L	REMARK
1.5	1.98	17	0.989	2.97	1.47	0.233	10	1.72	2.58	1.969	1.0	1.15	0.75	1.00	17.0	3.01	1.06	21.0	0.23	0.343	1.47	NL
3.0	1.98	19	0.977	5.95	2.95	0.231	9	1.72	5.16	1.392	1.0	1.15	0.80	1.00	11.5	3.43	1.07	15.8	0.17	0.252	1.09	NL
4.5	1.99	11	0.966	8.93	4.43	0.228	11	1.74	7.77	1.134	1.0	1.15	0.85	1.00	12.2	1.21	1.03	13.7	0.15	0.221	0.97	L
6.0	1.99	9	0.954	11.90	5.90	0.225	37	1.74	10.38	0.982	1.0	1.15	0.95	1.00	39.7	0.56	1.02	40.9	NA	NA	>1	NL
7.5	1.99	6	0.943	14.89	7.39	0.222	39	1.75	13.01	0.877	1.0	1.05	1.00	1.00	35.9	0.03	1.00	36.1	NA	NA	>1	NL
9.0	1.99	4	0.931	17.87	8.87	0.219	59	1.75	15.63	0.800	1.0	1.05	1.00	1.00	49.6	0.00	1.00	49.6	NA	NA	>1	NL
10.5	2.00	58	0.894	20.87	10.37	0.210	31	1.77	18.29	0.740	1.0	1.05	1.00	1.00	24.1	5.00	1.20	33.9	NA	NA	>1	NL
12.0	2.00	61	0.854	23.88	11.88	0.201	34	1.77	20.94	0.691	1.0	1.05	1.00	1.00	24.7	5.00	1.20	34.6	NA	NA	>1	NL
13.5	2.01	7	0.814	26.89	13.39	0.191	28	1.79	23.63	0.651	1.0	1.05	1.00	1.00	19.1	0.12	1.01	19.4	0.21	0.312	1.63	NL
15.0	2.01	6	0.774	29.90	14.90	0.182	37	2.01	25.14	0.631	1.0	1.05	1.00	1.00	24.5	0.03	1.00	24.6	0.29	0.428	2.35	NL
18.0	2.01	2	0.693	35.92	17.92	0.163	48	2.01	28.16	0.596	1.0	1.05	1.00	1.00	30.0	0.00	1.00	30.0	NA	NA	>1	NL
21.0	2.01	3	0.613	41.94	20.94	0.144	47	2.01	31.18	0.566	1.0	1.05	1.00	1.00	27.9	0.00	1.00	27.9	0.37	0.552	3.84	NL
24.0	2.01	4	0.552	47.96	23.96	0.129	49	2.01	34.20	0.541	1.0	1.05	1.00	1.00	27.8	0.00	1.00	27.8	0.36	0.545	4.22	NL
27.0	2.01	8	0.528	53.98	26.98	0.124	59	2.01	37.22	0.518	1.0	1.05	1.00	1.00	32.1	0.30	1.01	32.8	NA	NA	>1	NL
30.0	2.01	5	0.504	60.01	30.01	0.118	52	2.01	40.24	0.498	1.0	1.05	1.00	1.00	27.2	0.00	1.00	27.2	0.34	0.517	4.38	NL
33.0	2.02	55	0.500	66.06	33.06	0.117	29	2.02	43.29	0.481	1.0	1.05	1.00	1.00	14.6	5.00	1.20	22.6	0.25	0.375	3.21	NL
36.0	2.02	61	0.500	72.11	36.11	0.117	66	2.02	46.34	0.465	1.0	1.05	1.00	1.00	32.2	5.00	1.20	43.6	NA	NA	>1	NL
39.6	2.03	34	0.500	79.30	39.75	0.117	78	2.03	49.98	0.447	1.0	1.05	1.00	1.00	36.6	4.93	1.19	48.5	NA	NA	>1	NL

L=Liquefiable	NL=Non-Liquefiable

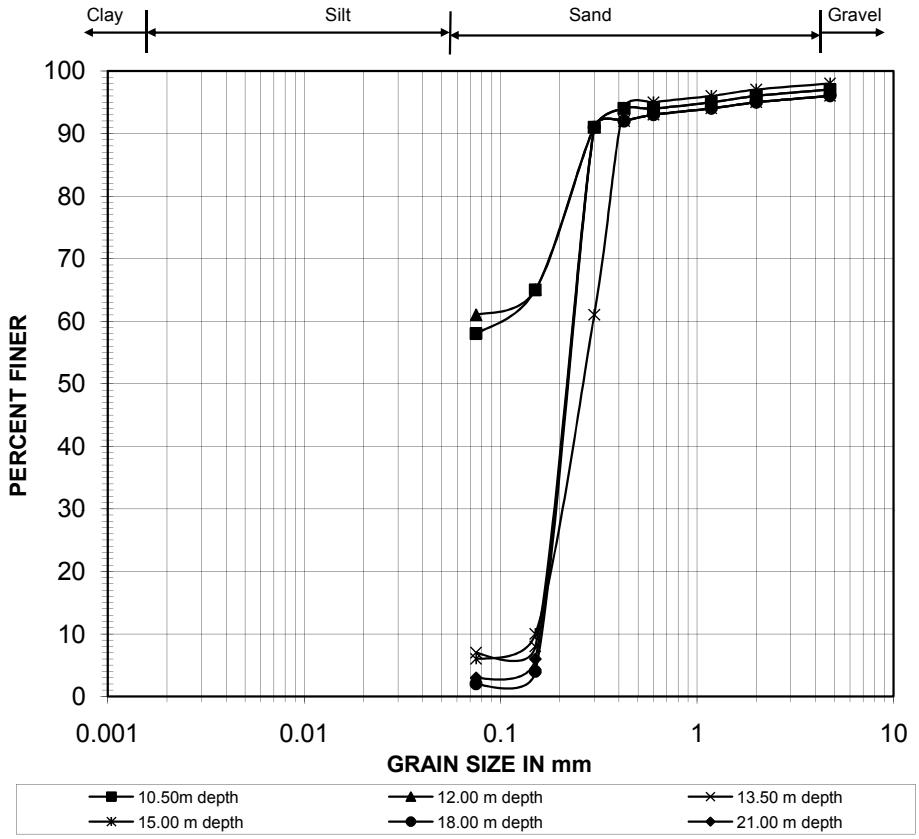
PARTICLE SIZE DISTRIBUTION CURVE for BH-1



Depth	Gravel (%)	Sand (%)	Silt + Clay (%)
1.50 m depth	1	82	17
3.00 m depth	1	80	19
4.50 m depth	3	86	11
6.00 m depth	2	89	9
7.50 m depth	4	90	6
9.00 m depth	3	93	4

Fig. - 2

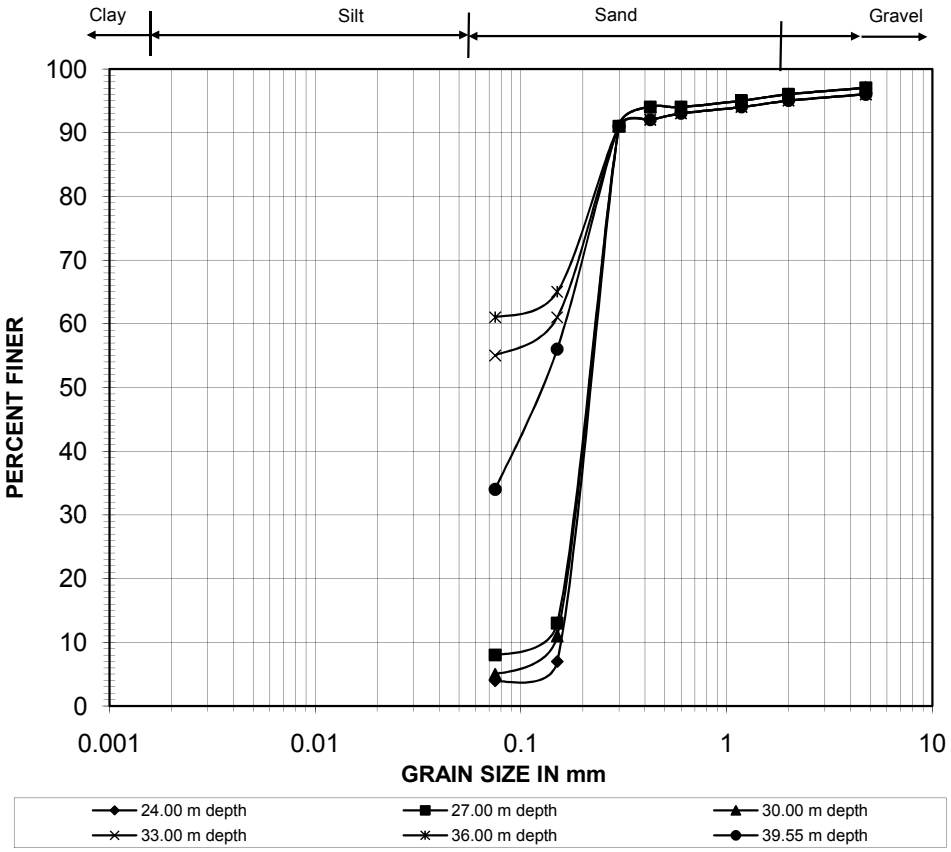
PARTICLE SIZE DISTRIBUTION CURVE for BH-1



Depth	Gravel (%)	Sand (%)	Silt + Clay (%)
10.50m depth	3	39	58
12.00 m depth	3	36	61
13.50 m depth	4	89	7
15.00 m depth	2	92	6
18.00 m depth	4	94	2
21.00 m depth	4	93	3

Fig. - 3

PARTICLE SIZE DISTRIBUTION CURVE for BH-1



Depth	Gravel (%)	Sand (%)	Silt + Clay (%)
24.00 m depth	3	93	4
27.00 m depth	3	89	8
30.00 m depth	3	92	5
33.00 m depth	4	41	55
36.00 m depth	4	35	61
39.55 m depth	4	62	34

Fig. - 4

VARIATION OF SPT 'N' WITH DEPTH for B.H.No.- 1

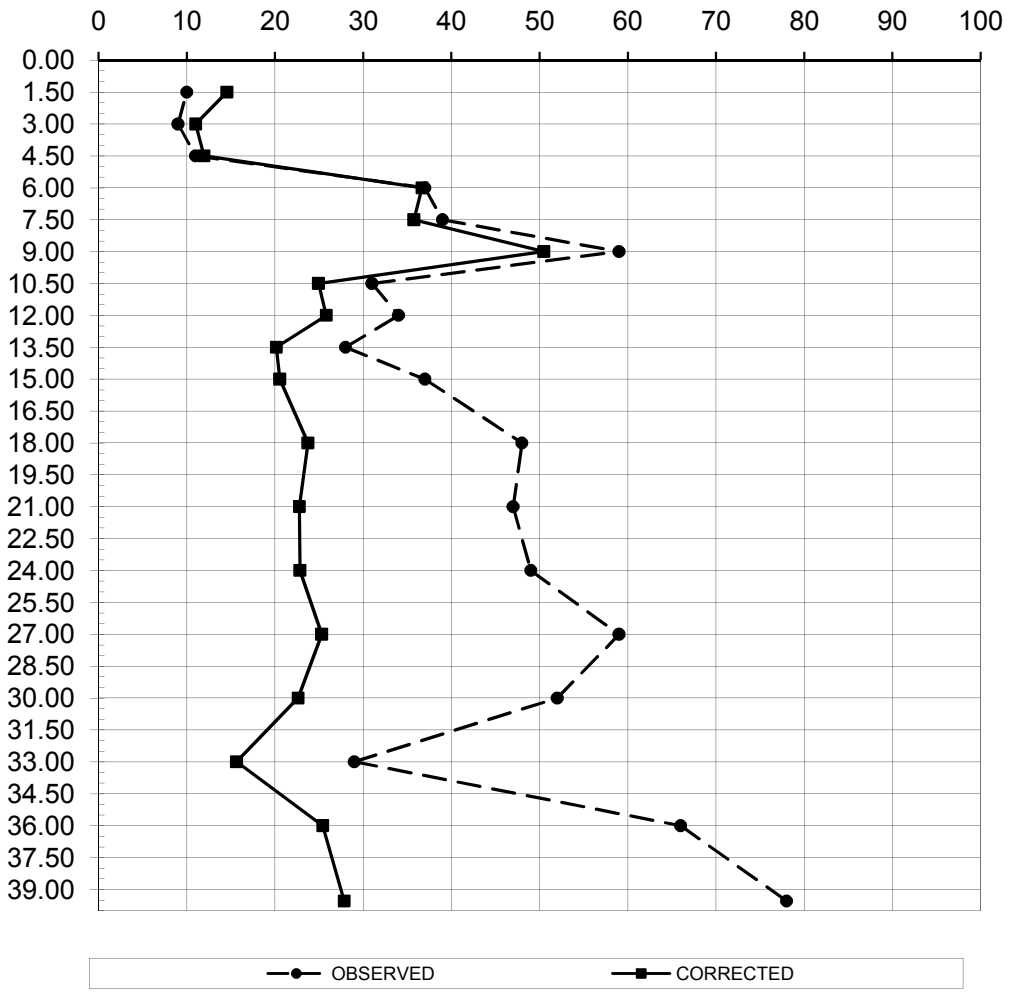


Fig. - 5

Details of BH- 2

FIELD BORELOG — Table No.- 4

METHOD OF BORING	: Shell & Auger Method	BORE HOLE NO.	: 2
CASING TYPE & DEPTH	: SX-6,30m	LOCATION	: As per attached location plan
WATER TABLE	: 15.0m	DATE START	: 10-03-2013
DEPTH OF BORING	: 30 m b.g.l	DATE COMPLETION	: 13-03-2013

DEPTH(m)	DISCRIPTION OF SOIL STRATA	SOIL CLASS.	LEGEND	STRATA THICK. (m)	SAMPLES DETAILS			SPT BLOWS COUNTS				REMARKS
					TYPE	NO.	TEST DEPTH (m)	15	30	45	"N"	
1.0	SANDY SILT	ML-CL		1.00	DS	1	0.00-0.50	COLLECTED				
2.0	SILTY SAND	SM		4.00	UDS	1	1.00-1.30	COLLECTED				
					SPT	1	1.50-1.95	4	5	6	11	
3.0												
					SPT	2	3.00-3.45	3	4	5	9	
4.0												
					UDS	2	4.00-4.30	COLLECTED				
5.0					SPT	3	4.50-4.95	4	5	6	11	
6.0	FINE SAND WITH GRAVEL	SP		23.00								
					SPT	4	6.00-6.45	5	6	7	13	
7.0												
					UDS	3	7.00-7.30	COLLECTED				
8.0					SPT	5	7.50-7.95	7	11	13	24	
9.0												
					SPT	6	9.00-9.45	9	13	16	29	
10.0												
					UDS	4	10.00-10.30	COLLECTED				
11.0					SPT	7	10.50-10.95	6	12	15	27	
12.0												
					SPT	8	12.00-12.45	8	15	18	33	
13.0												
					UDS	5	13.00-13.30	COLLECTED				
14.0					SPT	9	13.50-13.95	6	10	13	23	
15.0												
					SPT	10	15.00-15.45	5	9	11	20	
16.0												
					UDS	6	16.00-16.30	SLIPPED				
17.0												
18.0												
					SPT	11	18.00-18.45	11	15	19	34	
19.0												
					UDS	7	19.00-19.30	SLIPPED				
20.0												
21.0												
					SPT	12	21.00-21.45	9	17	26	43	
22.0												
					UDS	8	22.00-22.30	SLIPPED				
23.0												
24.0												
					SPT	13	24.00-24.45	13	19	29	48	
25.0												
					UDS	9	25.00-25.30	SLIPPED				
26.0												
27.0												
					SPT	14	27.00-27.45	8	13	16	29	
28.0												
					UDS	10	28.00-28.30	COLLECTED				
29.0	SILTY SAND WITH GRAVEL	SM		2.00								
30.0					SPT	15	29.55-30.00	13	22	25	47	

ABBREVIATION:- SPT - Standard Penetration Test UDS- Undisturbed Sample

LABORATORY TEST RESULTS OF BH-2

Table No.-5

DEPTH BELOW GL	TYPE / SAMPLE NO.	DEPTH OF SAMPLE	SPT VALUE 'N' OBSERVED	SPT VALUE 'N' CORRECTED	DESCRIPTION OF STRATA	LEGEND	GRAIN SIZE ANALYSIS GRAVEL (%)	GRAIN SIZE ANALYSIS SAND (%)	GRAIN SIZE ANALYSIS SILT + CLAY (%)	ATTERBERG LIMIT LIQUID LIMIT (%)	ATTERBERG LIMIT PLASTIC LIMIT (%)	ATTERBERG LIMIT PLASTICITY INDEX	BULK DENSITY in t/m^3	DRY DENSITY in t/m3	MOISTURE CONTENT (%)	SPECIFIC GRAVITY	SHEAR PARAMETER COHESION 'C' in t/m^4	SHEAR PARAMETER ANGLE of FRICTION
1.00	DS	0.00-0.50	COLLECTED		SANDY SILT (ML-CL)		1	41	58									
2.00	UDS	1.00-1.30	COLLECTED		SILTY SAND (SM)		1	66	33				1.71	1.56	9.85	2.66	0.00	31
	SPT	1.50-1.95	11	16			1	67	32									32
3.00												NON PLASTIC						
4.00	SPT	3.00-3.45	9	11			1	66	33									30
5.00	UDS	4.00-4.30	COLLECTED				1	72	27				1.73	1.57	10.14	2.66	0.00	30
	SPT	4.50-4.95	11	12			1	75	24									30
6.00																		
7.00	SPT	6.00-6.45	13	13			1	88	11									31
8.00	UDS	7.00-7.30	COLLECTED				2	90	8				1.74	1.58	10.22	2.66	0.00	31
	SPT	7.50-7.95	24	22			2	91	7									33
9.00																		
10.00	SPT	9.00-9.45	29	25			1	93	6									34
11.00	UDS	10.00-10.30	COLLECTED				1	92	7				1.80	1.63	10.74	2.66	0.00	32
	SPT	10.50-10.95	27	22			1	90	9									33
12.00																		
13.00	SPT	12.00-12.45	33	25			2	88	10									34
14.00	UDS	13.00-13.30	COLLECTED				3	90	7				1.81	1.63	11.05	2.66	0.00	31
	SPT	13.50-13.95	23	17			3	91	6									32
15.00																		
16.00	SPT	15.00-15.45	20	14			5	86	9									31
17.00	UDS	16.00-16.30	SLIPPED		FINE SAND WITH GRAVEL (SP)		-	-	-			NON PLASTIC	-	-	-	-	-	-
18.00																		
19.00	SPT	18.00-18.45	34	19			4	88	8									32
20.00	UDS	19.00-19.30	SLIPPED				-	-	-				-	-	-	-	-	-
21.00																		
22.00	SPT	21.00-21.45	43	21			2	91	7									33
23.00	UDS	22.00-22.30	SLIPPED				-	-	-				-	-	-	-	-	-
24.00																		
25.00	SPT	24.00-24.45	48	23			2	88	10									34
26.00	UDS	25.00-25.30	SLIPPED				-	-	-				-	-	-	-	-	-
27.00																		
28.00	SPT	27.00-27.45	29	16			1	92	7									32
29.00	UDS	28.00-28.30	COLLECTED		SILTY SAND WITH GRAVEL (SM)		2	56	42	24	20	4	1.82	1.62	12.06	2.66	0.00	32
30.00	SPT	29.55-30.00	47	21			2	55	43									33

Computation of Liquefaction Potential at Different Depth by Idriss and Seed Method	Table No.- 6

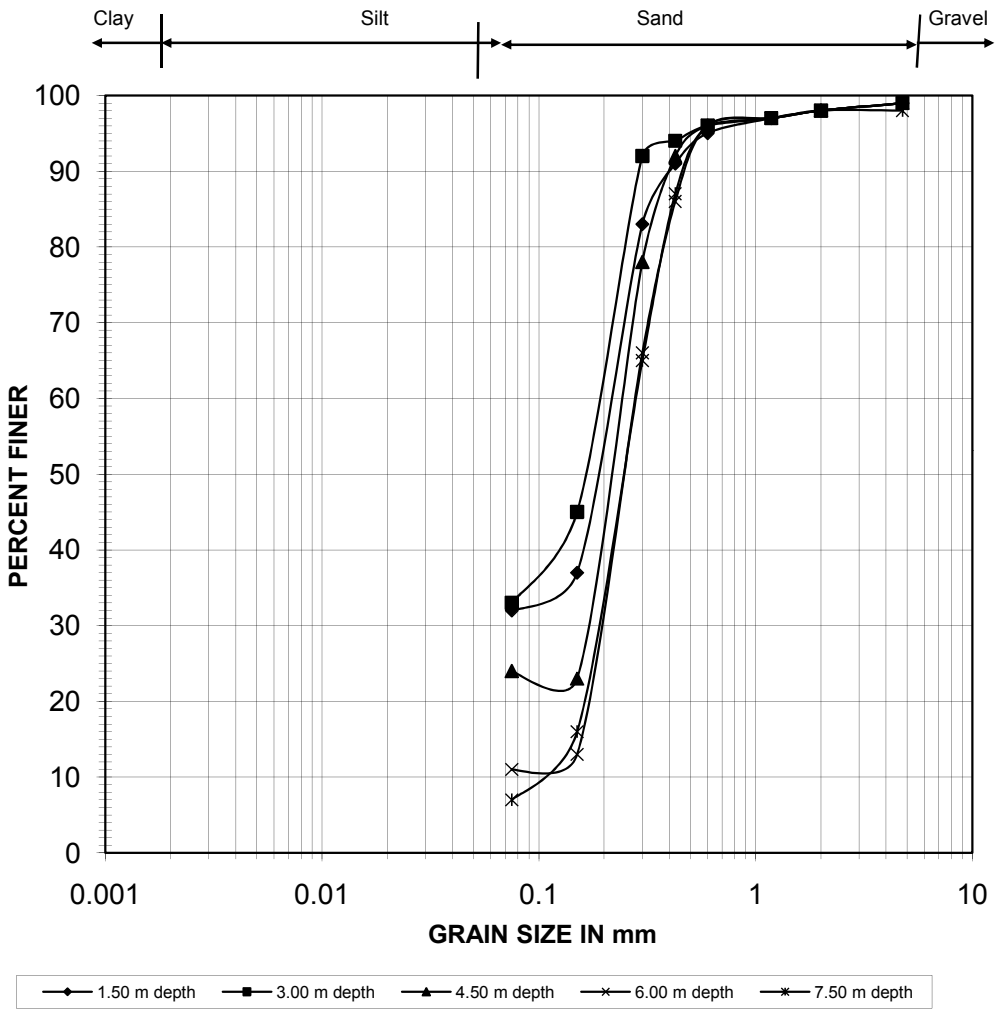
Borehole No.	2
Borehole dia.	150 mm
Water Table (in m below EGL)	15.00

Water Table (in m below EGL)	0.00

COMPUTATION DEPTH (h)	SAT. DENSITY (t/cum)	FINE CONTENT (%)	STRESS RED. RATIO (r_d)	Total overburden (σo)	Eff. overburden (σ_o)' for CSR (WT = 0)	Cyclic Stress ratio (CSR)	SPT Value (N)	Bulk Density	Eff. overburden (σ_o)' for CN (WT = Actual)	C_N	C_E	C_B	C_R	C_S	SPT Corrected $(N1)_{60}$	α	β	$(N1)_{60cs}$	$CRR_{M=7.5}$	CRR	FS_L	REMARK
1.5	1.97	32	0.989	2.96	1.46	0.235	11	1.71	2.57	1.974	1.0	1.15	0.75	1.00	18.7	4.83	1.17	26.8	0.33	0.498	2.12	NL
3.0	1.98	33	0.977	5.93	2.93	0.231	9	1.71	5.13	1.396	1.0	1.15	0.80	1.00	11.6	4.88	1.18	18.5	0.20	0.297	1.28	NL
4.5	1.98	24	0.966	8.90	4.40	0.229	11	1.73	7.73	1.138	1.0	1.15	0.85	1.00	12.2	4.18	1.11	17.7	0.19	0.283	1.24	NL
6.0	1.98	11	0.954	11.87	5.87	0.226	13	1.73	10.32	0.984	1.0	1.15	0.95	1.00	14.0	1.21	1.03	15.6	0.17	0.249	1.10	NL
7.5	1.99	7	0.943	14.85	7.35	0.223	24	1.74	12.93	0.879	1.0	1.05	0.95	1.00	21.1	0.12	1.01	21.4	0.23	0.349	1.57	NL
9.0	1.99	6	0.931	17.82	8.82	0.220	29	1.74	15.54	0.802	1.0	1.05	0.95	1.00	23.2	0.03	1.00	23.3	0.26	0.394	1.79	NL
10.5	2.01	9	0.894	20.85	10.35	0.211	27	1.80	18.24	0.740	1.0	1.05	1.00	1.00	21.0	0.56	1.02	21.9	0.24	0.361	1.71	NL
12.0	2.01	10	0.854	23.87	11.87	0.201	33	1.80	20.94	0.691	1.0	1.05	1.00	1.00	23.9	0.87	1.02	25.3	0.30	0.448	2.23	NL
13.5	2.02	6	0.814	26.89	13.39	0.191	23	1.81	23.66	0.650	1.0	1.05	1.00	1.00	15.7	0.03	1.00	15.8	0.17	0.252	1.32	NL
15.0	2.02	9	0.774	29.92	14.92	0.181	20	2.02	25.18	0.630	1.0	1.05	1.00	1.00	13.2	0.56	1.02	14.0	0.15	0.225	1.24	NL
18.0	2.02	8	0.693	35.97	17.97	0.162	34	2.02	28.23	0.595	1.0	1.05	1.00	1.00	21.2	0.30	1.01	21.8	0.24	0.359	2.21	NL
21.0	2.02	7	0.613	42.02	21.02	0.143	43	2.02	31.28	0.565	1.0	1.05	1.00	1.00	25.5	0.12	1.01	25.9	0.31	0.465	3.24	NL
24.0	2.02	10	0.552	48.07	24.07	0.129	48	2.02	34.34	0.540	1.0	1.05	1.00	1.00	27.2	0.87	1.02	28.7	0.39	0.592	4.59	NL
27.0	2.02	7	0.528	54.12	27.12	0.123	29	2.02	37.39	0.517	1.0	1.05	1.00	1.00	15.7	0.12	1.01	16.0	0.17	0.255	2.07	NL
30.0	2.01	43	0.504	60.16	30.16	0.118	47	2.01	40.43	0.497	1.0	1.05	1.00	1.00	24.5	5.00	1.20	34.5	NA	NA	>1	NL

L=Liquefiable	NL=Non-Liquefiable

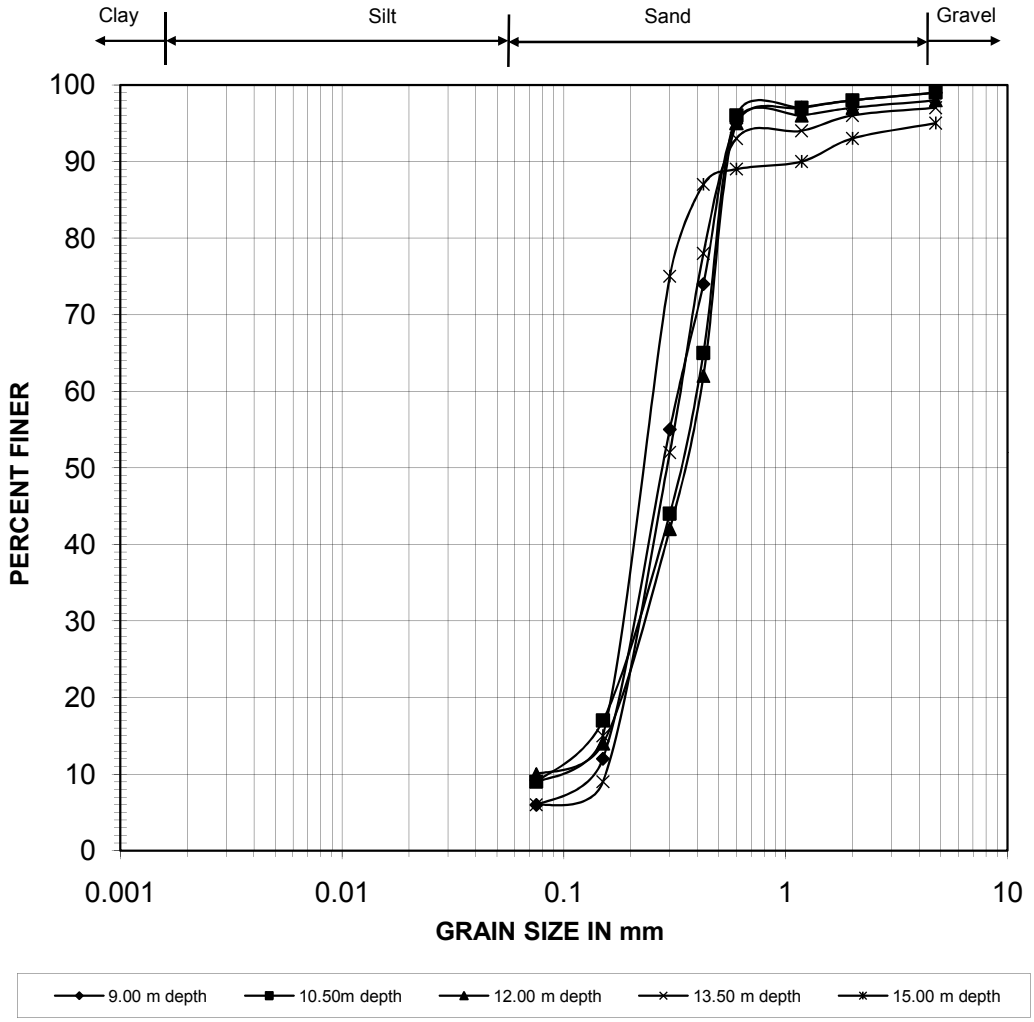
PARTICLE SIZE DISTRIBUTION CURVE for BH-2



Depth	Gravel (%)	Sand (%)	Silt + Clay (%)
1.50 m depth	1	67	32
3.00 m depth	1	66	33
4.50 m depth	1	75	24
6.00 m depth	1	88	11
7.50 m depth	2	91	7

Fig. - 6

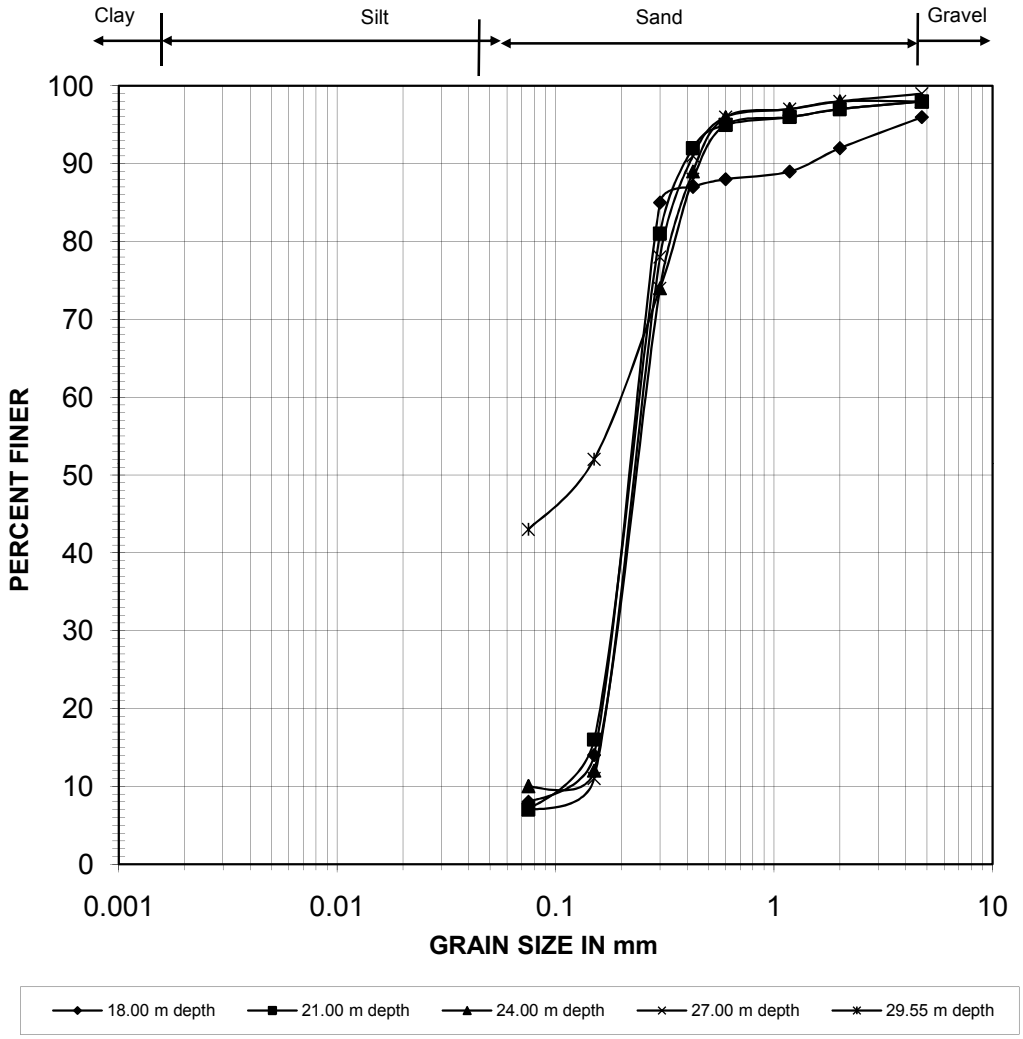
PARTICLE SIZE DISTRIBUTION CURVE for BH-2



Depth	Gravel (%)	Sand (%)	Silt + Clay (%)
9.00 m depth	1	93	6
10.50m depth	1	90	9
12.00 m depth	2	88	10
13.50 m depth	3	91	6
15.00 m depth	5	86	9

Fig. - 7

PARTICLE SIZE DISTRIBUTION CURVE for BH-2



Depth	Gravel (%)	Sand (%)	Silt + Clay (%)
18.00 m depth	4	88	8
21.00 m depth	2	91	7
24.00 m depth	2	88	10
27.00 m depth	1	92	7
29.55 m depth	2	55	43

Fig. - 8

VARIATION OF SPT 'N' WITH DEPTH for B.H.No.- 2

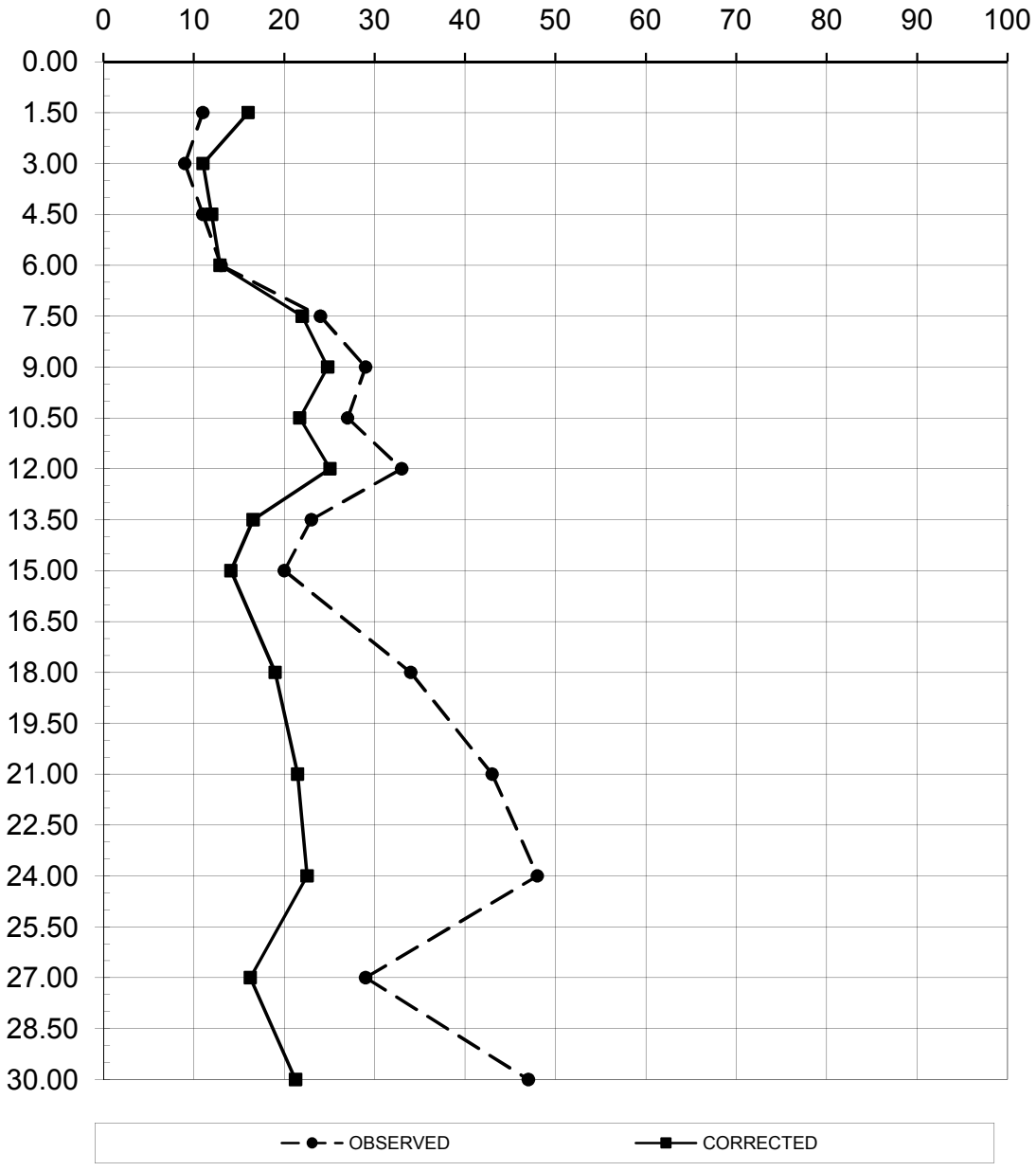


Fig. - 9

Details of BH- 3

FIELD BORELOG

Table No.- 7

METHOD OF BORING	: Shell & Auger Method	BORE HOLE NO.	: 3
CASING TYPE & DEPTH	: SX-6.40m	LOCATION	: As per attached location plan
WATER TABLE	: 15.0m	DATE START	: 07-03-2013
DEPTH OF BORING	: 40 m b.g.l	DATE COMPLETION	: 10-03-2013

DEPTH(m)	DISCRIPTION OF SOIL STRATA	SOIL CLASS.	LEGEND	STRATA THICK. (m)	SAMPLES DETAILS			SPT BLOWS COUNTS				REMARKS
					TYPE	NO.	TEST DEPTH (m)	15	30	45	"N"	
1.0	SANDY SILT	ML-CL		1.00	DS	1	0.00-0.50	COLLECTED				
2.0	SILTY SAND	SM		3.00	UDS	1	1.00-1.30	COLLECTED				
					SPT	1	1.50-1.95	3	3	3	6	
3.0												
4.0					SPT	2	3.00-3.45	3	4	4	8	
5.0	FINE SAND WITH GRAVEL	SP		24.00	UDS	2	4.00-4.30	COLLECTED				
					SPT	3	4.50-4.95	5	6	7	13	
6.0												
7.0					SPT	4	6.00-6.45	4	7	10	17	
8.0					UDS	3	7.00-7.30	COLLECTED				
					SPT	5	7.50-7.95	5	8	12	20	
9.0												
10.0					SPT	6	9.00-9.45	4	7	11	18	
11.0					UDS	4	10.00-10.30	COLLECTED				
					SPT	7	10.50-10.95	7	8	10	18	
12.0												
13.0					SPT	8	12.00-12.45	18	27	36	63	
14.0					UDS	5	13.00-13.30	COLLECTED				
					SPT	9	13.50-13.95	6	8	11	19	
15.0												
16.0					SPT	10	15.00-15.45	9	12	15	27	
17.0					UDS	6	16.00-16.30	SLIPPED				
18.0												
19.0					SPT	11	18.00-18.45	8	16	26	42	
20.0					UDS	7	19.00-19.30	SLIPPED				
21.0												
22.0					SPT	12	21.00-21.45	10	19	31	50	
23.0					UDS	8	22.00-22.30	SLIPPED				
24.0												
25.0					SPT	13	24.00-24.45	13	17	28	45	
26.0					UDS	9	25.00-25.30	SLIPPED				
27.0												
28.0					SPT	14	27.00-27.45	12	21	29	50	
29.0	SANDY SILT WITH GRAVEL	ML-CL		4.00	UDS	10	28.00-28.30	COLLECTED				
30.0												
31.0					SPT	15	30.00-30.45	14	23	25	48	
32.0					UDS	11	31.00-31.30	COLLECTED				
33.0	FINE SAND WITH GRAVEL	SP		2.00								
34.0					SPT	16	33.00-33.45	16	34	38	72	
35.0	SANDY SILT WITH GRAVEL	ML-CL		6.00	UDS	12	34.00-34.30	COLLECTED				
36.0												
37.0					SPT	17	36.00-36.45	15	26	28	54	
38.0					UDS	12	37.00-37.30	COLLECTED				
39.0												
40.0					SPT	19	39.55-40.00	17	28	35	63	

LABORATORY TEST RESULTS OF BH-3

Table No.-8

DEPTH BELOW GL	TYPE / SAMPLE NO.	DEPTH OF SAMPLE	SPT VALUE 'N' OBSERVED	SPT VALUE 'N' CORRECTED	DESCRIPTION OF STRATA	LEGEND	GRAIN SIZE ANALYSIS GRAVEL (%)	GRAIN SIZE ANALYSIS SAND (%)	GRAIN SIZE ANALYSIS SILT + CLAY (%)	ATTERBERG LIMIT LIQUID LIMIT (%)	ATTERBERG LIMIT PLASTIC LIMIT (%)	ATTERBERG LIMIT PLASTICITY INDEX	BULK DENSITY in t/m^3	DRY DENSITY in t/m3	MOISTURE CONTENT (%)	SPECIFIC GRAVITY	SHEAR PARAMETER COHESION 'C' in t/m^4	SHEAR PARAMETER ANGLE of FRICTION (Φ)
1.00	DS	0.00-0.50	COLLECTED		SANDY SILT (ML-CL)		1	42	57									
2.00	UDS	1.00-1.30	COLLECTED		SILTY SAND (SM)		1	78	21				1.71	1.57	9.22	2.66	0.00	30
	SPT	1.50-1.95	6	9			1	77	22									30
3.00										NON PLASTIC								
4.00	SPT	3.00-3.45	8	10			1	81	18									30
5.00	UDS	4.00-4.30	COLLECTED				3	89	8				1.73	1.57	10.04	2.65	0.00	30
	SPT	4.50-4.95	13	14			3	87	10									31
6.00																		
7.00	SPT	6.00-6.45	17	17			2	91	7									32
8.00	UDS	7.00-7.30	COLLECTED				2	89	9				1.76	1.60	10.25	2.65	0.00	31
	SPT	7.50-7.95	20	18			3	90	7									32
9.00																		
10.00	SPT	9.00-9.45	18	15			2	93	5									32
11.00	UDS	10.00-10.30	COLLECTED				2	91	7				1.79	1.62	10.36	2.65	0.00	31
	SPT	10.50-10.95	18	14			3	89	8									31
12.00																		
13.00	SPT	12.00-12.45	63	48			2	92	6									34
14.00	UDS	13.00-13.30	COLLECTED				4	88	8				1.80	1.62	11.29	2.65	0.00	31
	SPT	13.50-13.95	19	14			4	92	4									31
15.00																		
16.00	SPT	15.00-15.45	27	17	FINE SAND WITH GRAVEL (SP)		3	94	3									32
17.00	UDS	16.00-16.30	SLIPPED				-	-	-	NON PLASTIC			-	-	-	-	-	-
18.00																		
19.00	SPT	18.00-18.45	42	22			4	90	6									33
20.00	UDS	19.00-19.30	SLIPPED				-	-	-				-	-	-	-	-	-
21.00																		
22.00	SPT	21.00-21.45	50	24			3	88	9									34
23.00	UDS	22.00-22.30	SLIPPED				-	-	-				-	-	-	-	-	-
24.00																		
25.00	SPT	24.00-24.45	45	22			4	89	7									33
26.00	UDS	25.00-25.30	SLIPPED				-	-	-				-	-	-	-	-	-
27.00																		
28.00	SPT	27.00-27.45	50	23			4	88	8									34
29.0	UDS	28.00-28.30	COLLECTED				4	37	59	26	20	6	1.81	1.62	11.44	2.67	0.28	30
30.0					SANDY SILT WITH GRAVEL (ML-CL)													
31.00	SPT	30.00-30.45	48	21			3	35	62									
32.00	UDS	31.00-31.30	COLLECTED				2	40	58	26	20	6	1.82	1.62	12.14	2.67	0.30	30
33.00					FINE SAND WITH GRAVEL (SP)					NON-PLASTIC								
34.00	SPT	33.00-33.45	72	28			4	88	8									34
35.00	UDS	34.00-34.30	COLLECTED				3	40	57	26	20	6	1.83	1.63	12.29	2.67	0.30	30
36.00																		
37.00	SPT	36.00-36.45	54	22	SANDY SILT WITH GRAVEL (ML-CL)		4	38	58									
38.00	UDS	37.00-37.30	COLLECTED				4	37	59	26	20	6	1.84	1.64	12.33	2.67	0.31	30
39.00																		
40.00	SPT	39.55-40.00	63	24			3	36	61									

Computation of Liquefaction Potential at Different Depth by Idriss and Seed Method | **Table No.- 9**

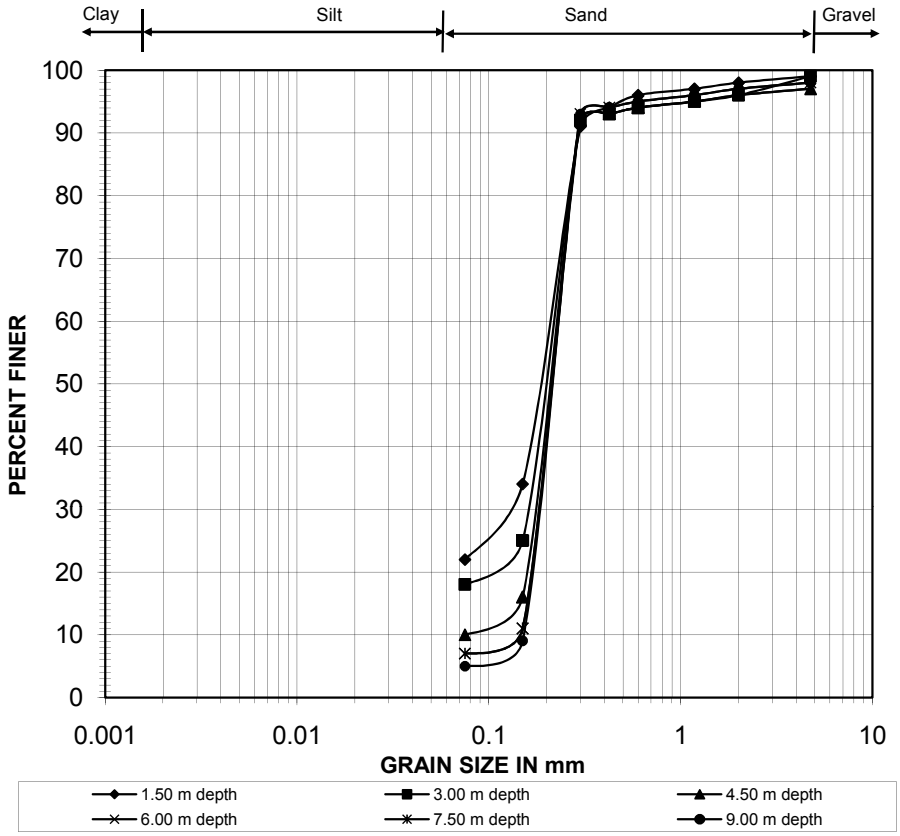
Borehole No.	3
Borehole dia.	150 mm
Water Table (in m below EGL)	15.00

Water Table (in m below EGL)	0.00

COMPUTATION DEPTH (h)	SAT. DENSITY (t/cum)	FINE CONTENT (%)	STRESS RED. RATIO (r_d)	Total overburden (σo)	Eff. overburden (σ_o)' for CSR (WT = 0)	Cyclic Stress ratio (CSR)	SPT Value (N)	Bulk Density	Eff. overburden (σ_o)' for CN (WT = Actual)	C_N	C_E	C_B	C_R	C_S	SPT Corrected $(N1)_{60}$	α	β	$(N1)_{60cs}$	$CRR_{M=7.5}$	CRR	FS_L	REMARK
1.5	1.98	22	0.989	2.97	1.47	0.234	6	1.71	2.57	1.974	1.0	1.15	0.75	1.00	10.2	3.93	1.09	15.1	0.16	0.242	1.03	NL
3.0	1.98	18	0.977	5.93	2.93	0.231	8	1.71	5.13	1.396	1.0	1.15	0.80	1.00	10.3	3.23	1.07	14.2	0.15	0.228	0.99	L
4.5	1.98	10	0.966	8.90	4.40	0.229	13	1.73	7.73	1.138	1.0	1.15	0.85	1.00	14.5	0.87	1.02	15.6	0.17	0.250	1.09	NL
6.0	1.98	7	0.954	11.87	5.87	0.226	17	1.73	10.32	0.984	1.0	1.15	0.95	1.00	18.3	0.12	1.01	18.6	0.20	0.297	1.32	NL
7.5	1.99	7	0.943	14.86	7.36	0.223	20	1.76	12.96	0.878	1.0	1.05	1.00	1.00	18.4	0.12	1.01	18.7	0.20	0.300	1.35	NL
9.0	1.99	5	0.931	17.85	8.85	0.220	18	1.76	15.60	0.801	1.0	1.05	1.00	1.00	15.1	0.00	1.00	15.1	0.16	0.242	1.10	NL
10.5	2.01	8	0.894	20.86	10.36	0.210	18	1.79	18.29	0.740	1.0	1.05	1.00	1.00	14.0	0.30	1.01	14.5	0.15	0.232	1.10	NL
12.0	2.01	6	0.854	23.88	11.88	0.201	63	1.79	20.97	0.691	1.0	1.05	1.00	1.00	45.7	0.03	1.00	45.9	NA	NA	>1	NL
13.5	2.01	4	0.814	26.89	13.39	0.191	19	1.80	23.67	0.650	1.0	1.05	1.00	1.00	13.0	0.00	1.00	13.0	0.14	0.210	1.10	NL
15.0	2.01	3	0.774	29.90	14.90	0.182	27	2.01	25.18	0.630	1.0	1.05	1.00	1.00	17.9	0.00	1.00	17.9	0.19	0.285	1.57	NL
18.0	2.01	6	0.693	35.92	17.92	0.163	42	2.01	28.20	0.595	1.0	1.05	1.00	1.00	26.3	0.03	1.00	26.4	0.32	0.484	2.98	NL
21.0	2.01	9	0.613	41.94	20.94	0.144	50	2.01	31.22	0.566	1.0	1.05	1.00	1.00	29.7	0.56	1.02	30.8	NA	NA	>1	NL
24.0	2.01	7	0.552	47.96	23.96	0.129	45	2.01	34.24	0.540	1.0	1.05	1.00	1.00	25.5	0.12	1.01	25.9	0.31	0.465	3.60	NL
27.0	2.01	8	0.528	53.99	26.99	0.124	50	2.01	37.27	0.518	1.0	1.05	1.00	1.00	27.2	0.30	1.01	27.8	0.36	0.546	4.42	NL
30.0	2.02	62	0.504	60.03	30.03	0.118	48	2.02	40.31	0.498	1.0	1.05	1.00	1.00	25.1	5.00	1.20	35.1	NA	NA	>1	NL
33.0	2.02	8	0.500	66.08	33.08	0.117	72	2.02	43.36	0.480	1.0	1.05	1.00	1.00	36.3	0.30	1.01	37.1	NA	NA	>1	NL
36.0	2.02	58	0.500	72.14	36.14	0.117	54	2.02	46.42	0.464	1.0	1.05	1.00	1.00	26.3	5.00	1.20	36.6	NA	NA	>1	NL
39.6	2.02	61	0.500	79.32	39.77	0.117	63	2.02	50.05	0.447	1.0	1.05	1.00	1.00	29.6	5.00	1.20	40.5	NA	NA	>1	NL

L=Liquefiable	NL=Non-Liquefiable

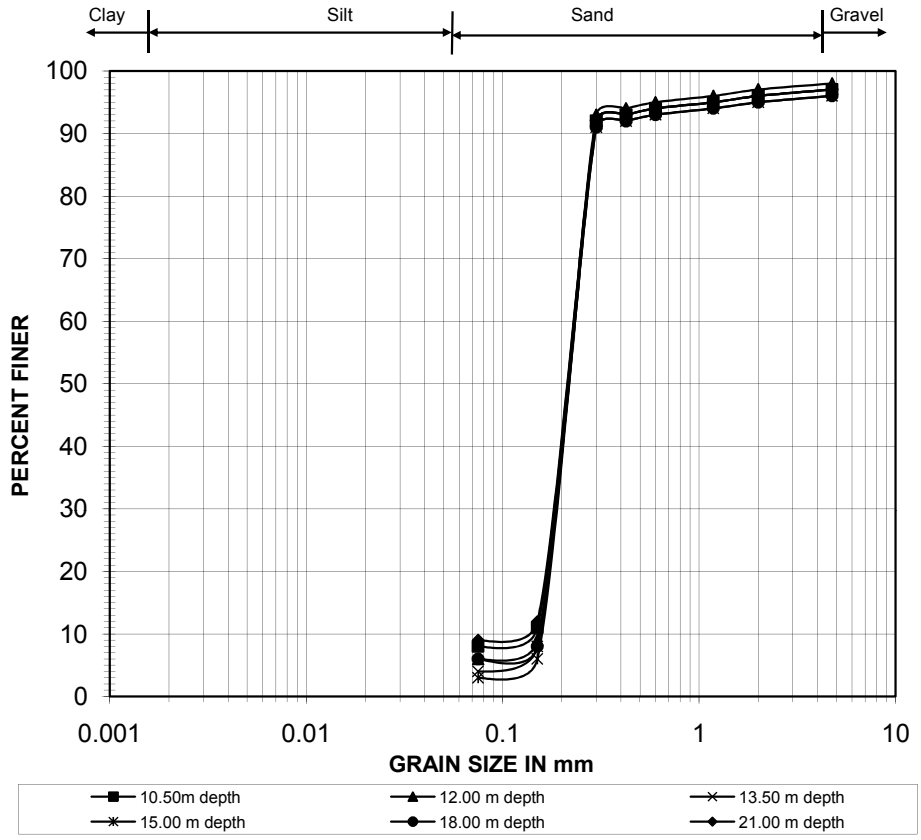
PARTICLE SIZE DISTRIBUTION CURVE for BH-3



Depth	Gravel (%)	Sand (%)	Silt + Clay (%)
1.50 m depth	1	77	22
3.00 m depth	1	81	18
4.50 m depth	3	87	10
6.00 m depth	2	91	7
7.50 m depth	3	90	7
9.00 m depth	2	93	5

Fig. - 10

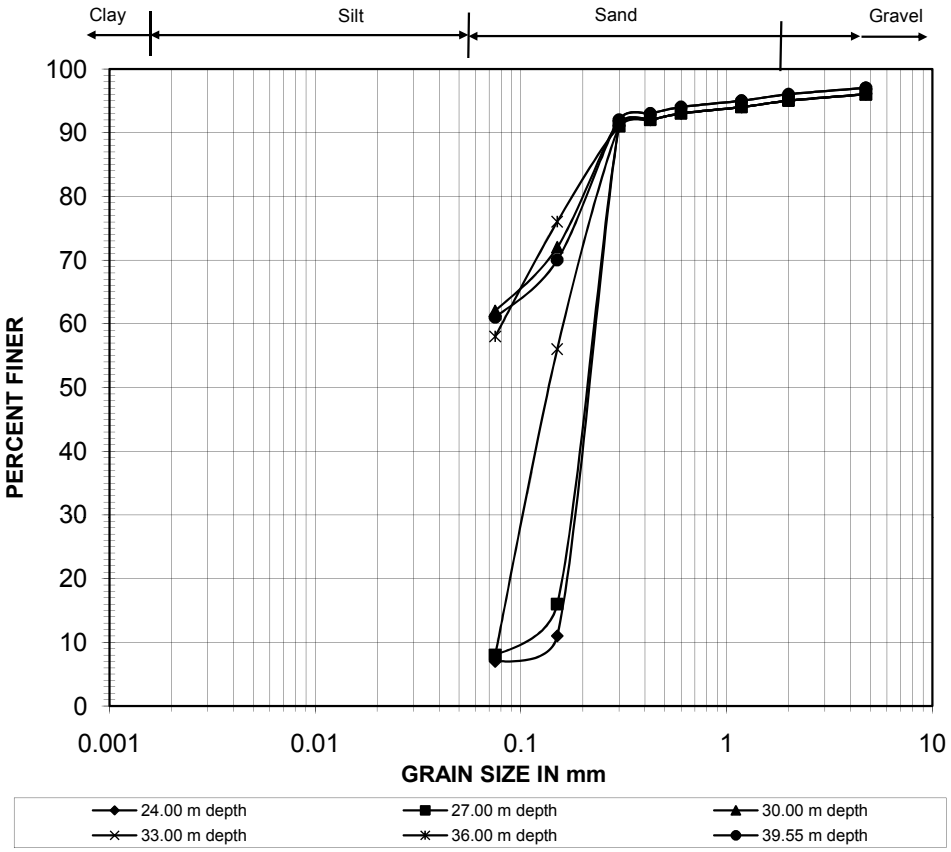
PARTICLE SIZE DISTRIBUTION CURVE for BH-3



Depth	Gravel (%)	Sand (%)	Silt + Clay (%)
10.50m depth	3	89	8
12.00 m depth	2	92	6
13.50 m depth	4	92	4
15.00 m depth	3	94	3
18.00 m depth	4	90	6
21.00 m depth	3	88	9

Fig. - 11

PARTICLE SIZE DISTRIBUTION CURVE for BH-3



Depth	Gravel (%)	Sand (%)	Silt + Clay (%)
24.00 m depth	4	89	7
27.00 m depth	4	88	8
30.00 m depth	3	35	62
33.00 m depth	4	88	8
36.00 m depth	4	38	58
39.55 m depth	3	36	61

Fig. - 12

VARIATION OF SPT 'N' WITH DEPTH for B.H.No.- 3

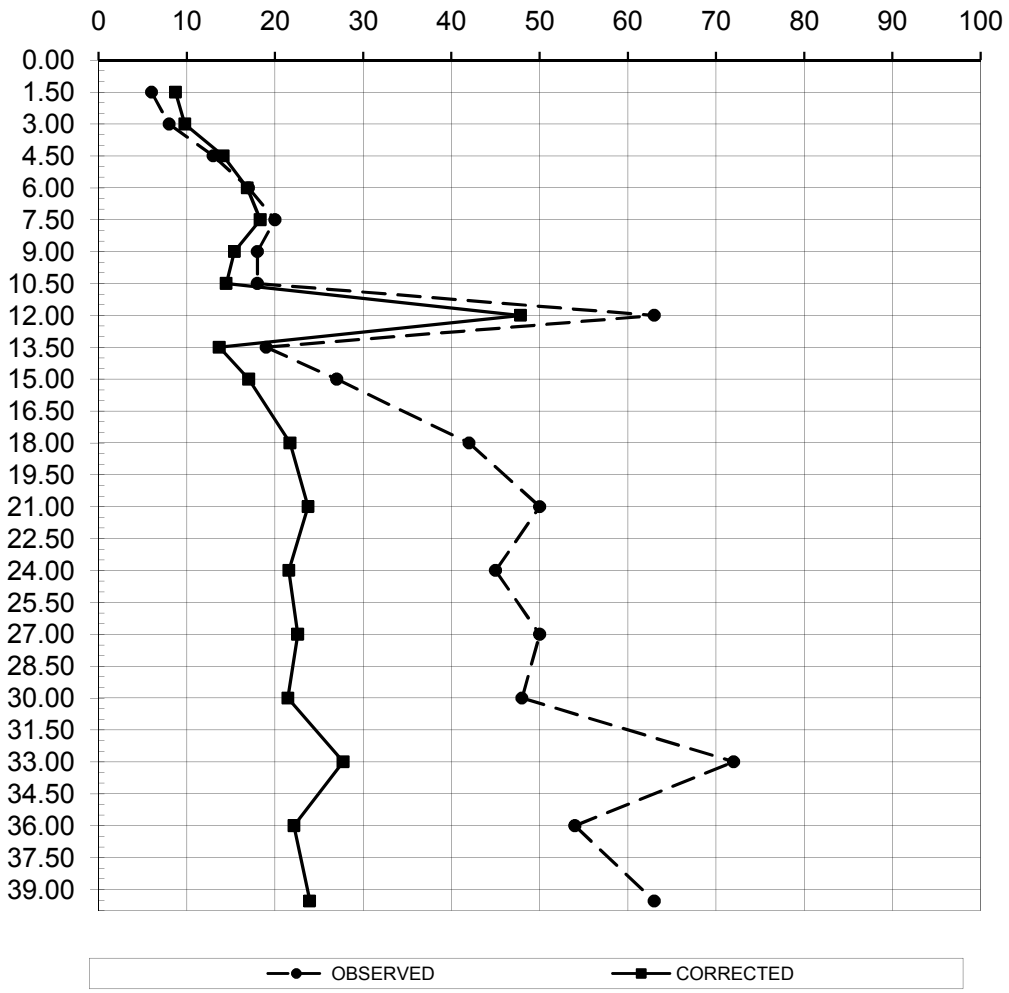


Fig. - 13

Details of BH- 4

FIELD BORELOG — Table No.- 10

METHOD OF BORING	: Shell & Auger Method	BORE HOLE NO.	: 4
CASING TYPE & DEPTH	: SX-6,30m	LOCATION	: As per attached location plan
WATER TABLE	: 15.0m	DATE START	: 04-03-2013
DEPTH OF BORING	: 30 m b.g.l	DATE COMPLETION	: 06-03-2013

DEPTH(m)	DISCRIPTION OF SOIL STRATA	SOIL CLASS.	LEGEND	STRATA THICK. (m)	SAMPLES DETAILS			SPT BLOWS COUNTS				REMARKS
					TYPE	NO.	TEST DEPTH (m)	15	30	45	"N"	
1.0	SILTY SAND	SM		4.00	DS	1	0.00-0.50	COLLECTED				
2.0					UDS	1	1.00-1.30	COLLECTED				
					SPT	1	1.50-1.95	3	4	4	8	
3.0												
4.0					SPT	2	3.00-3.45	2	3	4	7	
5.0	FINE SAND WITH GRAVEL	SP		22.00	UDS	2	4.00-4.30	COLLECTED				
					SPT	3	4.50-4.95	5	7	9	16	
6.0												
7.0					SPT	4	6.00-6.45	9	14	16	30	
8.0					UDS	3	7.00-7.30	COLLECTED				
					SPT	5	7.50-7.95	8	20	21	41	
9.0												
10.0					SPT	6	9.00-9.45	7	12	15	27	
11.0					UDS	4	10.00-10.30	COLLECTED				
					SPT	7	10.50-10.95	9	16	23	39	
12.0												
13.0					SPT	8	12.00-12.45	12	29	34	63	
14.0					UDS	5	13.00-13.30	COLLECTED				
					SPT	9	13.50-13.95	10	16	20	36	
15.0												
16.0					SPT	10	15.00-15.45	7	18	24	42	
17.0					UDS	6	16.00-16.30	SLIPPED				
18.0												
19.0					SPT	11	18.00-18.45	13	19	27	46	
20.0					UDS	7	19.00-19.30	SLIPPED				
21.0												
22.0					SPT	12	21.00-21.45	15	26	31	57	
23.0					UDS	8	22.00-22.30	SLIPPED				
24.0												
25.0					SPT	13	24.00-24.45	11	22	34	56	
26.0					UDS	9	25.00-25.30	SLIPPED				
27.0	SANDY SILT WITH GRAVEL	ML-CL		4.00								
28.0					SPT	14	27.00-27.45	7	12	15	27	
29.0					UDS	10	28.00-28.30	COLLECTED				
30.0					SPT	15	29.55-30.00	10	15	21	36	

ABBREVIATION:- SPT - Standard Penetration Test UDS- Undisturbed Sample

LABORATORY TEST RESULTS OF BH-4

Table No.-11

DEPTH BELOW GL	TYPE / SAMPLE NO.	DEPTH OF SAMPLE	SPT VALUE 'N' OBSERVED	SPT VALUE 'N' CORRECTED	DESCRIPTION OF STRATA	LEGEND	GRAIN SIZE ANALYSIS GRAVEL (%)	GRAIN SIZE ANALYSIS SAND (%)	GRAIN SIZE ANALYSIS SILT + CLAY (%)	ATTERBERG LIMIT LIQUID LIMIT (%)	ATTERBERG LIMIT PLASTIC LIMIT (%)	ATTERBERG LIMIT PLASTICITY INDEX	BULK DENSITY in t/m^3	DRY DENSITY in t/m3	MOISTURE CONTENT (%)	SPECIFIC GRAVITY	SHEAR PARAMETER COHESION 'C' in t/m^4	SHEAR PARAMETER ANGLE of FRICTION
1.00	DS	0.00-0.50	COLLECTED		SILTY SAND (SM)		1	56	43									
2.00	UDS	1.00-1.30	COLLECTED				1	57	42	24	20	4	1.72	1.56	10.04	2.66	0.00	30
	SPT	1.50-1.95	8	12			1	54	45									30
3.00																		
4.00	SPT	3.00-3.45	7	9			1	56	43									30
5.00	UDS	4.00-4.30	COLLECTED		FINE SAND WITH GRAVEL (SP)		1	88	11	NON PLASTIC			1.74	1.58	10.23	2.65	0.00	30
	SPT	4.50-4.95	16	17			1	91	8									32
6.00																		
7.00	SPT	6.00-6.45	30	30			1	90	9									34
8.00	UDS	7.00-7.30	COLLECTED				2	92	6				1.79	1.62	10.56	2.65	0.00	32
	SPT	7.50-7.95	41	38			2	91	7									34
9.00																		
10.00	SPT	9.00-9.45	27	23			1	93	6									34
11.00	UDS	10.00-10.30	COLLECTED				1	92	7				1.80	1.62	11.08	2.65	0.00	32
	SPT	10.50-10.95	39	31			1	91	8									34
12.00																		
13.00	SPT	12.00-12.45	63	48			2	89	9									34
14.00	UDS	13.00-13.30	COLLECTED				3	90	7				1.81	1.63	11.22	2.65	0.00	32
	SPT	13.50-13.95	36	26			3	91	6									34
15.00																		
16.00	SPT	15.00-15.45	42	22			5	86	9									34
17.00	UDS	16.00-16.30	SLIPPED				-	-	-				-	-	-	-	-	-
18.00																		
19.00	SPT	18.00-18.45	46	23			4	90	6									34
20.00	UDS	19.00-19.30	SLIPPED				-	-	-				-	-	-	-	-	-
21.00																		
22.00	SPT	21.00-21.45	57	26			2	90	8									34
23.00	UDS	22.00-22.30	SLIPPED				-	-	-				-	-	-	-	-	-
24.00																		
25.00	SPT	24.00-24.45	56	25			2	89	9									34
26.00	UDS	25.00-25.30	SLIPPED				-	-	-				-	-	-	-	-	-
27.00					SANDY SILT WITH GRAVEL (ML-CL)													
28.00	SPT	27.00-27.45	27	16			1	43	56									
29.00	UDS	28.00-28.30	COLLECTED				2	46	52	26	20	6	1.82	1.62	12.07	2.66	0.21	30
30.00	SPT	29.55-30.00	36	18			2	46	52									

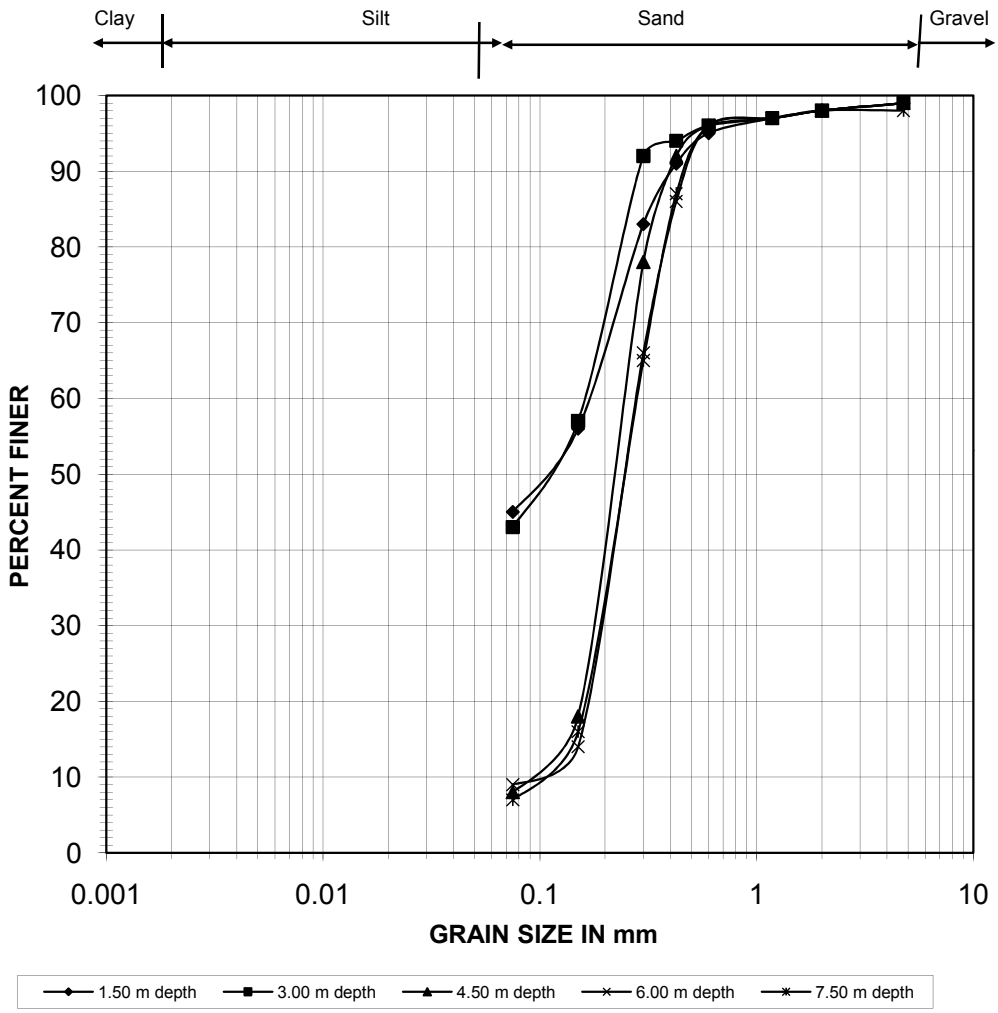
Computation of Liquefaction Potential at Different Depth by Idriss and Seed Method	Table No.- 12

Borehole No.	4
Borehole dia.	150 mm
Water Table (in m below EGL)	15.00

COMPUTATION DEPTH (h)	SAT. DENSITY (t/cum)	FINE CONTENT (%)	STRESS RED. RATIO (r_d)	Total overburden (σo)	Eff. overburden (σ_o)' for CSR (WT = 0)	Cyclic Stress ratio (CSR)	SPT Value (N)	Bulk Density	Eff. overburden (σ_o)' for CN (WT = Actual)	C_N	C_E	C_B	C_R	C_S	SPT Corrected $(N1)_{60}$	α	β	$(N1)_{60cs}$	$CRR_{M=7.5}$	CRR	FS_L	REMARK
1.5	1.98	45	0.989	2.96	1.46	0.234	8	1.72	2.58	1.969	1.0	1.15	0.75	1.00	13.6	5.00	1.20	21.3	0.23	0.348	1.49	NL
3.0	1.98	43	0.977	5.93	2.93	0.232	7	1.72	5.16	1.392	1.0	1.15	0.80	1.00	9.0	5.00	1.20	15.8	0.17	0.252	1.09	NL
4.5	1.98	8	0.966	8.90	4.40	0.228	16	1.74	7.77	1.134	1.0	1.15	0.85	1.00	17.7	0.30	1.01	18.3	0.19	0.292	1.28	NL
6.0	1.98	9	0.954	11.87	5.87	0.226	30	1.74	10.38	0.982	1.0	1.15	0.95	1.00	32.2	0.56	1.02	33.3	NA	NA	>1	NL
7.5	2.01	7	0.943	14.89	7.39	0.222	41	1.79	13.07	0.875	1.0	1.05	1.00	1.00	37.7	0.12	1.01	38.1	NA	NA	>1	NL
9.0	2.01	6	0.931	17.90	8.90	0.219	27	1.79	15.75	0.797	1.0	1.05	1.00	1.00	22.6	0.03	1.00	22.7	0.25	0.379	1.73	NL
10.5	2.01	8	0.894	20.91	10.41	0.210	39	1.80	18.45	0.736	1.0	1.05	1.00	1.00	30.1	0.30	1.01	30.8	NA	NA	>1	NL
12.0	2.01	9	0.854	23.93	11.93	0.200	63	1.80	21.15	0.688	1.0	1.05	1.00	1.00	45.5	0.56	1.02	46.8	NA	NA	>1	NL
13.5	2.01	6	0.814	26.95	13.45	0.191	36	1.81	23.87	0.647	1.0	1.05	1.00	1.00	24.5	0.03	1.00	24.6	0.28	0.427	2.24	NL
15.0	2.01	9	0.774	29.97	14.97	0.181	42	2.01	25.38	0.628	1.0	1.05	1.00	1.00	27.7	0.56	1.02	28.7	0.40	0.595	3.29	NL
18.0	2.01	6	0.693	36.01	18.01	0.162	46	2.01	28.42	0.593	1.0	1.05	1.00	1.00	28.6	0.03	1.00	28.8	0.40	0.602	3.71	NL
21.0	2.01	8	0.613	42.05	21.05	0.143	57	2.01	31.46	0.564	1.0	1.05	1.00	1.00	33.7	0.30	1.01	34.5	NA	NA	>1	NL
24.0	2.01	9	0.552	48.09	24.09	0.129	56	2.01	34.50	0.538	1.0	1.05	1.00	1.00	31.7	0.56	1.02	32.7	NA	NA	>1	NL
27.0	2.01	56	0.528	54.13	27.13	0.123	27	2.01	37.54	0.516	1.0	1.05	1.00	1.00	14.6	5.00	1.20	22.6	0.25	0.375	3.04	NL
30.0	2.01	52	0.504	60.17	30.17	0.118	36	2.01	40.58	0.496	1.0	1.05	1.00	1.00	18.8	5.00	1.20	27.5	0.35	0.530	4.51	NL

L=Liquefiable	NL=Non-Liquefiable

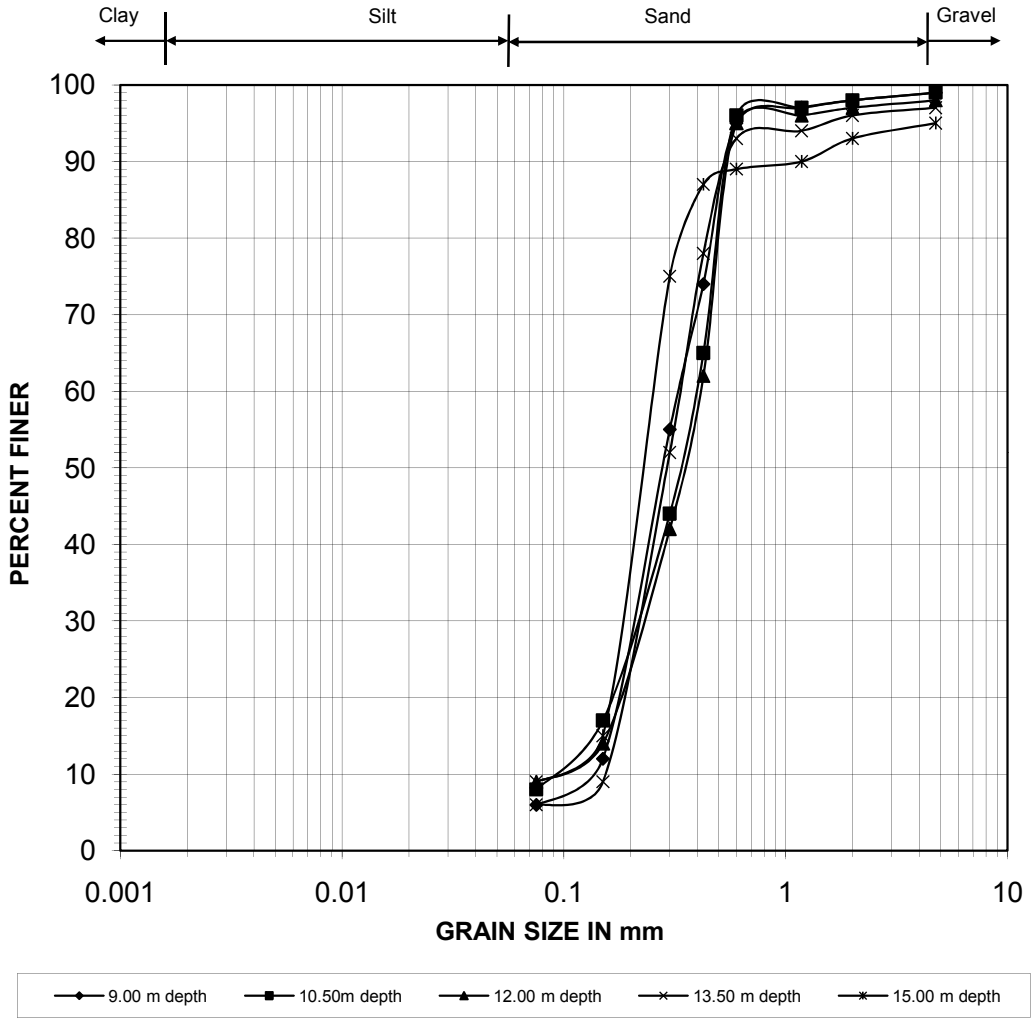
PARTICLE SIZE DISTRIBUTION CURVE for BH-4



Depth	Gravel (%)	Sand (%)	Silt + Clay (%)
1.50 m depth	1	54	45
3.00 m depth	1	56	43
4.50 m depth	1	91	8
6.00 m depth	1	90	9
7.50 m depth	2	91	7

Fig. - 14

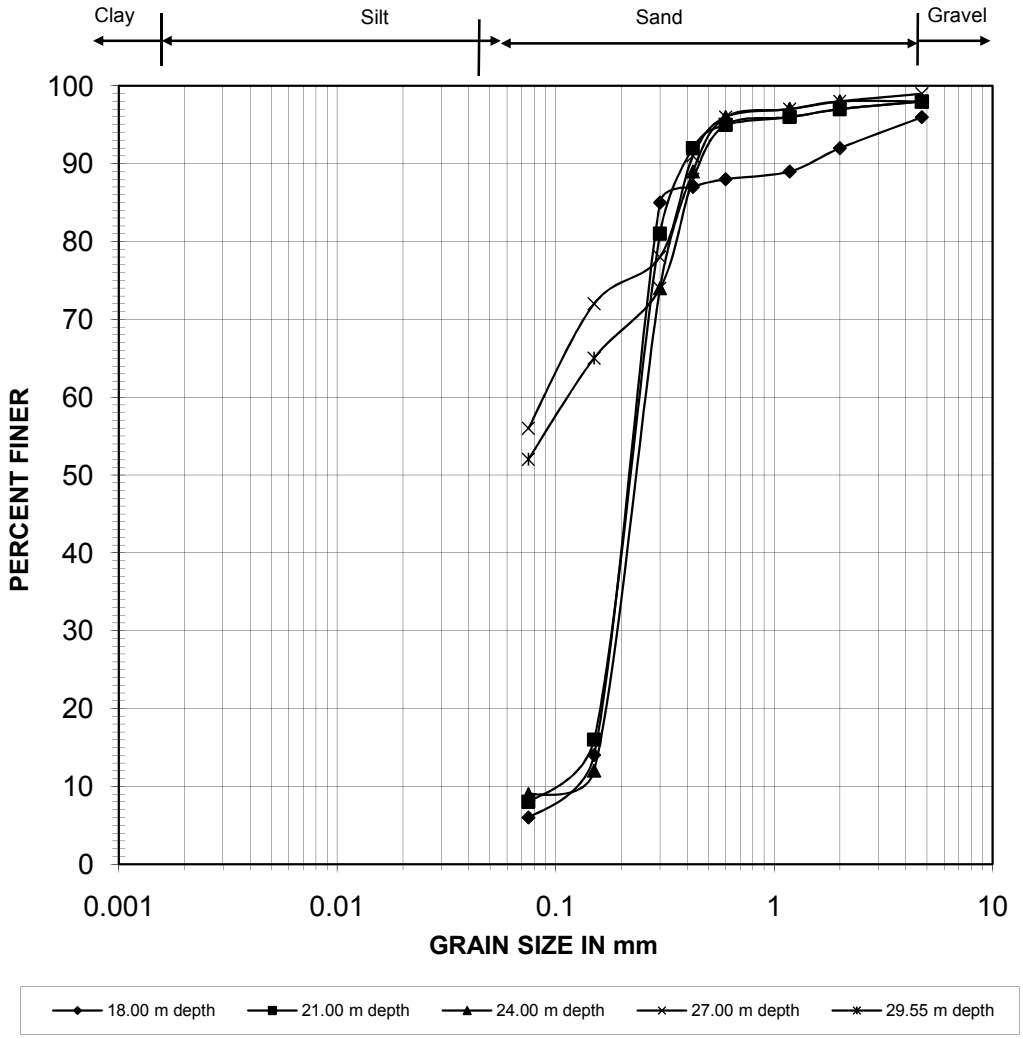
PARTICLE SIZE DISTRIBUTION CURVE for BH-4



Depth	Gravel (%)	Sand (%)	Silt + Clay (%)
9.00 m depth	1	93	6
10.50m depth	1	91	8
12.00 m depth	2	89	9
13.50 m depth	3	91	6
15.00 m depth	5	86	9

Fig. - 15

PARTICLE SIZE DISTRIBUTION CURVE for BH-4



Depth	Gravel (%)	Sand (%)	Silt + Clay (%)
18.00 m depth	4	90	6
21.00 m depth	2	90	8
24.00 m depth	2	89	9
27.00 m depth	1	43	56
29.55 m depth	2	46	52

Fig. - 16

VARIATION OF SPT 'N' WITH DEPTH for B.H.No.- 4

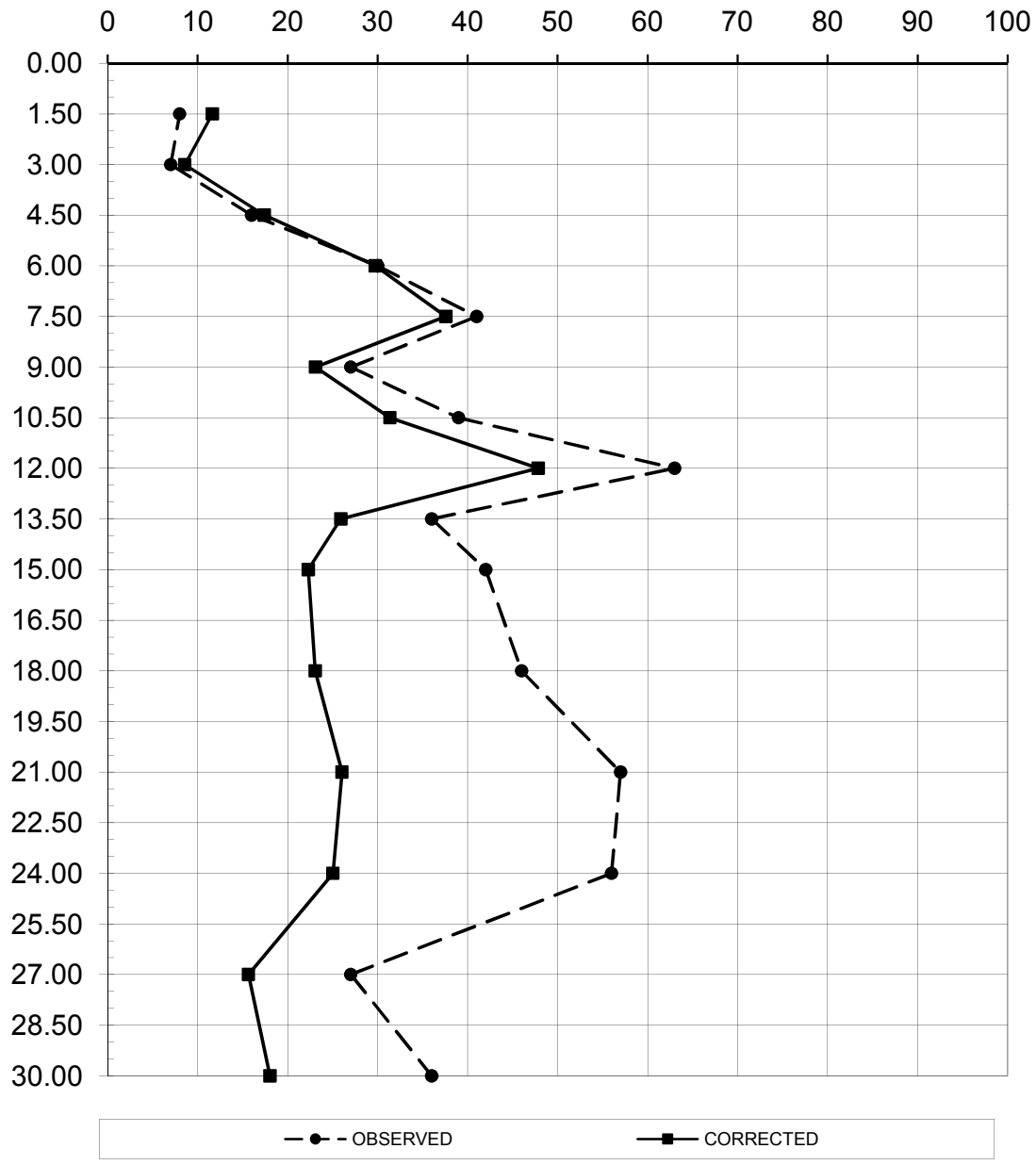


Fig. - 17

Details of BH- 5

FIELD BORELOG

Table No.- 13

METHOD OF BORING	: Shell & Auger Method	BORE HOLE NO.	: 5
CASING TYPE & DEPTH	: SX-6.40m	LOCATION	: As per attached location plan
WATER TABLE	: 15.0m	DATE START	: 28-02-2013
DEPTH OF BORING	: 40 m b.g.l	DATE COMPLETION	: 04-03-2013

DEPTH(m)	DISCRIPTION OF SOIL STRATA	SOIL CLASS.	LEGEND	STRATA THICK. (m)	SAMPLES DETAILS			SPT BLOWS COUNTS				REMARKS
					TYPE	NO.	TEST DEPTH (m)	15	30	45	"N"	
1.0	SANDY SILT	ML-CL		1.00	DS	1	0.00-0.50	COLLECTED				
2.0	SILTY SAND	SM		3.00	UDS	1	1.00-1.30	COLLECTED				
					SPT	1	1.50-1.95	3	5	6	11	
3.0												
4.0					SPT	2	3.00-3.45	3	4	4	8	
5.0	FINE SAND	SP		24.00	UDS	2	4.00-4.30	COLLECTED				
					SPT	3	4.50-4.95	3	4	6	10	
6.0												
7.0					SPT	4	6.00-6.45	4	7	10	17	
					UDS	3	7.00-7.30	COLLECTED				
8.0					SPT	5	7.50-7.95	5	8	13	21	
9.0												
10.0					SPT	6	9.00-9.45	6	11	15	26	
					UDS	4	10.00-10.30	COLLECTED				
11.0					SPT	7	10.50-10.95	7	13	17	30	
12.0												
13.0					SPT	8	12.00-12.45	8	14	22	36	
					UDS	5	13.00-13.30	COLLECTED				
14.0					SPT	9	13.50-13.95	5	7	10	17	
15.0												
16.0					SPT	10	15.00-15.45	1	19	21	40	
					UDS	6	16.00-16.30	SLIPPED				
17.0												
18.0												
19.0					SPT	11	18.00-18.45	10	14	24	38	
					UDS	7	19.00-19.30	SLIPPED				
20.0												
21.0												
22.0					SPT	12	21.00-21.45	13	24	28	52	
					UDS	8	22.00-22.30	SLIPPED				
23.0												
24.0												
25.0					SPT	13	24.00-24.45	15	21	27	48	
					UDS	9	25.00-25.30	SLIPPED				
26.0												
27.0												
28.0					SPT	14	27.00-27.45	18	27	29	56	
29.0	SILTY SAND	SM		5.00	UDS	10	28.00-28.30	SLIPPED				
30.0												
31.0					SPT	15	30.00-30.45	26	28	29	57	
					UDS	11	31.00-31.30	SLIPPED				
32.0												
33.0												
34.0	SANDY SILT	ML-CL		3.00	SPT	16	33.00-33.45	13	26	34	60	
					UDS	12	34.00-34.30	COLLECTED				
35.0												
36.0												
37.0	SILTY SAND	SM		2.00	SPT	17	36.00-36.45	15	32	38	70	
					UDS	12	37.00-37.30	SLIPPED				
38.0												
39.0	SANDY SILT	ML-CL		2.00								
40.0					SPT	19	39.55-40.00	19	39	46	85	

LABORATORY TEST RESULTS OF BH-5

Table No.-14

DEPTH BELOW GL	TYPE / SAMPLE NO.	DEPTH OF SAMPLE	SPT VALUE 'N' OBSERVED	SPT VALUE 'N' CORRECTED	DESCRIPTION OF STRATA	LEGEND	GRAIN SIZE ANALYSIS GRAVEL (%)	GRAIN SIZE ANALYSIS SAND (%)	GRAIN SIZE ANALYSIS SILT + CLAY (%)	ATTERBERG LIMIT LIQUID LIMIT (%)	ATTERBERG LIMIT PLASTIC LIMIT (%)	ATTERBERG LIMIT PLASTICITY INDEX	BULK DENSITY in t/m^3	DRY DENSITY in t/m3	MOISTURE CONTENT (%)	SPECIFIC GRAVITY	SHEAR PARAMETER COHESION 'C' in t/m^4	SHEAR PARAMETER ANGLE of FRICTION (Φ)
1.00	DS	0.00-0.50	COLLECTED		SANDY SILT (ML-CL)		1	41	58									
2.00	UDS	1.00-1.30	COLLECTED		SILTY SAND (SM)		1	81	18				1.70	1.55	9.36	2.66	0.00	31
	SPT	1.50-1.95	11	16			1	82	17									32
3.00										NON PLASTIC								
4.00	SPT	3.00-3.45	8	10			1	80	19									30
5.00	UDS	4.00-4.30	COLLECTED				1	90	9				1.71	1.55	10.29	2.65	0.00	30
	SPT	4.50-4.95	10	11			1	88	11									30
6.00																		
7.00	SPT	6.00-6.45	17	17			1	90	9									32
8.00	UDS	7.00-7.30	COLLECTED				1	91	8				1.73	1.57	10.47	2.65	0.00	31
	SPT	7.50-7.95	21	19			1	93	6									33
9.00																		
10.00	SPT	9.00-9.45	26	22			1	95	4									34
11.00	UDS	10.00-10.30	COLLECTED				1	93	6				1.76	1.58	11.54	2.65	0.00	33
	SPT	10.50-10.95	30	24			1	90	9									34
12.00																		
13.00	SPT	12.00-12.45	36	27			1	95	4									34
14.00	UDS	13.00-13.30	COLLECTED				1	92	7				1.79	1.60	11.80	2.65	0.00	31
	SPT	13.50-13.95	17	12			1	92	7									31
15.00																		
16.00	SPT	15.00-15.45	40	22			1	91	8									33
17.00	UDS	16.00-16.30	SLIPPED		FINE SAND (SP)		-	-	-	NON PLASTIC			-	-	-	-	-	-
18.00																		
19.00	SPT	18.00-18.45	38	20			1	93	6									33
20.00	UDS	19.00-19.30	SLIPPED				-	-	-				-	-	-	-	-	-
21.00																		
22.00	SPT	21.00-21.45	52	24			1	91	8									34
23.00	UDS	22.00-22.30	SLIPPED				-	-	-				-	-	-	-	-	-
24.00																		
25.00	SPT	24.00-24.45	48	23			1	92	7									34
26.00	UDS	25.00-25.30	SLIPPED				-	-	-				-	-	-	-	-	-
27.00																		
28.00	SPT	27.00-27.45	56	24			1	91	8									34
29.0	UDS	28.00-28.30	SLIPPED				-	-	-				-	-	-	-	-	-
30.0																		
31.00	SPT	30.00-30.45	57	24	SILTY SAND (SM)		1	75	24	NON PLASTIC								34
32.00	UDS	31.00-31.30	SLIPPED				-	-	-				-	-	-	-	-	-
33.00																		
34.00	SPT	33.00-33.45	60	24			1	45	54									
35.00	UDS	34.00-34.30	COLLECTED		SANDY SILT (ML-CL)		1	44	55	26	20	6	1.81	1.60	12.91	2.66	0.25	30
36.00																		
37.00	SPT	36.00-36.45	70	27	SILTY SAND (SM)		1	74	25	NON PLASTIC								34
38.00	UDS	37.00-37.30	SLIPPED				-	-	-				-	-	-	-	-	-
39.00					SANDY SILT (ML-CL)													
40.00	SPT	39.55-40.00	85	30			1	46	53									

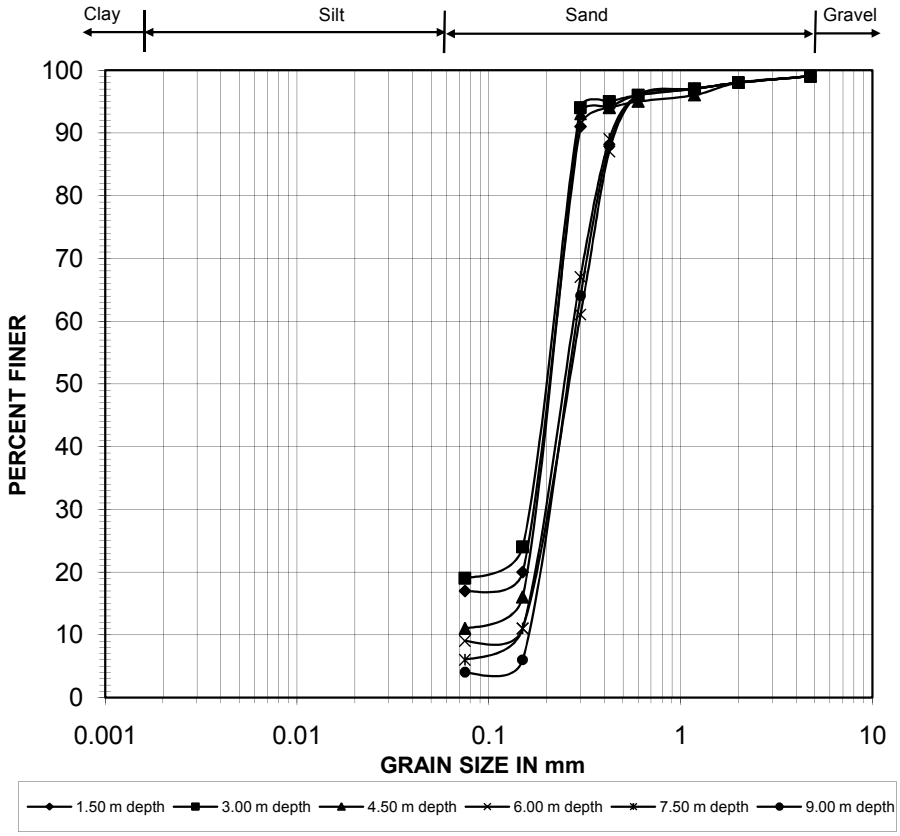
Computation of Liquefaction Potential at Different Depth by Idriss and Seed Method | **Table No.- 15**

Borehole No.	5
Borehole dia.	150 mm
Water Table (in m below EGL)	15.00

COMPUTATION DEPTH (h)	SAT. DENSITY (t/cum)	FINE CONTENT (%)	STRESS RED. RATIO (r_d)	Total overburden (σo)	Eff. overburden (σ_o)' for CSR (WT = 0)	Cyclic Stress ratio (CSR)	SPT Value (N)	Bulk Density	Eff. overburden (σ_o)' for CN (WT = Actual)	C_N	C_E	C_B	C_R	C_S	SPT Corrected $(N1)_{60}$	α	β	$(N1)_{60cs}$	$CRR_{M=7.5}$	CRR	FS_L	REMARK
1.5	1.97	17	0.989	2.96	1.46	0.235	11	1.70	2.55	1.980	1.0	1.15	0.75	1.00	18.8	3.01	1.06	22.9	0.26	0.384	1.63	NL
3.0	1.97	19	0.977	5.91	2.91	0.232	8	1.70	5.10	1.400	1.0	1.15	0.80	1.00	10.3	3.43	1.07	14.5	0.15	0.232	1.00	NL
4.5	1.97	11	0.966	8.86	4.36	0.230	10	1.71	7.67	1.142	1.0	1.15	0.85	1.00	11.2	1.21	1.03	12.7	0.14	0.206	0.90	L
6.0	1.97	9	0.954	11.81	5.81	0.227	17	1.71	10.23	0.989	1.0	1.15	0.95	1.00	18.4	0.56	1.02	19.2	0.21	0.309	1.36	NL
7.5	1.98	6	0.943	14.77	7.27	0.224	21	1.73	12.83	0.883	1.0	1.05	1.00	1.00	19.5	0.03	1.00	19.6	0.21	0.316	1.41	NL
9.0	1.98	4	0.931	17.73	8.73	0.221	26	1.73	15.42	0.805	1.0	1.05	1.00	1.00	22.0	0.00	1.00	22.0	0.24	0.363	1.64	NL
10.5	1.98	9	0.894	20.71	10.21	0.212	30	1.76	18.06	0.744	1.0	1.05	1.00	1.00	23.4	0.56	1.02	24.4	0.28	0.421	1.98	NL
12.0	1.98	4	0.854	23.68	11.68	0.202	36	1.76	20.70	0.695	1.0	1.05	1.00	1.00	26.3	0.00	1.00	26.3	0.32	0.479	2.37	NL
13.5	2.00	7	0.814	26.67	13.17	0.193	17	1.79	23.39	0.654	1.0	1.05	1.00	1.00	11.7	0.12	1.01	11.9	0.13	0.195	1.01	NL
15.0	2.00	8	0.774	29.67	14.67	0.183	40	2.00	24.88	0.634	1.0	1.05	1.00	1.00	26.6	0.30	1.01	27.3	0.35	0.519	2.83	NL
18.0	2.00	6	0.693	35.66	17.66	0.164	38	2.00	27.87	0.599	1.0	1.05	1.00	1.00	23.9	0.03	1.00	24.0	0.27	0.411	2.51	NL
21.0	2.00	8	0.613	41.65	20.65	0.145	52	2.00	30.86	0.569	1.0	1.05	1.00	1.00	31.1	0.30	1.01	31.8	NA	NA	>1	NL
24.0	2.00	7	0.552	47.64	23.64	0.130	48	2.00	33.85	0.544	1.0	1.05	1.00	1.00	27.4	0.12	1.01	27.7	0.36	0.541	4.16	NL
27.0	2.00	8	0.528	53.63	26.63	0.124	56	2.00	36.84	0.521	1.0	1.05	1.00	1.00	30.6	0.30	1.01	31.3	NA	NA	>1	NL
30.0	2.00	24	0.504	59.62	29.62	0.119	57	2.00	39.83	0.501	1.0	1.05	1.00	1.00	30.0	4.18	1.11	37.4	NA	NA	>1	NL
33.0	2.00	54	0.500	65.61	32.61	0.118	60	2.00	42.82	0.483	1.0	1.05	1.00	1.00	30.4	5.00	1.20	41.5	NA	NA	>1	NL
36.0	2.00	25	0.500	71.62	35.62	0.118	70	2.00	45.83	0.467	1.0	1.05	1.00	1.00	34.3	4.29	1.12	42.6	NA	NA	>1	NL
39.6	2.00	53	0.500	78.72	39.17	0.118	85	2.00	49.38	0.450	1.0	1.05	1.00	1.00	40.2	5.00	1.20	53.2	NA	NA	>1	NL

L=Liquefiable	NL=Non-Liquefiable

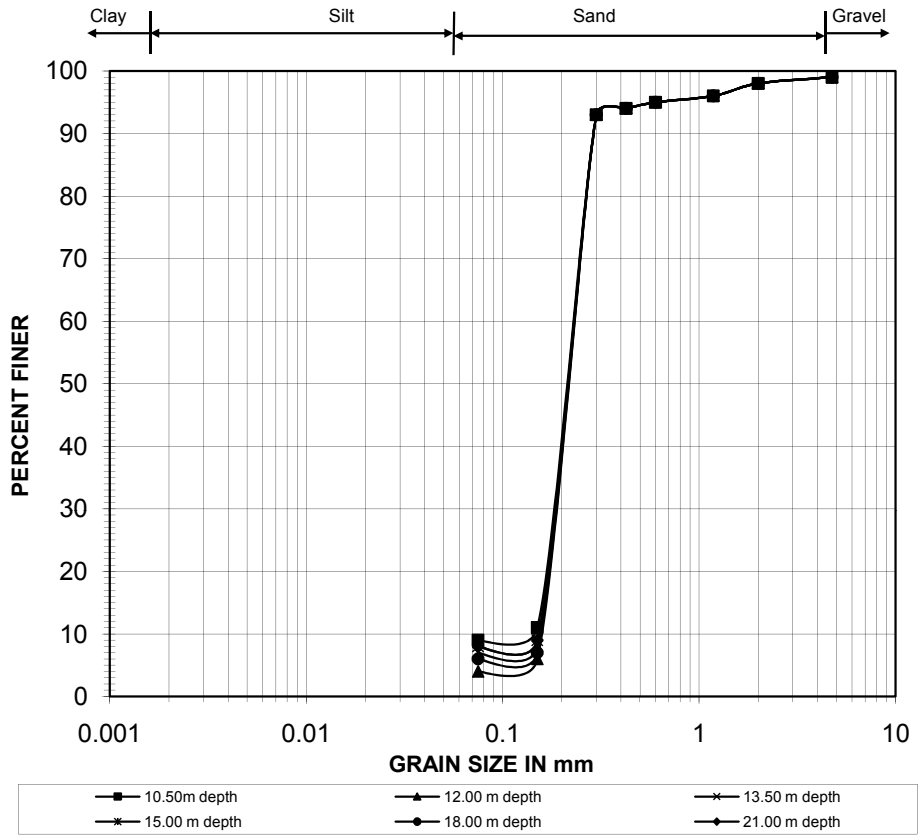
PARTICLE SIZE DISTRIBUTION CURVE for BH-5



Depth	Gravel (%)	Sand (%)	Silt + Clay (%)
1.50 m depth	1	82	17
3.00 m depth	1	80	19
4.50 m depth	1	88	11
6.00 m depth	1	90	9
7.50 m depth	1	93	6
9.00 m depth	1	95	4

Fig. - 18

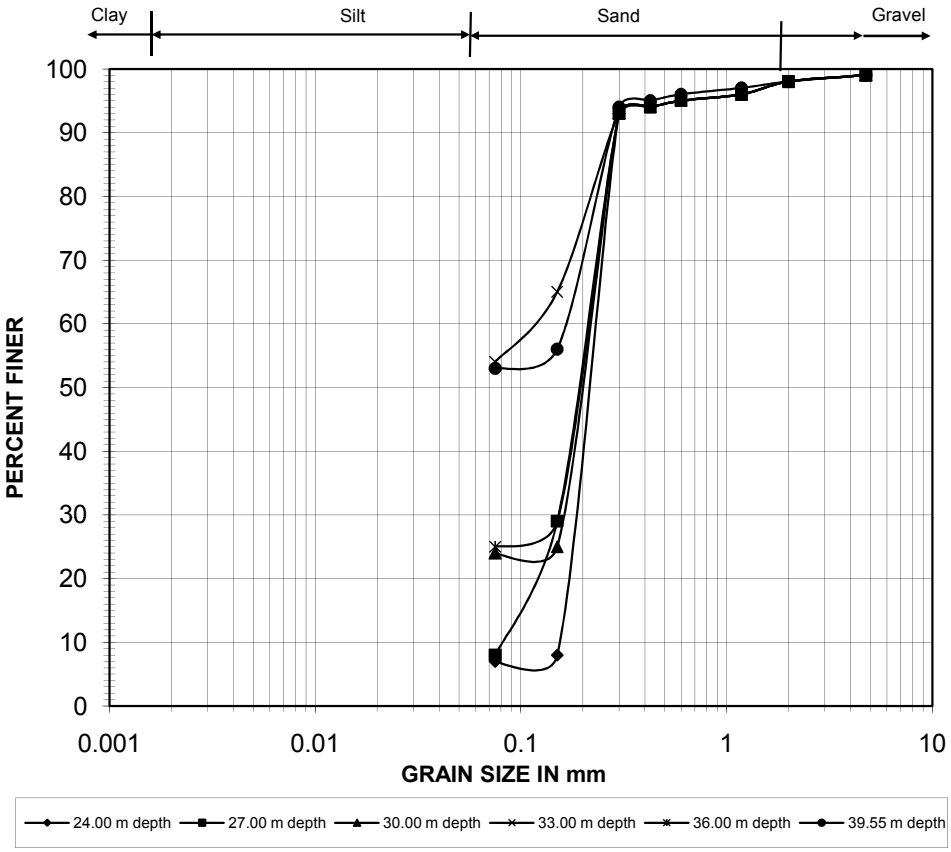
PARTICLE SIZE DISTRIBUTION CURVE for BH-5



Depth	Gravel (%)	Sand (%)	Silt + Clay (%)
10.50m depth	1	90	9
12.00 m depth	1	95	4
13.50 m depth	1	92	7
15.00 m depth	1	91	8
18.00 m depth	1	93	6
21.00 m depth	1	91	8

Fig. - 19

PARTICLE SIZE DISTRIBUTION CURVE for BH-5



Depth	Gravel (%)	Sand (%)	Silt + Clay (%)
24.00 m depth	1	92	7
27.00 m depth	1	91	8
30.00 m depth	1	75	24
33.00 m depth	1	45	54
36.00 m depth	1	74	25
39.55 m depth	1	46	53

Fig. - 20

VARIATION OF SPT 'N' WITH DEPTH for B.H.No.- 5

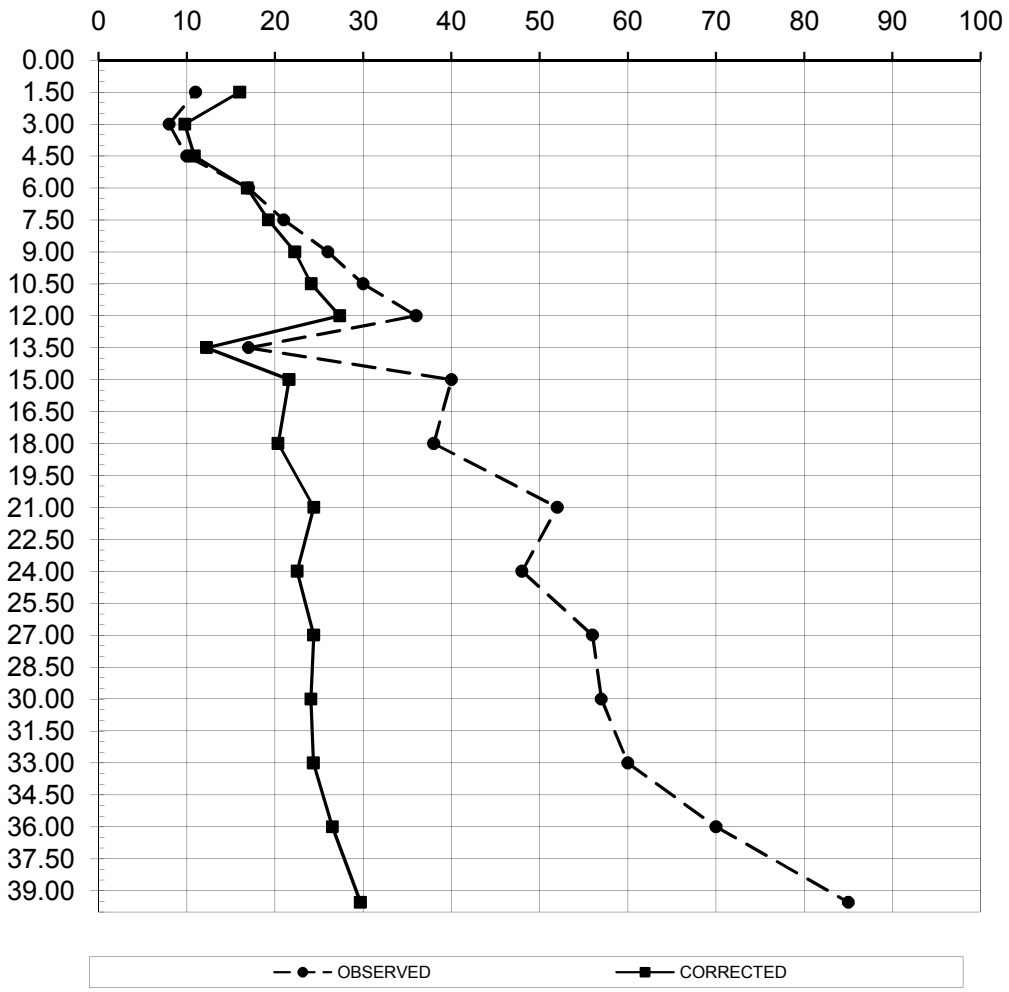


Fig. - 21

Details of BH-6

FIELD BORELOG — Table No.- 16

METHOD OF BORING	: Shell & Auger Method	BORE HOLE NO.	: 6
CASING TYPE & DEPTH	: SX-6,20m	LOCATION	: As per attached location plan
WATER TABLE	: 15.0m	DATE START	: 26-02-2013
DEPTH OF BORING	: 20 m b.g.l	DATE COMPLETION	: 27-02-2013

DEPTH(m)	DISCRIPTION OF SOIL STRATA	SOIL CLASS.	LEGEND	STRATA THICK. (m)	SAMPLES DETAILS			SPT BLOWS COUNTS				REMARKS
					TYPE	NO.	TEST DEPTH (m)	15	30	45	"N"	
1.0	SANDY SILT	ML-CL		1.00	DS	1	0.00-0.50	COLLECTED				
2.0	SILTY SAND	SM		3.00	UDS	1	1.00-1.30	COLLECTED				
					SPT	1	1.50-1.95	4	4	5	9	
3.0												
4.0					SPT	2	3.00-3.45	3	4	4	8	
5.0	FINE SAND WITH GRAVEL	SP		16.00	UDS	2	4.00-4.30	COLLECTED				
					SPT	3	4.50-4.95	6	6	7	13	
6.0												
7.0					SPT	4	6.00-6.45	9	10	12	22	
8.0					UDS	3	7.00-7.30	COLLECTED				
					SPT	5	7.50-7.95	4	9	13	22	
9.0												
10.0					SPT	6	9.00-9.45	6	14	13	27	
11.0					UDS	4	10.00-10.30	COLLECTED				
					SPT	7	10.50-10.95	6	12	16	28	
12.0												
13.0					SPT	8	12.00-12.45	7	12	21	33	
14.0					UDS	5	13.00-13.30	COLLECTED				
					SPT	9	13.50-13.95	21	29	36	65	
15.0												
16.0					SPT	10	15.00-15.45	9	9	12	21	
17.0					UDS	6	16.00-16.30	SLIPPED				
18.0												
19.0					SPT	11	18.00-18.45	8	10	20	30	
20.0					UDS	7	19.00-19.30	SLIPPED				
					SPT	10	19.55-20.00	11	26	32	58	

ABBREVIATION:- SPT - Standard Penetration Test UDS- Undisturbed Sample

LABORATORY TEST RESULTS OF BH-6 — **Table No.-17**

DEPTH BELOW GL	TYPE / SAMPLE NO.	DEPTH OF SAMPLE	SPT VALUE 'N' OBSERVED	SPT VALUE 'N' CORRECTED	DESCRIPTION OF STRATA	LEGEND	GRAIN SIZE ANALYSIS GRAVEL (%)	GRAIN SIZE ANALYSIS SAND (%)	GRAIN SIZE ANALYSIS SILT + CLAY (%)	ATTERBERG LIMIT LIQUID LIMIT (%)	ATTERBERG LIMIT PLASTIC LIMIT (%)	ATTERBERG LIMIT PLASTICITY INDEX	BULK DENSITY in t/m^3	DRY DENSITY in t/m3	MOISTURE CONTENT (%)	SPECIFIC GRAVITY	SHEAR PARAMETER COHESION 'C' in t/m^4	SHEAR PARAMETER ANGLE of FRICTION
1.00	DS	0.00-0.50	COLLECTED		SANDY SILT (ML-CL)		1	46	53									
2.00	UDS	1.00-1.30	COLLECTED		SILTY SAND (SM)		1	71	28	NON PLASTIC			1.72	1.56	9.95	2.66	0.00	30
	SPT	1.50-1.95	9	13			1	70	29									31
3.00																		
4.00	SPT	3.00-3.45	8	10			1	64	35									30
5.00	UDS	4.00-4.30	COLLECTED		FINE SAND WITH GRAVEL (SP)		1	90	9	NON PLASTIC			1.75	1.59	10.17	2.65	0.00	30
	SPT	4.50-4.95	13	14			1	91	8									31
6.00																		
7.00	SPT	6.00-6.45	22	22			1	89	10									33
8.00	UDS	7.00-7.30	COLLECTED				2	90	8				1.79	1.62	10.59	2.65	0.00	32
	SPT	7.50-7.95	22	20			2	92	6									33
9.00																		
10.00	SPT	9.00-9.45	27	23			2	91	7									34
11.00	UDS	10.00-10.30	COLLECTED				2	91	7				1.80	1.62	11.39	2.65	0.00	32
	SPT	10.50-10.95	28	23			2	90	8									34
12.00																		
13.00	SPT	12.00-12.45	33	25			2	91	7									34
14.00	UDS	13.00-13.30	COLLECTED				2	89	9				1.81	1.62	11.88	2.65	0.00	32
	SPT	13.50-13.95	65	47			2	90	8									34
15.00																		
16.00	SPT	15.00-15.45	21	15			1	89	10									31
17.00	UDS	16.00-16.30	SLIPPED				-	-	-				-	-	-	-	-	-
18.00																		
19.00	SPT	18.00-18.45	30	18			2	90	8									32
20.00	UDS	19.00-19.30	SLIPPED				-	-	-				-	-	-	-	-	-
	SPT	19.55-20.00	58	27			2	89	6									34

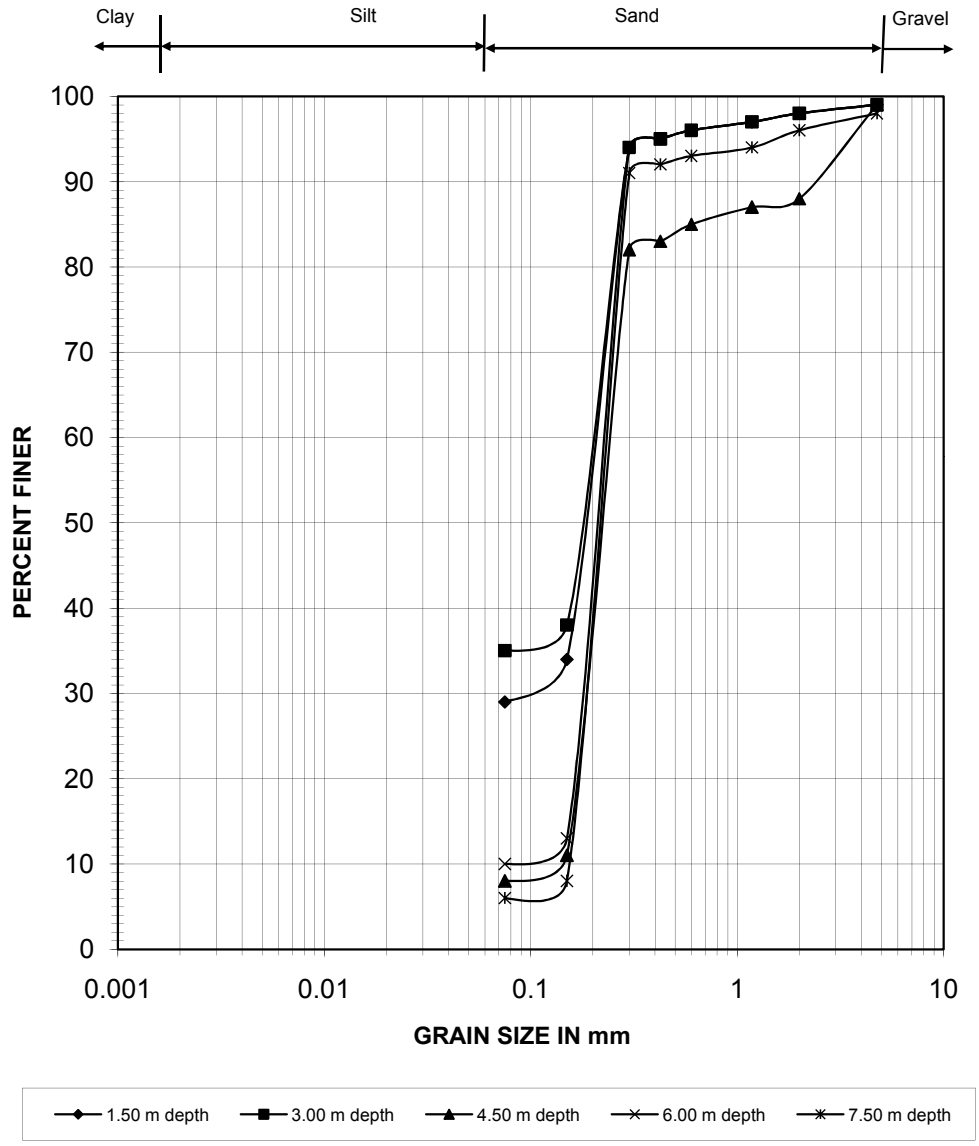
Computation of Liquefaction Potential at Different Depth by Idriss and Seed Method	Table No.- 18

Borehole No.	6
Borehole dia.	150 mm
Water Table (in m below EGL)	15.00

COMPUTATION DEPTH (h)	SAT. DENSITY (t/cum)	FINE CONTENT (%)	STRESS RED. RATIO (r_d)	Total overburden (σo)	Eff. overburden (σ_o)' for CSR (WT = 0)	Cyclic Stress ratio (CSR)	SPT Value (N)	Bulk Density	Eff. overburden (σ_o)' for CN (WT = Actual)	C_N	C_E	C_B	C_R	C_S	SPT Corrected $(N1)_{60}$	α	β	$(N1)_{60cs}$	$CRR_{M=7.5}$	CRR	FS_L	REMARK
1.5	1.98	29	0.989	2.96	1.46	0.234	9	1.72	2.58	1.969	1.0	1.15	0.75	1.00	15.3	4.64	1.15	22.2	0.24	0.366	1.56	NL
3.0	1.98	35	0.977	5.93	2.93	0.231	8	1.72	5.16	1.392	1.0	1.15	0.80	1.00	10.2	5.00	1.20	17.3	0.18	0.276	1.19	NL
4.5	1.99	8	0.966	8.91	4.41	0.228	13	1.75	7.79	1.133	1.0	1.15	0.85	1.00	14.4	0.30	1.01	14.9	0.16	0.238	1.04	NL
6.0	1.99	10	0.954	11.90	5.90	0.225	22	1.75	10.41	0.980	1.0	1.15	0.95	1.00	23.6	0.87	1.02	24.9	0.29	0.436	1.94	NL
7.5	2.01	6	0.943	14.91	7.41	0.222	22	1.79	13.10	0.874	1.0	1.05	1.00	1.00	20.2	0.03	1.00	20.3	0.22	0.329	1.48	NL
9.0	2.01	7	0.931	17.92	8.92	0.219	27	1.79	15.78	0.796	1.0	1.05	1.00	1.00	22.6	0.12	1.01	22.9	0.26	0.383	1.75	NL
10.5	2.01	8	0.894	20.93	10.43	0.210	28	1.80	18.48	0.736	1.0	1.05	1.00	1.00	21.6	0.30	1.01	22.2	0.24	0.367	1.75	NL
12.0	2.01	7	0.854	23.94	11.94	0.200	33	1.80	21.18	0.687	1.0	1.05	1.00	1.00	23.8	0.12	1.01	24.1	0.28	0.414	2.07	NL
13.5	2.01	8	0.814	26.95	13.45	0.191	65	1.81	23.90	0.647	1.0	1.05	1.00	1.00	44.2	0.30	1.01	45.0	NA	NA	>1	NL
15.0	2.01	10	0.774	29.96	14.96	0.181	21	2.01	25.41	0.627	1.0	1.05	1.00	1.00	13.8	0.87	1.02	15.0	0.16	0.240	1.32	NL
18.0	2.01	8	0.693	35.98	17.98	0.162	30	2.01	28.43	0.593	1.0	1.05	1.00	1.00	18.7	0.30	1.01	19.2	0.21	0.309	1.90	NL
19.6	2.01	6	0.652	39.09	19.54	0.153	58	2.01	29.99	0.577	1.0	1.05	1.00	1.00	35.2	0.03	1.00	35.4	NA	NA	>1	NL

L=Liquefiable	NL=Non-Liquefiable

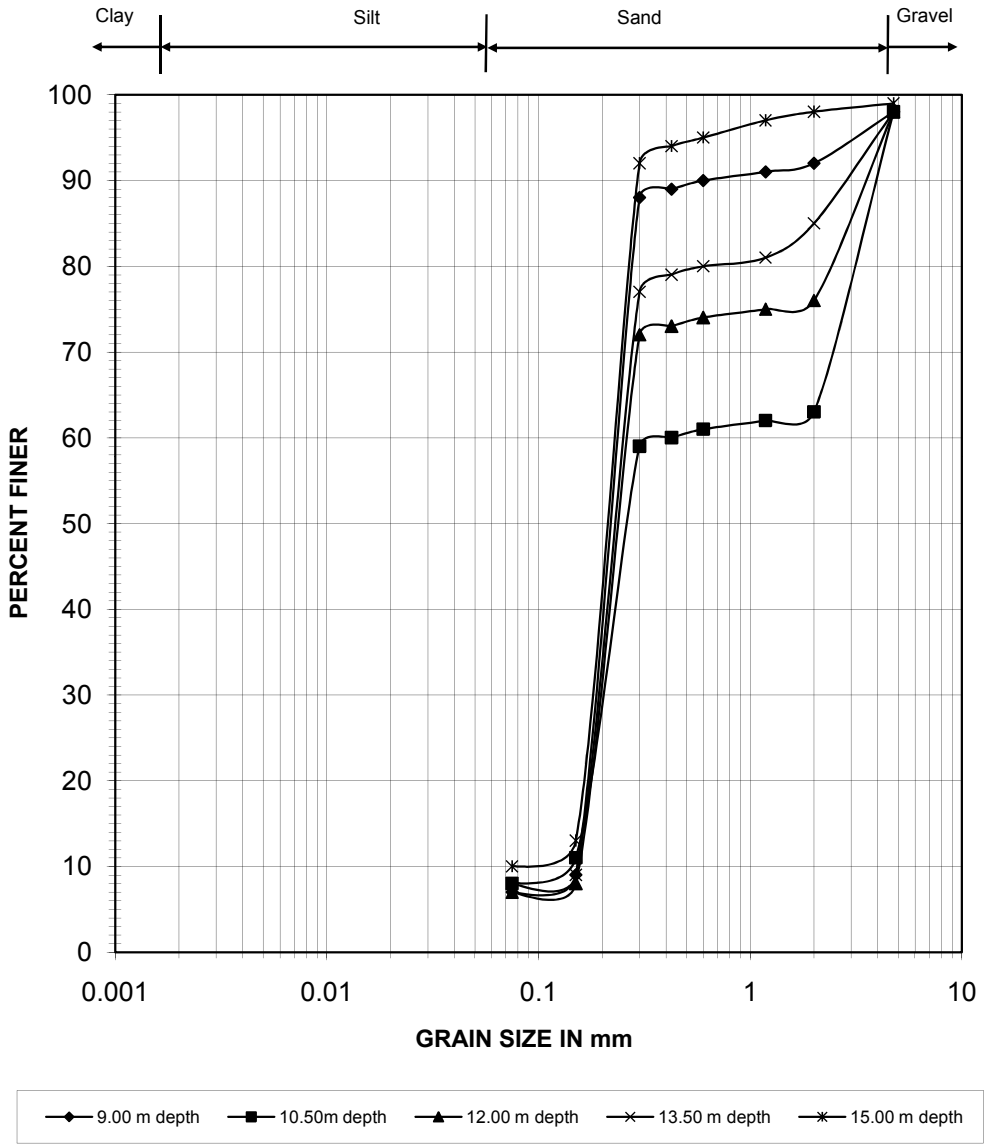
PARTICLE SIZE DISTRIBUTION CURVE for BH-6



Depth	Gravel (%)	Sand (%)	Silt + Clay (%)
1.50 m depth	1	70	29
3.00 m depth	1	64	35
4.50 m depth	1	91	8
6.00 m depth	1	89	10
7.50 m depth	2	92	6

Fig. - 22

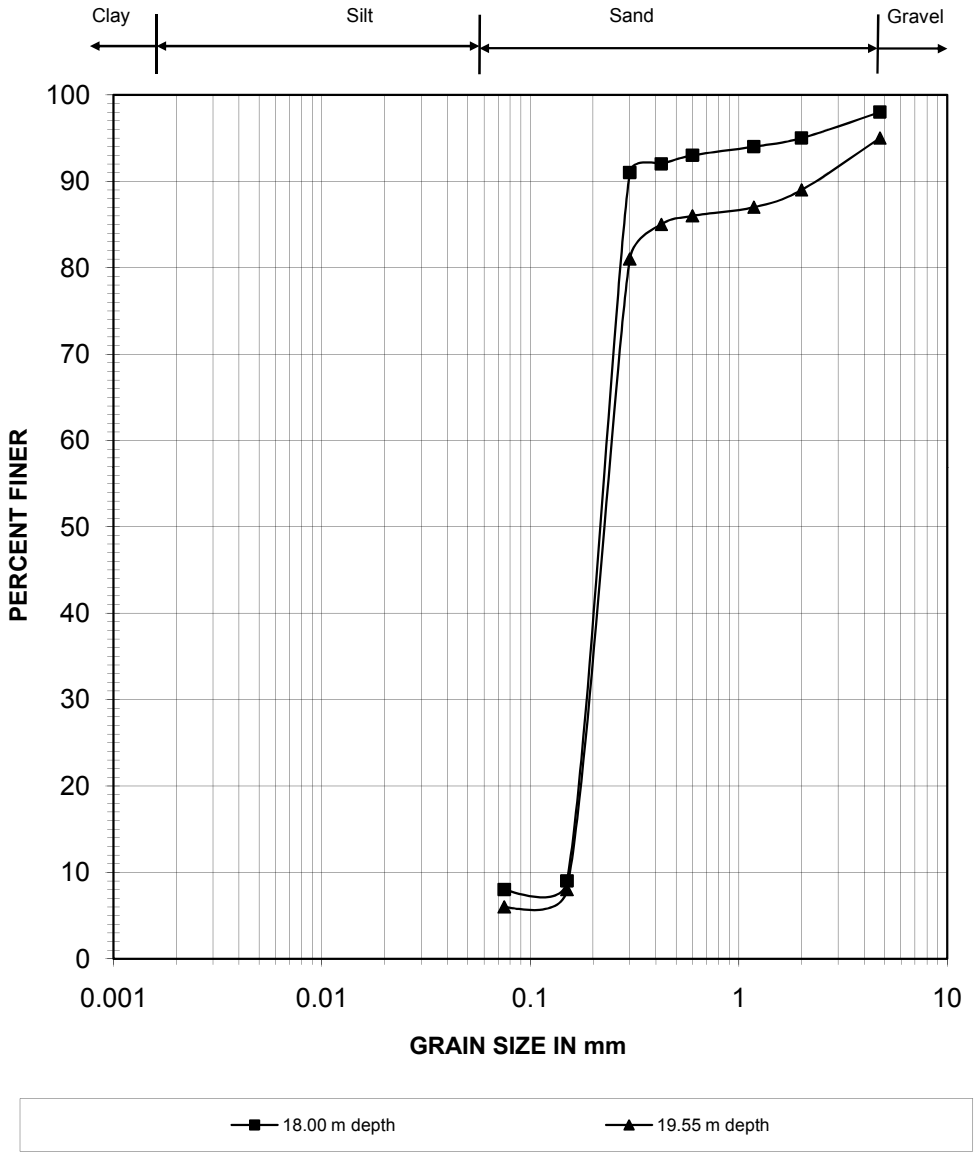
PARTICLE SIZE DISTRIBUTION CURVE for BH-6



Depth	Gravel (%)	Sand (%)	Silt + Clay (%)
9.00 m depth	2	91	7
10.50m depth	2	90	8
12.00 m depth	2	91	7
13.50 m depth	2	90	8
15.00 m depth	1	89	10

Fig. - 23

PARTICLE SIZE DISTRIBUTION CURVE for BH-6



Depth	Gravel (%)	Sand (%)	Silt + Clay (%)
18.00 m depth	2	90	8
19.55 m depth	2	89	6

Fig. - 24

VARIATION OF SPT 'N' WITH DEPTH for B.H.No.- 6

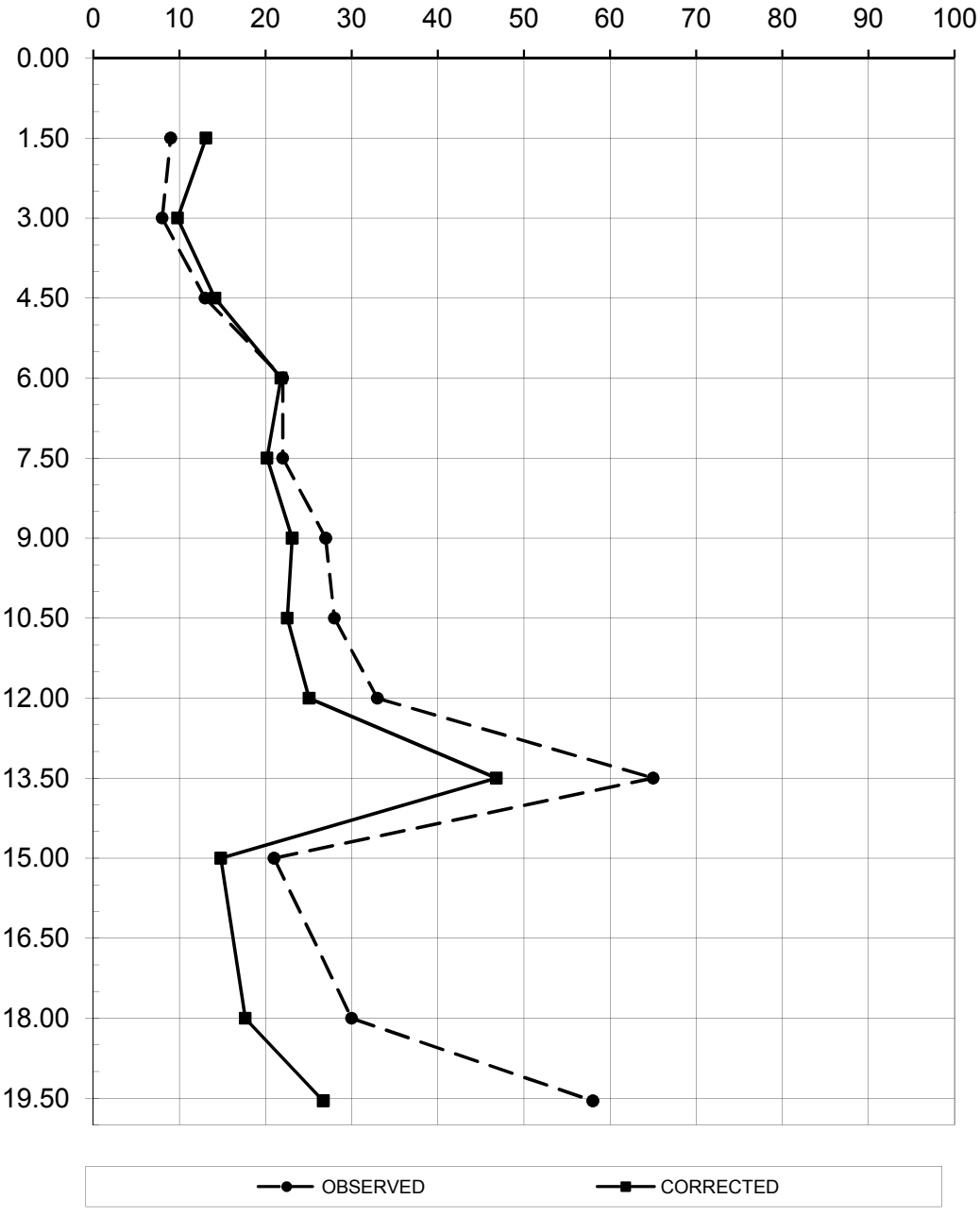


Fig. - 25

Details of BH-7

FIELD BORELOG — Table No.- 19

METHOD OF BORING	: Shell & Auger Method	BORE HOLE NO.	: 7
CASING TYPE & DEPTH	: SX-6,10m	LOCATION	: As per attached location plan
WATER TABLE	: Not Encountered	DATE START	: 19-03-2013
DEPTH OF BORING	: 10 m b.g.l	DATE COMPLETION	: 19-03-2013

DEPTH(m)	DISCRIPTION OF SOIL STRATA	SOIL CLASS.	LEGEND	STRATA THICK. (m)	SAMPLES DETAILS			SPT BLOWS COUNTS				REMARKS
					TYPE	NO.	TEST DEPTH (m)	15	30	45	"N"	
					DS	1	0.00-0.50	COLLECTED				
1.0												
	SILTY SAND	SM		3.00	UDS	1	1.00-1.30	COLLECTED				
					SPT	1	1.50-1.95	2	2	4	6	
2.0												
3.0												
					SPT	2	3.00-3.45	4	6	8	14	
4.0												
					UDS	2	4.00-4.30	COLLECTED				
					SPT	3	4.50-4.95	5	9	12	21	
5.0												
6.0												
	FINE SAND WITH GRAVEL	SP		7.00	SPT	4	6.00-6.45	4	8	14	22	
7.0												
					UDS	3	7.00-7.30	COLLECTED				
					SPT	5	7.50-7.95	6	10	15	25	
8.0												
9.0												
					SPT	6	9.55-10.00	8	12	16	28	
10.0												

LABORATORY TEST RESULTS OF BH-7 — Table No.-20

DEPTH BELOW GL	TYPE / SAMPLE NO.	DEPTH OF SAMPLE	SPT VALUE 'N' OBSERVED	SPT VALUE 'N' CORRECTED	DESCRIPTION OF STRATA	LEGEND	GRAIN SIZE ANALYSIS GRAVEL (%)	GRAIN SIZE ANALYSIS SAND (%)	GRAIN SIZE ANALYSIS SILT + CLAY (%)	ATTERBERG LIMIT LIQUID LIMIT (%)	ATTERBERG LIMIT PLASTIC LIMIT (%)	ATTERBERG LIMIT PLASTICITY INDEX	BULK DENSITY in t/m^3	DRY DENSITY in t/m3	MOISTURE CONTENT (%)	SPECIFIC GRAVITY	SHEAR PARAMETER COHESION 'C' in t/m^4	SHEAR PARAMETER ANGLE of FRICTION
	DS	0.00-0.50	COLLECTED		SILTY SAND (SM)		1	65	34									
1.00																		
	UDS	1.00-1.30	COLLECTED				1	63	36	24	20	4	1.70	1.56	8.89	2.66	0.00	30
2.00	SPT	1.50-1.95	6	9			1	59	40									30
3.00																		
	SPT	3.00-3.45	14	17	FINE SAND WITH GRAVEL (SP)		2	87	11	NON-PLASTIC								32
4.00																		
	UDS	4.00-4.30	COLLECTED				2	89	9				1.74	1.59	9.59	2.65	0.00	31
5.00	SPT	4.50-4.95	21	23			1	92	7									34
6.00																		
	SPT	6.00-6.45	22	22			2	92	6									33
7.00																		
	UDS	7.00-7.30	COLLECTED				2	90	8				1.79	1.61	11.05	2.66	0.00	32
8.00	SPT	7.50-7.95	25	23			2	92	6									34
9.00																		
10.00	SPT	9.55-10.00	28	23			1	92	7									34

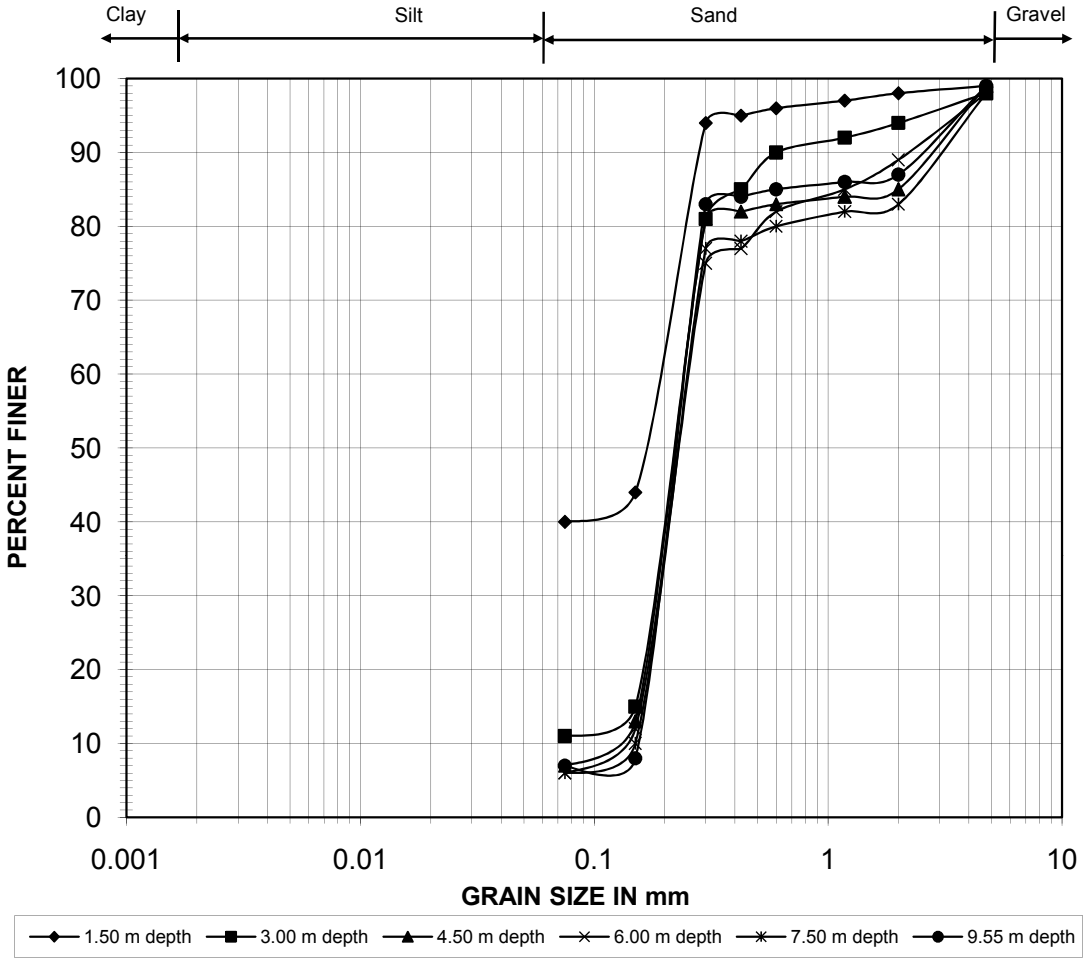
Computation of Liquefaction Potential at Different Depth by Idriss and Seed Method	Table No.- 21

Borehole No.	7
Borehole dia.	150 mm

COMPUTATION DEPTH (h)	SAT. DENSITY (t/cum)	FINE CONTENT (%)	STRESS RED. RATIO (r_d)	Total overburden (σo)	Eff. overburden (σ_o)' for CSR (WT = 0)	Cyclic Stress ratio (CSR)	SPT Value (N)	Bulk Density	Eff. overburden (σ_o)' for CN (WT = Actual)	C_N	C_E	C_B	C_R	C_S	SPT Corrected $(N1)_{60}$	α	β	$(N1)_{60cs}$	$CRR_{M=7.5}$	CRR	FS_L	REMARK
1.5	1.97	40	0.989	2.96	1.46	0.234	6	1.70	2.55	1.980	1.0	1.15	0.75	1.00	10.2	5.00	1.20	17.3	0.18	0.276	1.18	NL
3.0	1.97	11	0.977	5.92	2.92	0.232	14	1.70	5.10	1.400	1.0	1.15	0.80	1.00	18.0	1.21	1.03	19.7	0.21	0.318	1.37	NL
4.5	1.99	7	0.966	8.91	4.41	0.228	21	1.74	7.71	1.139	1.0	1.15	0.85	1.00	23.4	0.12	1.01	23.7	0.27	0.402	1.76	NL
6.0	1.99	6	0.954	11.89	5.89	0.225	22	1.74	10.32	0.984	1.0	1.15	0.95	1.00	23.7	0.03	1.00	23.8	0.27	0.405	1.80	NL
7.5	2.01	6	0.943	14.90	7.40	0.222	25	1.79	13.01	0.877	1.0	1.05	1.00	1.00	23.0	0.03	1.00	23.2	0.26	0.389	1.75	NL
9.55	2.01	7	0.919	19.01	9.46	0.216	28	1.79	16.67	0.774	1.0	1.05	1.00	1.00	22.8	0.12	1.01	23.1	0.26	0.387	1.79	NL

L=Liquefiable	NL=Non-Liquefiable

PARTICLE SIZE DISTRIBUTION CURVE for BH-7



Depth	Gravel (%)	Sand (%)	Silt + Clay (%)
1.50 m depth	1	59	40
3.00 m depth	2	87	11
4.50 m depth	1	92	7
6.00 m depth	2	92	6
7.50 m depth	2	92	6
9.55 m depth	1	92	7

Fig. - 26

VARIATION OF SPT 'N' WITH DEPTH for B.H.No.- 7

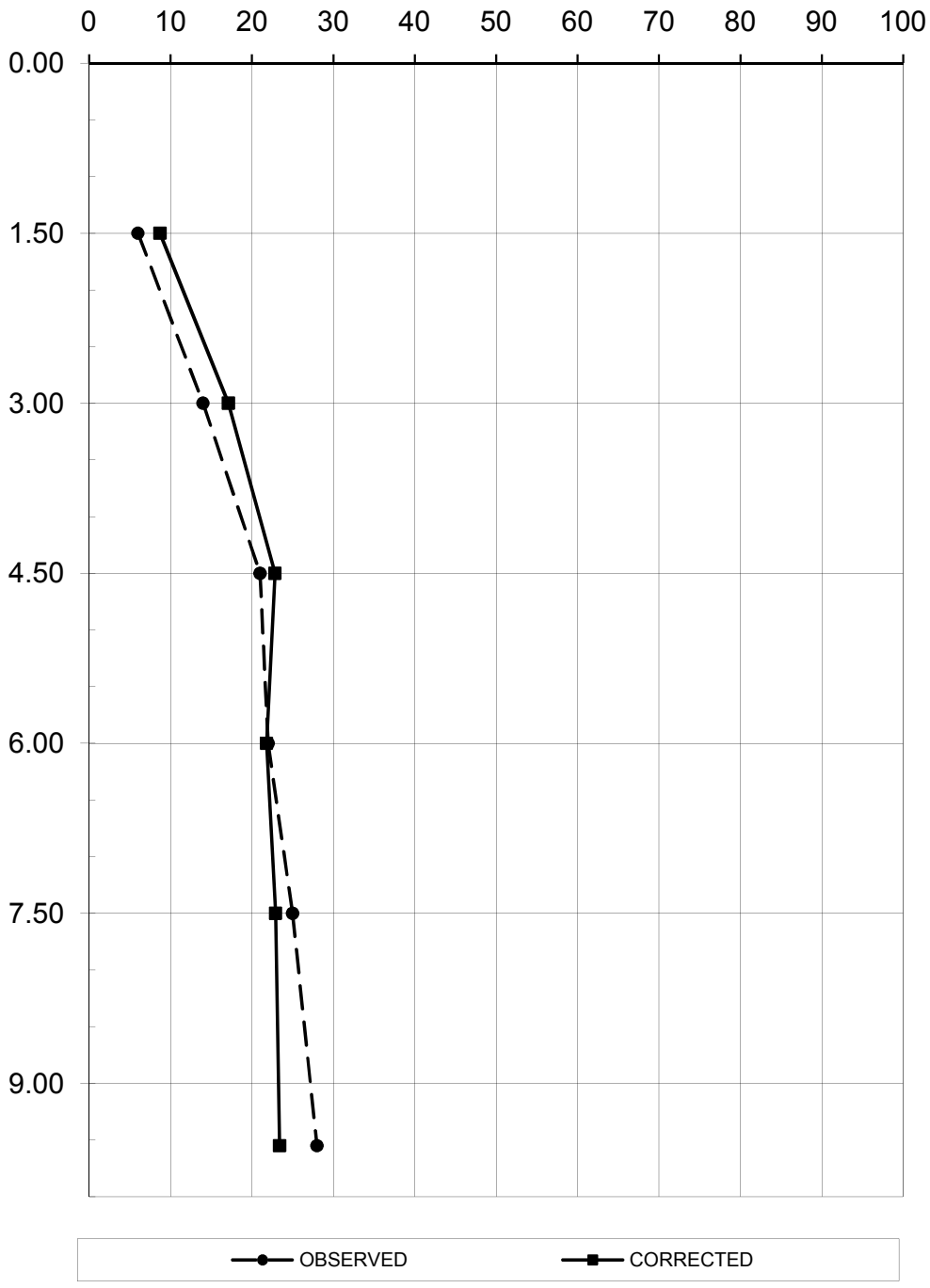


Fig. - 27

Details of DCPT

Title : **BORE LOG of DCPT**	***Table No.:22***

D.C.P. Test No.	: 01	Weight of hammer	: 63.5 Kg.
Location	: As per site plan	Height of drop	: 75 cm
Cone dia.	: 50mm	Depth of Test	: 10.00 m

Depth in m	***No. of blows per 30 cm***	***Depth in m***	***No. of blows per 30 cm***
0.00-0.30	7	5.10-5.40	15
0.30-0.60	8	5.40-5.70	14
0.60-0.90	6	5.70-6.00	14
0.90-1.20	5	6.00-6.30	12
1.20-1.50	8	6.30-6.60	13
1.50-1.80	8	6.60-6.90	21
1.80-2.10	11	6.90-7.20	20
2.10-2.40	11	7.20-7.50	16
2.40-2.70	12	7.50-7.80	17
2.70-3.00	13	7.80-8.10	22
3.00-3.30	14	8.10-8.40	16
3.30-3.60	13	8.40-8.70	23
3.60-3.90	22	8.70-9.00	19
3.90-4.20	16	9.00-9.30	24
4.20-4.50	19	9.30-9.60	20
4.50-4.80	17	9.60-9.90	14
4.80-5.10	16		

Title : **BORE LOG of DCPT**	***Table No.:23***

D.C.P. Test No.	: 02	Weight of hammer	: 63.5 Kg.
Location	: As per site plan	Height of drop	: 75 cm
Cone dia	: 50mm	Depth of Test	: 10.00 m

Depth in m	***No. of blows per 30 cm***	***Depth in m***	***No. of blows per 30 cm***
0.00-0.30	8	5.10-5.40	14
0.30-0.60	8	5.40-5.70	15
0.60-0.90	6	5.70-6.00	17
0.90-1.20	8	6.00-6.30	21
1.20-1.50	9	6.30-6.60	31
1.50-1.80	8	6.60-6.90	23
1.80-2.10	13	6.90-7.20	19
2.10-2.40	12	7.20-7.50	21
2.40-2.70	11	7.50-7.80	19
2.70-3.00	11	7.80-8.10	15
3.00-3.30	10	8.10-8.40	15
3.30-3.60	13	8.40-8.70	14
3.60-3.90	14	8.70-9.00	15
3.90-4.20	12	9.00-9.30	18
4.20-4.50	12	9.30-9.60	22
4.50-4.80	14	9.60-9.90	23
4.80-5.10	14		

Annexure-A
Bearing Capacity Calculations

ANNEXURE-A
Bearing Capacity calculations
(as per IS:6403-1981)

I. Shear Failure Criterion :

Founding level below EGL =1.5m		**14.5m**	**15.0m**	**15.5m**	**16.0m**
Average Bulk density [t/m^3] =1.72		1.78	1.79	1.80	1.82
Average Dry density [t/m^3] =1.57		1.60	1.61	1.61	1.62
C [t/m^2]	= 0	0	0	0	0
ϕ[in degree]	= 30	31	31	31	31
ϕ = 30°	$\Rightarrow$ Nc =18.08		Nq =8.88	N_y =8.73	
ϕ = 31°	$\Rightarrow$ Nc =21.63		Nq =11.77	N_y =13.12	

Depth of Foundation	Thickness of Foundation	Type of Foundation	Width / size	Sc	Sq	Sy	dc	dq = dy	q net safe in t/m^2
1.50 m (Buildings without basement Floor)	1.50m	Isolated Strip	2.0m	1	1	1	1.259	1.130	10.48
			2.5m	1	1	1	1.208	1.104	10.93
		Isolated Square	2.5m X 2.5m	1.3	1.2	0.8	1.208	1.104	11.74
			3.0m X 3.0m	1.3	1.2	0.8	1.173	1.086	12.10
		Raft	25.0m X 25.0m	1.3	1.2	0.8	1.021	1.010	33.50
14.50 m (Buildings with three basement Floors)	1.50m	Raft	25.0mX25.0m	1.3	1.2	0.8	1.021	1.011	50.96
			30.0mX30.0m	1.3	1.2	0.8	1.018	1.009	58.72
			35.0mX35.0m	1.3	1.2	0.8	1.015	1.008	66.49
15.00 m (Buildings with three basement floors)	1.50m	Raft	25.0mX25.0m	1.3	1.2	0.8	1.021	1.011	51.25
			30.0mX30.0m	1.3	1.2	0.8	1.018	1.009	59.05
			35.0mX35.0m	1.3	1.2	0.8	1.015	1.008	66.87
15.50 m (Buildings with three basement Floors)	1.50m	Raft	25.0mX25.0m	1.3	1.2	0.8	1.021	1.011	51.53
			30.0mX30.0m	1.3	1.2	0.8	1.018	1.009	59.38
			35.0mX35.0m	1.3	1.2	0.8	1.015	1.008	67.24
16.00 m (Buildings with three basement Floors)	1.50m	Raft	25.0mX25.0m	1.3	1.2	0.8	1.021	1.011	52.10
			30.0mX30.0m	1.3	1.2	0.8	1.018	1.009	60.04
			35.0mX35.0m	1.3	1.2	0.8	1.015	1.008	67.99

The values of bearing capacity factors Nc, Nq and Nγ have been arrived at from table 1 of IS: 6403-1981.

The depth factors dc, dq and dγ have been calculated as per clause 5.1.2.2 of IS:6403-1981.

The Shape factors Sc, Sq, Sy have taken from clause 5.1.2.1 of IS: 6403-1981.

II. Settlement Criterion:

As per IS:8009-1976 Part-I- Clause-9.1.4, the settlement for different width has been computed. For the allowable total settlement of 50mm for isolated footing and 75mm for raft as per IS:1904) the safe bearing pressure is computed and tabulated as following:

Depth of foundation below EGL	Type of Foundation	Size of Foundation	N Value	Settlement in mm for a pressure of 10 t /m^2	Safe Bearing Pressure (t/m^2)
1.50 m (Buildings without basement Floor)	Isolated Strip	2.0m	12	39.00	12.82
		2.5m	13	39.00	12.82
	Isolated Square	2.5mX2.5m	13	34.53	14.48
		3.0mX3.0m	13	38.08	13.13
	Raft	25.0mX25.0m	15	36.06	20.80
14.50 m (Buildings with basement Floors)	Raft	25.0mX25.0m	22	15.94	47.06
		30.0mX30.0m		16.51	45.42
		35.0mX35.0m		16.70	44.90
15.00 m (Buildings with three basement Floors)	Raft	25.0mX25.0m	22	15.74	47.64
		30.0mX30.0m		16.32	45.96
		35.0mX35.0m		16.51	45.42
15.50 m (Buildings with three basement Floors)	Raft	25.0mX25.0m	23	14.26	52.61
		30.0mX30.0m		14.61	51.34
		35.0mX35.0m		14.78	50.73
16.00 m (Buildings with three basement Floors)	Raft	25.0mX25.0m	23	14.08	53.27
		30.0mX30.0m		14.43	51.97
		35.0mX35.0m		14.61	51.34

Hence the values of allowable bearing capacity as chosen the minimum value (rounded off) from above two criterions are as following:

Depth of Foundation	Thickness of Foundation	Type of Foundation	Size of Foundation	$q_{allowable}$ (t/m^2)
1.50 m (Buildings without basement Floor)	1.50m	Isolated Strip	2.0m	10.50
			2.5m	11.00
		Isolated Square	2.5m X 2.5m	11.75
			3.0m X 3.0m	12.00
		Raft	25.0m X 25.0m	20.75
14.50 m (Buildings with three basement Floors)	1.50m	Raft	25.0mX25.0m	47.00
			30.0mX30.0m	45.25
			35.0mX35.0m	44.75

Depth of Foundation	Thickness of Foundation	Type of Foundation	Size of Foundation	$q_{allowable}$ (t/m^2)
15.00 m (Buildings with three basement Floors)	1.50m	Raft	25.0mX25.0m	47.50
			30.0mX30.0m	45.75
			35.0mX35.0m	45.25
15.50 m (Buildings with three basement Floors)	1.50m	Raft	25.0mX25.0m	51.50
			30.0mX30.0m	51.25
			35.0mX35.0m	50.75
16.00 m (Buildings with three basement Floors)	1.50m	Raft	25.0mX25.0m	52.00
			30.0mX30.0m	51.75
			35.0mX35.0m	51.25

Annexure- B
Pile Capacity Calculations

ANNEXURE-B

$$Q_u = A_p.(Nc.Cp + P_D.N_q) + \sum_{i=1}^{n} (\alpha.C + K.P_{di} \tan\delta) A_{si}$$

A_p = Cross sectional area of pile toe
P_D = Effective overburden pressure at pile toe taken as corresponding to 17*pile dia
N_q = Bearing capacity factor depending upon the angle of internal friction at toe
Nc = Bearing capacity factor usually taken as 9
K = Coefficient of earth pressure
Cp = Average cohesion at pile tip
α = Reduction factor
C = Average cohesion throughout the length of the pile
P_{di} = Effective overburden pressure at the i^{th} layer [i varies from1to n]
δ = Angle of wall friction between pile and soil in degrees taken as Φ
A_{si} = Surface area of the pile stem in the i^{th} layer [i varies from1 to n]

Diameter of the pile =600mm
Adhesion Factor =0.5
Coefficient of earth pressure K=1.50
Nq = 20 & 22 for Φ =30^0 & 31^0

Depth	Thick. of the strata in m	Gama in [t/cum]	α.c	Phi	Pd in [t/sqm]	Unit Skin Friction [t/sqm]	Skin Friction in [t]	Cum. Skin Friction in [t]	Unit End Bearing in [t/sqm]	End Bearing in [t]	Qu in [t]	Qu/F.S in [t]	Uplift capacity in t
14.0													
	1.0	0	0	0									
15.0					0.00								
15.0					0.00	0.00							
	5.0	1.96	0.0	31			20.39	20.39					
20.0					4.80	4.33							
20.0					4.80	4.33							
	5.0	2.00	0.0	31			62.01	82.39		61	143.3	**57**	**16**
25.0					9.80	8.83			216				
25.0					9.80	8.83							
	3.0	2.02	0.0	31			49.94	132.3		61	193.3		
28.0					9.80	8.83			216				
28.0					9.80	8.49							
	2.0	2.04	0.0	30			31.99	164.3		55	219.7	**88**	**33**
30.0					9.80	8.49			196				
30.0					9.80	8.49							
	2.0	2.05	0.0	30			31.99	196.3		55	251.7		
32.0					9.80	8.49			196				
32.0					9.80	8.49							
	3.0	2.05	0.0	30			47.99	244.3		55	299.7	**120**	**49**
35.0					9.80	8.49			196				
35.0					9.80	8.83							
	5.0	2.05	0.0	31			83.24	327.5		61	388.5	**155**	**66**
40.0					9.80	8.83			216				

As described above, considering the seismic condition, the pile capacity computations for cast-in-situ bored piles are made as per IS:2911-1980(Part-I) .The cut off level has been considered as 15.0 m below the ground surface.

The safe load carrying capacity of the piles with different effective length has been calculated as above and the recommended values are as following:

Diameter of Pile (m)	Length of Pile Below Cut-off Level	Safe Axial Load Carrying Capacity (t)	
		In compression	Uplift
0.60	10.0 m	55	15
	15.0 m*	85	30
	20.0 m*	120	45
	25.0 m	155	65
0.75	10.0 m	75	20
	15.0 m*	135	45
	20.0 m*	190	70
	25.0 m	240	95

* For 0.6 m and 0.75 m pile diameter piles, the pile length of 15m and 20m are actually terminated in sandy silt / clay layer which has some plasticity / compressibility. Hence settlement has to be calculated and checked for the limits at working loads.

Calculation of Lateral Load Capacity of Bored Cast- in- Situ Piles as per IS: 2911

End Condition	Diameter of pile in m	Reduction Factor K1 in kg/m^3	Young's modulus of pile material E in kg/m^2	Moment of Inertia m^4	T	L_f/T	L_f in m	L_1	Permissible deflection Y, cm	Calculated Lateral Load in kg	Recommended Lateral Load, T	Minimum Length of Pile (4T)
Free Head	0.6	5000	27386128	0.0063617	2.03	1.91	3.89	0	0.5	4454.67	4.5	8.14m
Fixed Head	0.6	5000	27386128	0.0063617	2.03	2.18	4.43	0	0.5	11984.12	11.5	8.14m
Free Head	0.75	5000	27386128	0.0155316	2.43	1.91	4.65	0	0.5	6366.07	6.0	9.73m
Fixed Head	0.75	5000	27386128	0.0155316	2.43	2.18	5.30	0	0.5	17126.24	17.0	9.73m

Annexure-C
List of Referred IS Codes

ANNEXURE-C
LIST OF REFERRED IS CODES

Field Investigation

1. IS : 1948-1970 Classification and identification of soils for general engineering purposes (first revision) Amendment 2

2. IS : 1892-1979 Code of practice for sub surface investigations for foundations

3. IS : 2131-1981 Method of standard penetration tests for soils

4. IS : 2132-1986 Code of practice for thin walled tube sampling of soils

Laboratory tests

1. IS : 2720-1983 (Part 1) Methods of tests for soils: Preparation of dry soil samples for various tests (second revision)

2. IS : 2720-1980 (Part-2) Methods of test for soils: Determination of water content (second revision) Amendment 1

3. IS : 2720-1980 (Part-3/Sec 1) Method of test for soil : Determination of specific gravity : Fine grained soils

4. IS : 2720-1980 (Part-3/Sec 2) Method of test for soil : Determination of specific gravity : Fine , medium & coarse grained soils.(First revision)

5. IS : 2720-1985 (Part-4) Methods of test for soils: Grain size analysis (Second revision)

6. IS : 2720-1985 (Part-6) Methods of test for soils: Determination of liquid and plastic limit (Second revision)

Foundation construction

1. IS : 1904-1986 Code of practice for design and construction of foundation in soils : General requirements (Third revision)

2. IS : 6403-1981 Code of practice for determination of bearing capacity of shallow foundations

3. IS : 8009-1976 (Part-1) Code of practice for calculation of settlements of foundations : Shallow foundations subjected to symmetrical static vertical loads (Amendment 2)