GEO TECHNICAL INVESTIGATION REPORT

(1449-R2-NALANDA UNIVERSITY)

AT THE SITE FOR

PROPOSED SITE FOR NEW CAMPUS OF NALANDA UNIVERSITY, RAJGIR, DISTT. NALANDA,

FOR

UNIVERSITY ENGINEER

NALANDA UNIVERSITY,

COUNCIL FOR SOCIAL DEVELOPMENT BUILDING,

LODHI ESTATE, NEW DELHI

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ACKNOWLEDGEMENTS

We feel pleasure to submit the report of Geo-technical investigation work conducted at site for proposed construction at Nalanda University, Rajgir, Bihar.

We are thankful to Dr. Gopa Sabarwal, Vice Chancellor Nalanda University, for his trust shown to us by awarding the work of soil investigation. We are also grateful to Er. M K Prasad Engineer, Nalanda University, for their help rendered during and prior to the investigation work.

We are also thankful to our staff members for conducting field and laboratory test, preparing the sketches and typing the report.

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1. INTRODUCTION:

This report deals with Geo-technical investigation at the site for proposed construction of new Campus of Nalanda University which consist of various blocks of multi storied buildings, roads and other infrastructural facilities at Rajgir, Bihar. It is proposed to construct up to four storied buildings. The work of geotechnical investigation has been awarded to us, wide work order No. NU/229 dated 09-10-2014 from the office of Nalanda University, Council for Social Development building, Lodhi Estate New Delhi.

The report includes the recommendations on type, depth and safe allowable bearing capacity for the safe and strong foundation for the proposed building structures and California Bearing ratio for construction of roads.

2. SCOPE OF WORK:

For the proposed construction of buildings structures, it is required to determine the safe allowable bearing capacity together with necessary engineering characteristics of underlying soil strata. Since the safe bearing capacity of soils must be evaluated on the considerations covering shear failure and permissible settlement of sub-soil strata as per IS: 6403-1981, IS: 1904-1978, IS: 8009 (part-I)-1976, and IS 2911 (part-1, section -2)-2010 hence the scope of work is as follows:

2.1 Boring five numbers of boreholes of 150mm diameter within the proposed area of construction up to a maximum depth of 20.00 meter.

2.2 Conducting the Standard Penetration Test (SPT) at every 1.50 metre interval or at change of strata in all the boreholes.

2.3 Collecting disturbed soil samples at every 1.50 metre interval or at change of strata from the boreholes.

2.4 Collecting undisturbed soil samples from the boreholes at 2.50 metre interval or change of strata.

2.5 Transporting all the disturbed and undisturbed soil samples collected during the field investigation for further examination and testing to our soil mechanics laboratory at Delhi.

2.6 Conducting the laboratory test on all the soil samples collected during field investigation for determination of their engineering characteristics.

2.7 Compilation of field and laboratory test results, working out the safe allowable bearing capacity and preparing the report including detailed recommendations and necessary precautions.

3. PROJECT LOCATION:

The site for proposed construction of new campus of Nalanda University is situated at Rajgir, Bihar. The site is located about 10.00 km from the main road of Bihar Sarif to Nalanda

4. OBSERVATIONS AT SITE:

The following observations have been made at the site:-

4.1 Effects of saltpetre and termites have not been observed at the site.

4.2 The site is 0.50 metre below in reference with the adjacent road.

4.3 The site is not free from flooding and it may accumulate rain water on it..

5. FIELD INVESTIGATION:

The field investigation work at this site was carried out from October 10th; 2014 to October. 16th; 2014. The following investigation work was done:

5.1. **Five numbers** of boreholes of diameter 150 mm were made within the proposed layout of the various buildings and ancillary structures. The boreholes were progressed using manually operated augers and further advanced by use of mechanically operated shell casing to the desired depth. Where caving of the

borehole occurred, casing was used to keep the borehole stable. All boreholes were made up to the depth of 20.00 meter. The locations of boreholes have been reported in "BOREHOLES LOCATION PLAN" in Appendix A.

5.2. **Standard Penetration Tests** were conducted as per IS: 2131-1981 at 1.50 metre interval in all the bore holes. The number of blows for each 15 cm of penetration was recorded. The blows required to penetrate the initial 15 cm of the split spoon for seating the sampler is ignored due to the possible presence of loose materials or cuttings from the drilling operation. The cumulative number of blows required to penetrate the balance 30 cm of the 45 cm split spoon sampler is termed the SPT value or the 'N' value. The results have been reported in table 1 of Appendix B under the title "SUMMARY OF TEST RESULTS".

5.3. **Disturbed soil samples** were collected from the boreholes at an interval of 1.50 metre. In the entire bore holes. Disturbed samples were collected from the split spoon after conducting SPT. The samples were preserved in transparent polythene bags. The results have been reported in table 1 of Appendix B under the title "SUMMARY OF TEST RESULTS".

5.4. **Undisturbed soil samples** were collected from the boreholes at 1.00 metre, 2.50 metre, 5.00 metre, 8.00 metre, 11.00 meter, 14.00 meter, 17.00 meter & 20.00 meter depth. Undisturbed samples were collected by attaching a 100 mm diameter thin walled 'Shelby' tubes and driving the sampler using a 63.5 kg hammer in accordance with IS:2132-1986. The tubes were sealed with wax at both ends. The results have been reported in table 1 of Appendix B under the title "SUMMARY OF TEST RESULTS".

5.5 Undisturbed soil samples for performing **California Bearing Ratio** test have been collected at locations marked as CBR-1 to CBR-19, in accordance with IS 2720 (part-16)-1987. CBR tests have been conducted on un soaked samples and after soaking for 4 hours. The locations have been marked in Appendix-A Bore hole location plan

5.6 Observation of **water table** has been made as per IS 6935-1973 and reported in item No. 7 of the test report.

6 LABORATORY TESTS:

The laboratory-testing program was aimed at verifying the field classifications and developing parameters for engineering analysis. All the tests were performed in accordance with the current applicable IS specifications. The following laboratory tests were conducted to determine the engineering characteristics of sub-soils:

6.1 Field moisture contents were determined by oven drying method as per IS 2720 (part-II)-1997. The results have been reported in table 1 "SUMMARY OF TEST RESULTS" of Appendix B.

6.2 Field density of soil strata were obtained using Shelby tubes in accordance with IS 2720 (part XXIX)-1975. The results have been reported in table 1: "SUMMARY OF TEST RESULTS" of Appendix B.

6.3 Mechanical sieve analysis test were performed in accordance with IS 2720 (Part IV) - 1985, for the purpose of identification by grain size analysis, on coarse part of the soil samples and the results have been reported in table 1 "SUMMARY OF TEST RESULTS" of Appendix B**.**

6.4 Particle size analysis test by hydrometer method were performed in accordance with IS 2720 (Part IV) - 1965 on the part of soil samples obtained after the sieve analysis. The results have been reported in table 1 "SUMMARY OF TEST RESULTS" of Appendix B.

6.5 Atterbergs' limits tests were performed in accordance with IS 2720 (part V)-1985 and results have been reported in table 1 **"**SUMMARY OF TEST RESULTS" of Appendix B.

6.6 Specific gravity tests were performed in accordance with IS 2720 (part III-sec. 1) - 1980 and the results have been reported in table 1 "SUMMARY OF TEST RESULTS" of Appendix B.

6.7 **Chemical tests** were performed on **soil samples** as per the respective IS code of practice. The results have been reported in table 3 "CHEMICAL TEST RESULTS" of Appendix B.

6.8 **Chemical tests** were performed on **water samples** obtained from the bore holes as per the respective IS code of practice. The results have been reported in table 4 "CHEMICAL TEST RESULTS" of Appendix B.

6.9 **Free-Swell Index** tests were performed in accordance with IS: 2720 (part-XXXX) - 1977 and the results have been reported in table 1: SUMMARY OF TEST RESULTS of Appendix B.

6.10 **California Bearing Ratio** tests were performed at 2.50 metre depth in accordance with IS 2720 (part-16)-1987 marked as CBR-1 to CBR-19 and results have been reported in table 2 "CBR TEST RESULTS" of Appendix B.

6.11 **Triaxial Compression** under undrained unconsolidated tests were performed as per IS 2720 (part XI)-1971, on the undisturbed soil samples obtained during the field investigation. The results have been reported in table 1 "SUMMARY OF TEST RESULTS" of Appendix B.

6.12 **Shrinkage Limit** tests were performed in accordance with IS: 2720 (part-VI) -1972 and the results have been reported in table 1: SUMMARY OF TEST RESULTS of Appendix B.

7 WATER TABLE:

The water table at this site was encountered during the boring operation. Depth of water table was recorded as per IS 6935-1973. Recorded depth of water table in different bore holes are as under:

BORE HOLE NO.	DEPTH OF WATER TABLE(metre)
BH-1	1.60
BH-2	1.00
BH-3	1.00
BH-4	1.20
BH-5	1.00

8 SITE STRATIGRAPHY:

The classification of soil strata have been done with the help of soil characteristics obtained in laboratory tests as per IS 1498-1978. The detailed nature of the soil strata have been reported in table 1: "SUMMARY OF TEST RESULTS" of Appendix B.

In general, all boreholes have soil strata which are non-expansive in nature, containing no organic matter and harmful salts. The soil strata in all the bore holes predominantly consist of Silts and Silty Clays with Intermediate plasticity.

9 RECOMMENDATIONS:

Keeping in mind, the field test results, laboratory test results and IS codes of practice the following recommendations are hereby made:

9.1 **Isolated footing** shall be provided for all building structures to be constructed on framed columns. The depth of the foundation shall be measured from the lowest relative level of natural existing ground at the site.

Depth of foundation (m)	Safe Bearing Capacity (kN/m^2)
1.50	80.00
2.00	90.00
2.50	100.00

9.3 **Strip type of wall footing** shall be provided for load bearing brick or stone masonry walls in boundary wall etc. The depth and corresponding safe allowable bearing capacity shall be as follows:

Depth of foundation (metre)	Safe bearing capacity (kN/m^2)
1.00	60.00
1.25	64.00
1.50	66.00

9.4 **Raft foundation** may be provided for the all RCC framed columns of building structures. The depth and corresponding safe allowable bearing capacity shall be as follows:

Depth of foundation (Metre)	Safe bearing capacity (kN/m^2)
1.50	73.00
2.00	86.50

Depth of foundation (Metre)	Safe bearing capacity (kN/m^2)
2.50	89.5

9.5 Pile Load Capacity:

Bored cast in-situ RCC Piles may also be provided for the foundation of the proposed building structures: Load capacities of pile of diameter 450 mm and length 15.00 meter for various bole holes have been listed in the table below:

Bore No.	PILE LOAD CAPACITIES (kN)											
	For Pile Length =15.00 metre						For Pile Length =18.00 metre					
	450Φ		500Φ		600Φ		450Φ		500Φ		600Φ	
	COMP.	UPLIFT	COMP.	UPLIFT	COMP.	UPLIFT	COMP.	UPLIFT	COMP.	UPLIFT	COMP.	UPLIFT
BH-1	300.0	236.0	358.0	280.0	482.0	369.0	360.0	291.0	433.0	347.0	585.0	461.0
BH-2	380.0	296.0	454.0	354.0	615.0	470.0	449.0	357.0	541.0	429.0	730.0	574.0
BH-3	405.0	311.0	487.0	369.0	657.0	486.0	492.0	394.0	593.0	472.0	803.0	629.0
BH-4	335.0	269.0	396.00	315.0	520.0	406.0	397.0	320.0	470.0	377.0	624.0	492.0
BH-5	335.0	261.0	407.0	314.0	559.0	420.0	395.0	317.0	484.0	386.0	668.0	524.0

9.6 All depth shall be measured from existing level of ground.

9.7 Calculations for assessment of liquefaction potential of the soil strata, has been made and no such potential has been found.

9.8 If any loose pocket strata are found during the excavation, the foundation shall be laid only after ensuring that the same has been cleared and appropriate remedial measures have been adopted. If needed, the same may please be brought to the notice of the undersigned

9.9 The modulus of subgrade reaction shall be taken as 2000 T/m^3.

9.10 It is strongly recommended to do investigation with additional bore holes for individual buildings as the distance between boreholes in quite large.

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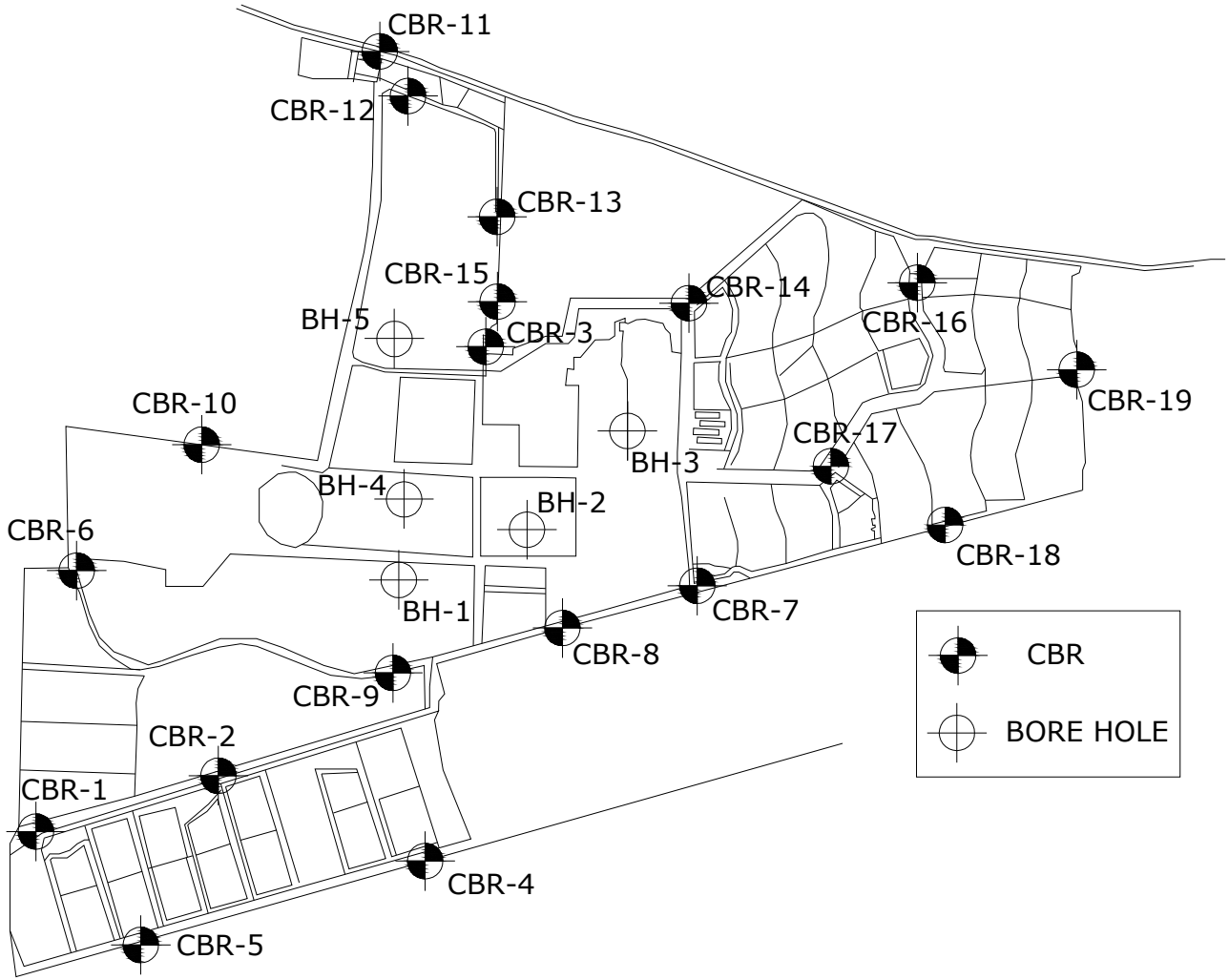
APPENDIX – A
BORE HOLES LOCATION PLAN



APPENDIX 'B'
SUMMARY OF TEST RESULTS (BH-1)

Bore hole depth	Soil Description	Soil classification	SPT		Grain Size Analysis						Density and Moisture			Atterberg Limits			Shear Strength Parameters			Shrinkage Limit (%)	Free Swell Index (%)	Specific Gravity Gs	Consolidation Characteristic	
			Observed	Corrected	Gravel (%)	Course Sand (%)	Medium Sand (%)	Fine Sand (%)	Silt (%)	Clay (%)	moisture Content (%)	Bulk Density (gm/cc)	Dry Density (gm/ cc)	Liquid Limit (%)	Plastic Limit (%)	Plastic Index (%)	Type of test	C (KN/m^2)	Φ (Degrees)				C_c	Void Ratio, e_0
1.00	**Inorganic silty clays of intermediate plasticity**	CI	-	-	1	3	6	3	76	11	20.10	1.850	1.540	45	30	15	UU	30	11	11	12	2.66	0.120	0.727
1.50		-	9	12.88	-	-	-	-	-	-	20.29	-	-	-	-	-	-	-	-	-	-	-	-	-
2.50	**Inorganic clay with high plasticity**	CH	-	-	2	3	5	3	69	18	28.13	1.925	1.502	54	27	27	UU	40	8	13	15	2.67	0.135	0.778
3.00		-	13	15.50	-	-	-	-	-	-	23.30	-	-	-	-	-	-	-	-	-	-	-	-	-
4.50		-	17	16.87	-	-	-	-	-	-	17.11	-	-	-	-	-	-	-	-	-	-	-	-	-
5.00	**Inorganic clay of intermediate plasticity**	CI	-	-	0	0	2	6	79	13	21.85	2.009	1.649	45	26	19	UU	30	9	12	11	2.67	0.125	0.619
6.00		-	19	16.21	-	-	-	-	-	-	21.28	-	-	-	-	-	-	-	-	-	-	-	-	-
7.50		-	22	16.20	-	-	-	-	-	-	19.05	-	-	-	-	-	-	-	-	-	-	-	-	-
8.00	**Inorganic silts of intermediate plasticity**	MI	-	-	2	1	1	8	76	12	17.12	1.940	1.656	40	26	14	UU	27	10	12	10	2.67	0.122	0.612
9.00		-	33	19.56	-	-	-	-	-	-	17.60	-	-	-	-	-	-	-	-	-	-	-	-	-
10.50		-	34	18.71	-	-	-	-	-	-	19.46	-	-	-	-	-	-	-	-	-	-	-	-	-
11.00		MI		-	1	1	1	15	74	8	17.50	1.968	1.675	40	28	12	UU	22	13	-	-	2.66	0.110	0.588
12.00		-	32	16.88	-	-	-	-	-	-	14.96	-	-	-	-	-	-	-	-	-	-	-	-	-
13.50		-	42	19.34	-	-	-	-	-	-	15.20	-	-	-	-	-	-	-	-	-	-	-	-	-

APPENDIX 'B'
SUMMARY OF TEST RESULTS (BH-1)

Bore hole depth	Soil Description	Soil classification	SPT		Grain Size Analysis						Density and Moisture			Atterberg Limits			Shear Strength Parameters			Shrinkage Limit (%)	Free Swell Index (%)	Specific Gravity Gs	Consolidation Characteristic	
			Observed	Corrected	Gravel (%)	Course Sand (%)	Medium Sand (%)	Fine Sand (%)	Silt (%)	Clay (%)	moisture Content (%)	Bulk Density (gm/cc)	Dry Density (gm/ cc)	Liquid Limit (%)	Plastic Limit (%)	Plastic Index (%)	Type of test	C (KN/m^2)	Φ (Degrees)				C_c	Void Ratio, e_0
14.00	**Inorganic silts of intermediate plasticity**	MI		-	4	2	3	3	84	4	15.30	1.949	1.690	36	28	8	UU	17	18	-	-	2.66	0.105	0.574
15.00		-	45	19.30	-	-	-	-	-	-	15.44	-	-	-	-	-	-	-	-	-	-	-	-	-
16.50		-	38	16.20	-	-	-	-	-	-	15.41	-	-	-	-	-	-	-	-	-	-	-	-	-
17.00		MI	-	-	2	1	3	6	82	6	15.40	1.956	1.695	40	28	12	UU	20	16	-		2.66	0.107	0.569
18.00		-	42	16.59	-	-	-	-	-	-	15.39	-	-	-	-	-	-	-	-	-	-	-	-	-
19.50		-	57	19.99	-	-	-	-	-	-	17.38	-	-	-	-	-	-	-	-	-	-	-	-	-
20.00		MI	-	-	2	2	3	7	81	5	18.30	2.017	1.705	36	28	8	UU	19	16	-	-	2.66	0.105	0.560

APPENDIX 'B'
SUMMARY OF TEST RESULTS (BH-2)

Bore hole depth	Soil Description	Soil classification	SPT		Grain Size Analysis						Density and Moisture			Atterberg Limits			Shear Strength Parameters			Shrinkage Limit (%)	Free Swell Index (%)	Specific Gravity Gs	Consolidation Characteristic	
			Observed	Corrected	Gravel (%)	Course Sand (%)	Medium Sand (%)	Fine Sand (%)	Silt (%)	Clay (%)	moisture Content (%)	Bulk Density (gm/cc)	Dry Density (gm/ cc)	Liquid Limit (%)	Plastic Limit (%)	Plastic Index (%)	Type of test	C (KN/m^2)	Φ (Degrees)				C_c	Void Ratio, e_0
1.00	**Inorganic silts of intermediate and high plasticity**	MI-MH	-	-	0	1	6	7	69	17	21.18	2.008	1.657	50	30	20	UU	38	7	12	19	2.67	0.120	0.611
1.50		-	7	9.82	-	-	-	-	-	-	20.17	-	-	-	-	-	-	-	-	-	-	-	-	-
2.50	**Inorganic clay of intermediate and high plasticity**	CI-CH	-	-	1	1	3	5	70	20	27.87	2.048	1.602	50	27	23	UU	45	6	14	21	2.67	0.140	0.667
3.00		-	12	14.02	-	-	-	-	-	-	22.21	-	-	-	-	-	-	-	-	-	-	-	-	-
4.50		-	16	15.98	-	-	-	-	-	-	14.14	-	-	-	-	-	-	-	-	-	-	-	-	-
5.00	**Silty sand**	SM	-	-	0	1	10	28	61	0	13.15	1.878	1.660	Non-Plastic			DST	0	24	-	-	2.65	0.070	0.596
6.00		-	10	9.42	-	-	-	-	-	-	12.76	-	-	-	-	-	-	-	-	-	-	-	-	-
7.50		-	18	14.37	-	-	-	-	-	-	19.16	-	-	-	-	-	-	-	-	-	-	-	-	-
8.00	**Inorganic silts of intermediate plasticity**	MI	-	-	4	5	6	5	66	14	19.59	2.051	1.715	41	26	15	UU	30	18	13	-	2.67	0.110	0.557
9.00		-	18	13.33	-	-	-	-	-	-	17.88	-	-	-	-	-	-	-	-	-	-	-	-	-
10.50		-	23	14.34	-	-	-	-	-	-	19.12	-	-	-	-	-	-	-	-	-	-	-	-	-
11.00	**Inorganic silts of low and intermediate plasticity**	ML-MI		-	2	1	2	3	86	6	18.25	2.034	1.720	35	26	9	UU	25	14	16	-	2.66	0.102	0.547
12.00		-	34	17.37	-	-	-	-	-	-	17.60	-	-	-	-	-	-	-	-	-	-	-	-	-

APPENDIX 'B'
SUMMARY OF TEST RESULTS (BH-2)

Bore hole depth	Soil Description	Soil classification	SPT		Grain Size Analysis						Density and Moisture			Atterberg Limits			Shear Strength Parameters			Shrinkage Limit (%)	Free Swell Index (%)	Specific Gravity Gs	Consolidation Characteristic	
			Observed	Corrected	Gravel (%)	Course Sand (%)	Medium Sand (%)	Fine Sand (%)	Silt (%)	Clay (%)	moisture Content (%)	Bulk Density (gm/cc)	Dry Density (gm/ cc)	Liquid Limit (%)	Plastic Limit (%)	Plastic Index (%)	Type of test	C (KN/m^2)	Φ (Degrees)				C_c	Void Ratio, e_0
13.50	**Inorganic silts of intermediate plasticity**	-	41	18.73	-	-	-	-	-	-	16.02	-	-	-	-	-	-	-	-	-	-	-	-	-
14.00		MI		-	9	3	6	3	68	11	18.15	2.038	1.725	40	27	13	UU	28	20	13	-	2.66	0.107	0.542
15.00		-	37	16.46	-	-	-	-	-	-	17.83	-	-	-	-	-	-	-	-	-	-	-	-	-
16.50		-	44	17.73	-	-	-	-	-	-	19.34	-	-	-	-	-	-	-	-	-	-	-	-	-
17.00	**Inorganic silts of intermediate plasticity**	MI	-	-	4	2	4	3	75	12	17.25	2.005	1.710	42	28	14	UU	29	16	-	-	2.66	0.108	0.556
18.00		-	45	17.16	-	-	-	-	-	-	18.95	-	-	-	-	-	-	-	-	-	-	-	-	-
19.50		-	57	19.63	-	-	-	-	-	-	18.74	-	-	-	-	-	-	-	-	-	-	-	-	-
20.00	**Inorganic clay of intermediate and high plasticity**	MI-MH	-	-	1	1	1	3	78	16	17.45	2.014	1.715	50	30	20	UU	45	9	-	-	2.66	0.115	0.551

APPENDIX 'B'
SUMMARY OF TEST RESULTS (BH-3)

Bore hole depth	Soil Description	Soil classification	SPT		Grain Size Analysis						Density and Moisture			Atterberg Limits			Shear Strength Parameters			Shrinkage Limit (%)	Free Swell Index (%)	Specific Gravity Gs	Consolidation Characteristic	
			Observed	Corrected	Gravel (%)	Course Sand (%)	Medium Sand (%)	Fine Sand (%)	Silt (%)	Clay (%)	moisture Content (%)	Bulk Density (gm/cc)	Dry Density (gm/ cc)	Liquid Limit (%)	Plastic Limit (%)	Plastic Index (%)	Type of test	C (KN/m^2)	Φ (Degrees)				C_c	Void Ratio, e_0
1.00	**Inorganic Silts of intermediate and high plasticity**	MI-MH	-	-	0	1	4	4	74	17	22.02	1.949	1.597	50	30	20	UU	40	7	11	17	2.67	0.120	0.672
1.50		-	7	9.89	-	-	-	-	-	-	23.03	-	-	-	-	-	-	-	-	-	-	-	-	-
2.50	**Inorganic silts of High plasticity**	MH	-	-	0	0	2	2	78	18	22.70	1.980	1.614	52	30	22	UU	42	6	13	19	2.67	0.122	0.654
3.00		-	9	10.61	-	-	-	-	-	-	22.32	-	-	-	-	-	-	-	-	-	-	-	-	-
4.50		-	11	11.46	-	-	-	-	-	-	24.29	-	-	-	-	-	-	-	-	-	-	-	-	-
5.00		MH	-	-	5	2	2	2	73	16	21.30	2.010	1.657	51	30	21	UU	42	16	12	15	2.67	0.115	0.611
6.00		-	17	15.11	-	-	-	-	-	-	18.69	-	-	-	-	-	-	-	-	-	-	-	-	-
7.50		-	14	12.16	-	-	-	-	-	-	16.55	-	-	-	-	-	-	-	-	-	-	-	-	-
8.00	**Inorganic silts of intermediate plasticity**	MI	-	-	1	4	6	5	70	14	17.50	2.128	1.811	45	28	17	UU	40	12	14	-	2.67	0.115	0.474
9.00		-	20	14.06	-	-	-	-	-	-	17.62	-	-	-	-	-	-	-	-	-	-	-	-	-
10.50		-	22	13.86	-	-	-	-	-	-	17.42	-	-	-	-	-	-	-	-	-	-	-	-	-
11.00		MI		-	9	6	6	3	64	12	16.30	2.152	1.850	41	28	13	UU	38	20	10	-	2.67	0.105	0.443
12.00		-	26	14.39	-	-	-	-	-	-	14.64	-	-	-	-	-	-	-	-	-	-	-	-	-
13.50		-	40	18.17	-	-	-	-	-	-	16.75	-	-	-	-	-	-	-	-	-	-	-	-	-

APPENDIX 'B'
SUMMARY OF TEST RESULTS (BH-3)

Bore hole depth	Soil Description	Soil classification	SPT		Grain Size Analysis						Density and Moisture			Atterberg Limits			Shear Strength Parameters			Shrinkage Limit (%)	Free Swell Index (%)	Specific Gravity Gs	Consolidation Characteristic	
			Observed	Corrected	Gravel (%)	Course Sand (%)	Medium Sand (%)	Fine Sand (%)	Silt (%)	Clay (%)	moisture Content (%)	Bulk Density (gm/cc)	Dry Density (gm/ cc)	Liquid Limit (%)	Plastic Limit (%)	Plastic Index (%)	Type of test	C (KN/m^2)	Φ (Degrees)				C_c	Void Ratio, e_0
14.00	**Inorganic silts of intermediate plasticity**	MI		-	2	2	6	4	77	9	16.30	2.140	1.840	42	28	14	UU	35	14	-	-	2.67	0.108	0.451
15.00		-	48	19.66	-	-	-	-	-	-	16.11	-	-	-	-	-	-	-	-	-	-	-	-	-
16.50		-	57	21.28	-	-	-	-	-	-	16.69	-	-	-	-	-	-	-	-	-	-	-	-	-
17.00		MI	-	-	7	2	3	4	72	12	13.46	2.172	1.914	41	26	15	UU	35	18	-		2.67	0.107	0.395
18.00		-	65	22.42	-	-	-	-	-	-	15.26	-	-	-	-	-	-	-	-	-	-	-	-	-
19.50		-	68	22.11	-	-	-	-	-	-	14.22	-	-	-	-	-	-	-	-	-	-	-	-	-
20.00		MI	-	-	5	5	5	3	75	7	14.10	2.160	1.893	40	28	12	UU	25	16	-	-	2.67	0	0.410

APPENDIX 'B'
SUMMARY OF TEST RESULTS (BH-4)

Bore hole depth	Soil Description	Soil classification	SPT		Grain Size Analysis						Density and Moisture			Atterberg Limits			Shear Strength Parameters			Shrinkage Limit (%)	Free Swell Index (%)	Specific Gravity Gs	Consolidation Characteristic	
			Observed	Corrected	Gravel (%)	Course Sand (%)	Medium Sand (%)	Fine Sand (%)	Silt (%)	Clay (%)	moisture Content (%)	Bulk Density (gm/cc)	Dry Density (gm/ cc)	Liquid Limit (%)	Plastic Limit (%)	Plastic Index (%)	Type of test	C (KN/m^2)	Φ (Degrees)				C_c	Void Ratio, e_0
1.00	**Inorganic clay of intermediate and high plasticity**	CI-CH	-	-	0	1	2	2	75	20	21.90	1.871	1.535	50	30	22	UU	45	7	14	21	2.67	0.135	0.739
1.50		-	7	9.99	-	-	-	-	-	-	21.77	-	-	-	-	-	-	-	-	-	-	-	-	-
2.50	**Inorganic silts of intermediate plasticity**	MI	-	-	3	1	3	2	75	16	25.63	1.936	1.541	48	28	20	UU	41	9	13	15	2.67	0.120	0.733
3.00		-	10	11.89	-	-	-	-	-	-	21.84	-	-	-	-	-	-	-	-	-	-	-	-	-
4.50		-	11	11.57	-	-	-	-	-	-	24.08	-	-	-	-	-	-	-	-	-	-	-	-	-
5.00	**Inorganic Silts of intermediate and high plasticity**	MI-MH	-	-	1	1	3	2	77	16	21.37	1.895	1.561	50	30	20	UU	45	11	12	-	2.67	0.120	0.710
6.00		-	15	14.34	-	-	-	-	-	-	19.80	-	-	-	-	-	-	-	-	-	-	-	-	-
7.50		-	17	14.12	-	-	-	-	-	-	18.02	-	-	-	-	-	-	-	-	-	-	-	-	-
8.00	**Inorganic clay of intermediate plasticity**	CI	-	-	1	1	1	2	80	15	20.81	1.945	1.610	45	26	19	UU	40	12	13	-	2.67	0.117	0.658
9.00		-	20	14.35	-	-	-	-	-	-	17.26	-	-	-	-	-	-	-	-	-	-	-	-	-
10.50		-	23	14.59	-	-	-	-	-	-	17.72	-	-	-	-	-	-	-	-	-	-	-	-	-
11.00	**Inorganic silts of intermediate plasticity**	MI		-	1	3	2	6	75	13	17.76	1.945	1.652	42	27	15	UU	38	11	12	-	2.67	0.115	0.616
12.00		-	22	13.37	-	-	-	-	-	-	17.17	-	-	-	-	-	-	-	-	-	-	-	-	-
13.50		-	31	15.70	-	-	-	-	-	-	18.70	-	-	-	-	-	-	-	-	-	-	-	-	-

APPENDIX 'B'
SUMMARY OF TEST RESULTS (BH-4)

Bore hole depth	Soil Description	Soil classification	SPT		Grain Size Analysis						Density and Moisture			Atterberg Limits			Shear Strength Parameters			Shrinkage Limit (%)	Free Swell Index (%)	Specific Gravity Gs	Consolidation Characteristic	
			Observed	Corrected	Gravel (%)	Course Sand (%)	Medium Sand (%)	Fine Sand (%)	Silt (%)	Clay (%)	moisture Content (%)	Bulk Density (gm/cc)	Dry Density (gm/ cc)	Liquid Limit (%)	Plastic Limit (%)	Plastic Index (%)	Type of test	C (KN/m^2)	Φ (Degrees)				C_c	Void Ratio, e_0
14.00		MI		-	1	1	3	3	80	12	18.60	1.981	1.670	42	27	15	UU	39	12	-	-	2.67	0.112	0.599
15.00	**Inorganic silts of intermediate plasticity**	-	40	17.78	-	-	-	-	-	-	18.50	-	-	-	-	-	-	-	-	-	-	-	-	-
16.50		-	40	16.88	-	-	-	-	-	-	18.83	-	-	-	-	-	-	-	-	-	-	-	-	-
17.00		MI	-	-	2	2	4	5	80	7	15.30	1.949	1.690	40	28	12	UU	20	15	-		2.66	0.106	0.574
18.00		-	46	17.83	-	-	-	-	-	-	13.55	-	-	-	-	-	-	-	-	-	-	-	-	-
19.50		-	58	20.35	-	-	-	-	-	-	19.12	-	-	-	-	-	-	-	-	-	-	-	-	-
20.00		MI	-	-	3	1	3	3	83	7	19.50	2.037	1.705	40	28	12	UU	20	16	-	-	2.66	0.105	0.560

APPENDIX 'B'
SUMMARY OF TEST RESULTS (BH-5)

Bore hole depth	Soil Description	Soil classification	SPT		Grain Size Analysis						Density and Moisture			Atterberg Limits			Shear Strength Parameters			Shrinkage Limit (%)	Free Swell Index (%)	Specific Gravity Gs	Consolidation Characteristic	
			Observed	Corrected	Gravel (%)	Course Sand (%)	Medium Sand (%)	Fine Sand (%)	Silt (%)	Clay (%)	moisture Content (%)	Bulk Density (gm/cc)	Dry Density (gm/ cc)	Liquid Limit (%)	Plastic Limit (%)	Plastic Index (%)	Type of test	C (KN/m^2)	Φ (Degrees)				C_c	Void Ratio, e_0
1.00	**Inorganic silt of high plasticity**	MH	-	-	1	2	7	9	64	17	22.36	1.909	1.560	52	30	22	UU	35	10	15	18	2.67	0.120	0.712
1.50		-	10	14.20	-	-	-	-	-	-	18.53	-	-	-	-	-	-	-	-	-	-	-	-	-
2.50	**Inorganic silts of intermediate and high plasticity**	MI-MH	-	-	2	2	4	12	65	15	20.82	1.921	1.590	50	30	20	UU	35	10	14	14	2.67	0.118	0.679
3.00		-	9	10.68	-	-	-	-	-	-	19.37	-	-	-	-	-	-	-	-	-	-	-	-	-
4.50		-	14	14.72	-	-	-	-	-	-	20.20	-	-	-	-	-	-	-	-	-	-	-	-	-
5.00	**Inorganic silts of intermediate plasticity**	MI	-	-	3	3	6	14	64	10	18.10	1.984	1.680	42	28	14	UU	28	16	12	-	2.66	0.110	0.583
6.00		-	13	12.38	-	-	-	-	-	-	15.55	-	-	-	-	-	-	-	-	-	-	-	-	-
7.50		-	15	13.14	-	-	-	-	-	-	17.88	-	-	-	-	-	-	-	-	-	-	-	-	-
8.00		MI	-	-	2	1	2	5	81	9	19.45	2.205	1.846	41	28	13	UU	26	15	11	-	2.66	0.111	0.441
9.00		-	16	12.51	-	-	-	-	-	-	18.17	-	-	-	-	-	-	-	-	-	-	-	-	-
10.50		-	18	12.39	-	-	-	-	-	-	17.62	-	-	-	-	-	-	-	-	-	-	-	-	-
11.00		MI		-	0	0	1	3	85	11	15.60	2.150	1.860	45	28	17	UU	29	13	12	-	2.66	0.112	0.430
12.00		-	23	13.36	-	-	-	-	-	-	13.39	-	-	-	-	-	-	-	-	-	-	-	-	-
13.50		-	31	15.22	-	-	-	-	-	-	15.94	-	-	-	-	-	-	-	-	-	-	-	-	-

APPENDIX 'B'
SUMMARY OF TEST RESULTS (BH-5)

Bore hole depth	Soil Description	Soil classification	SPT		Grain Size Analysis						Density and Moisture			Atterberg Limits			Shear Strength Parameters			Shrinkage Limit (%)	Free Swell Index (%)	Specific Gravity Gs	Consolidation Characteristic	
			Observed	Corrected	Gravel (%)	Course Sand (%)	Medium Sand (%)	Fine Sand (%)	Silt (%)	Clay (%)	moisture Content (%)	Bulk Density (gm/cc)	Dry Density (gm/ cc)	Liquid Limit (%)	Plastic Limit (%)	Plastic Index (%)	Type of test	C (KN/m^2)	Φ (Degrees)				C_c	Void Ratio, e_0
14.00	**Inorganic silts of intermediate plasticity**	MI		-	4	3	5	6	74	8	15.75	2.159	1.865	40	28	12	UU	20	16	-	-	2.66	0.107	0.426
15.00		-	44	18.43	-	-	-	-	-	-	15.63	-	-	-	-	-	-	-	-	-	-	-	-	-
16.50		-	49	18.92	-	-	-	-	-	-	14.99	-	-	-	-	-	-	-	-	-	-	-	-	-
17.00		MI	-	-	6	4	8	8	68	6	17.50	2.200	1.872	38	28	10	UU	16	18	-		2.66	0.106	0.421
18.00		-	59	20.74	-	-	-	-	-	-	21.04	-	-	-	-	-	-	-	-	-	-	-	-	-
19.50		-	67	21.82	-	-	-	-	-	-	20.61	-	-	-	-	-	-	-	-	-	-	-	-	-
20.00		MI	-	-	3	0	3	18	70	6	20.90	2.291	1.895	40	28	12	UU	16	16	-	-	2.66	0.106	0.404

APPENDIX 'B'
TABLE-2 : CBR TEST RESULTS

CBR SAMPLE NO.	Soil Description	Soil Classification	CBR VALUE		Grain Size Analysis						Density and Moisture			Atterberg Limits		
			Unsoaked	Soaked (4.0H)	Gravel (%)	Course Sand (%)	Medium Sand (%)	Fine Sand (%)	Silt (%)	Clay (%)	Moisture Content (%)	Dry density after Soaking (gm/cc)	Bulk density after soaking (gm/cc)	Liquid Limit (%)	Plastic Limit (%)	Plastic Index (%)
1	Inorganic silts of intermediate plasticity	MI	7.9	5.4	7	3	2	1	75	12	20.30	1.630	1.960	38	28	10
2	Inorganic clays of intermediate plasticity	CI	6.7	4.7	8	4	1	1	68	18	24.50	1.560	1.942	45	26	19
3	Inorganic silts of intermediate plasticity	MI	7.7	4.7	0	1	0	1	85	13	25.50	1.580	1.982	45	28	17
4		MI	7.8	4.8	1	0	1	1	85	12	22.50	1.570	1.923	40	28	12
5		MI	8.2	5.2	1	1	1	2	84	11	22.30	1.530	1.871	41	28	13
6	Inorganic clays of intermediate plasticity	CI	6.5	5.5	4	1	1	2	76	16	20.50	1.545	1.861	47	26	21
7	Inorganic silts of intermediate plasticity	MI	8.3	5.6	2	1	1	2	82	12	20.30	1.550	1.864	42	28	14
8		MI	7.5	4.5	0	0	1	3	86	10	17.50	1.520	1.786	40	28	12
9		MI	8.7	6.7	5	6	1	1	76	11	16.90	1.565	1.829	41	28	13

CBR SAMPLE NO.	Soil Description	Soil Classification	CBR VALUE		Grain Size Analysis						Density and Moisture			Atterberg Limits		
			Unsoaked	Soaked (4.0 Hours)	Gravel (%)	Course Sand (%)	Medium Sand (%)	Fine Sand (%)	Silt (%)	Clay (%)	Moisture Content (%)	Dry density after Soaking (gm/cc)	Bulk density after soaking (gm/cc)	Liquid Limit (%)	Plastic Limit (%)	Plastic Index (%)
10	**Inorganic silts of intermediate plasticity**	MI	7.9	6.4	11	9	2	1	70	7	20.50	1.560	1.879	40	28	12
11		MI	7.7	6.0	12	5	2	5	66	11	15.90	1.565	1.813	41	28	13
12		MI	7.5	5.0	0	3	5	2	80	10	22.50	1.580	1.935	47	26	21
13		MI	8.1	6.2	0	7	12	5	66	11	18.30	1.575	1.863	42	28	14
14		MI	7.9	5.4	0	2	1	0	85	12	12.50	1.560	1.755	40	28	12
15		MI	7.8	5.6	0	1	1	0	88	10	12.80	1.570	1.771	41	28	13
16		MI	7.5	6.0	0	1	8	8	76	12	20.10	1.530	1.837	40	28	12
17		MI	7.9	6.9	0	1	6	7	76	10	21.18	1.520	1.849	41	28	13
18		MI	7.9	6.5	0	1	4	4	79	12	22.02	1.521	1.858	47	26	21
19		MI	7.1	6.5	0	1	2	2	84	11	21.90	1.530	1.865	42	28	14

APPENDIX-B

TABLE-3 : CHEMICAL TEST RESULTS ON SOIL SAMPLES

Bore No.	Depth of Sample (m)	pH	Salt (mg/litre)	
			Sulphates	Chlorides
BH-1	2.50	7.30	230	240
BH-2	2.50	7.50	235	266
BH-3	2.50	7.40	245	255
BH-4	2.50	7.45	238	245
BH-5	2.50	7.55	220	235

APPENDIX-B

TABLE-4 : CHEMICAL TEST RESULTS ON WATER SAMPLES

Bore No.	Depth of Sample (m)	pH	Salt (mg/litre)			
			Sulphates	Chlorides	Hardness	Iron
BH-1	1.60	7.60	225	265	1250	1.2
BH-2	1.00	7.50	235	270	1300	1.1
BH-3	1.00	7.40	240	275	1320	1.3
BH-4	1.20	7.70	230	280	1300	1.1
BH-5	1.00	7.50	225	260	1350	1.3

APPENDIX- C
CHART 1: - BORE LOG CHART (BH-1)

Techpro EngineersPvt. Ltd. — **Bore/ Drill Log**

Project:. GEO-TECH Inv. Nalanda University. Rajgir. Bihar
Bore Hole No.: 01
Location:. Nalanda-University. Bihar
Ground Elevation:
Method of Boring/ Drilling: Auger. Shell
Water Level (Static): 1.60 mt
Boring/ Drilling Equipments: Power. Winch
Dia. Of Boring / Drilling :. 150 mm
Casing Lowered : 20
Date: From 10-10-14 to 10-10-14

Date (dd/ mm)	Elevation (m)	Depth/ RUN (m) From	To	Length (m)	Nature of Sampling	SPT: No. of blows 0-15 cm	15-30 cm	30-45 cm	N Value	Time Taken (min)	Total length of Core Pieces (m)	Core Recovery (%)	R. Q. D. (%)	Description
		1.00	1.45	0.45	U	—	—	—						Clay Soil
		1.50	1.95	"	DS	3	4	5	9					"
		2.50	2.95	"	U	—	—	—						"
		3.00	3.45	"	DS	5	6	7	13					"
		4.50	4.95	"	DS	5	6	11	17					"
		5.00	5.45	"	U	—	—	—						"
		6.00	6.45	"	DS	4	7	12	19					"
		7.50	7.95	"	DS	5	9	13	22					"
		8.00	8.45	"	U	—	—	—						"
		9.00	9.45	"	DS	8	14	19	33					"
		10.50	10.95	"	DS	8	13	21	34					Clay Gravel Soil
		11.00	11.45	"	U	—	—	—						"
		12.00	12.45	"	DS	7	11	21	32					"
		13.50	13.95	"	DS	8	19	23	42					"
		14.00	14.45	"	U	—	—	—						"
		15.00	15.45	"	DS	7	15	20	45					"
		16.50	16.95	"	DS	9	16	22	38					"
		17.00	17.45	"	U	—	—	—						"
		18.00	18.45	"	DS	12	18	24	42					"
		19.50	19.95	"	DS	15	21	36	57					"
		20.00	20.45	"	U	—	—	—						"

For Techpro Engineers Pvt. Ltd.
Site Supervisor
10/10/14

Abbreviation Used: U - Undisturbed Sample C-Core Sample D- Disturbed Sample P - Standard Penetration Test
R: Refusal (Standard Penetration Test (N) >100)

APPENDIX- C
CHART 2: - BORE LOG CHART (BH-2)

Techpro EngineersPvt. Ltd. — **Bore/ Drill Log**

Project:. Geotech Invtgt. Nalanda University Rajgir. Bihar — Bore Hole No.: 02

Location:. Kamal Sagar Nalanda University. Bihar — Ground Elevation:

Method of Boring/ Drilling: Auger. Shell — Water Level (Static): 1. mt

Boring/ Drilling Equipments: Power winch — Dia. Of Boring / Drilling :. 150mm

Casing Lowered : 20 — Date: From 11-10-14 to 11-10-14

Date (dd/ mm)	Elevation (m)	Depth/ RUN (m) From	Depth/ RUN (m) To	Length (m)	Nature of Sampling	SPT: No. of blows 0-15 cm	15-30 cm	30-45 cm	N Value	Time Taken (min)	Total length of Core Pieces (m)	Core Recovery (%)	R. Q. D. (%)	Description
		1.00	1.45	045	U	—	—	—						Clay Gravel Soil
		1.50	1.95	"	DS	2	3	4	7					"
		2.50	2.95	"	U	—	—	—						"
		3.00	3.45	"	DS	3	5	7	12					"
		4.50	4.95	"	DS	4	7	9	16					"
		5.00	5.45	"	U	—	—	—						"
		6.00	6.45	"	DS	3	4	6	10					Clay Moorum Soil
		7.50	7.95	"	DS	5	7	11	18					Clay Gravel Soil
		8.00	8.45	"	U	—	—	—						"
		9.00	9.45	"	DS	6	8	10	18					"
		10.50	10.95	"	DS	8	10	13	23					"
		11.00	11.45	"	U	—	—	—						"
		12.00	12.45	"	DS	7	15	19	34					"
		13.50	13.95	"	DS	7	18	23	41					"
		14.00	14.45	"	U	—	—	—						"
		15.00	15.45	"	DS	9	16	21	37					"
		16.50	16.95	"	DS	12	19	25	44					"
		17.00	17.45	"	U	—	—	—						"
		18.00	18.45	"	DS	11	20	25	45					"
		19.50	19.95	"	DS	13	24	33	57					"
		20.00	20.45	"	U	—	—	—						"

For Techpro Engineers Pvt. Ltd.
Site Supervisor
11/10/14

Abbreviation Used: U - Undisturbed Sample C-Core Sample D- Disturbed Sample P - Standard Penetration Test
R: Refusal (Standard Penetration Test (N) >100)

APPENDIX- C
CHART 3: - BORE LOG CHART (BH-3)

Techpro EngineersPvt. Ltd. — **Bore/ Drill Log**

Project:: Geotech Inv. for Nalanda University Rajgir Bihar — Bore Hole No.: 03 BHA-01

Location:: Nalanda University Rajgir Bihar — Ground Elevation:

Method of Boring/ Drilling: Auger Shell — Water Level (Static): 1 mt

Boring/ Drilling Equipments: Power Winch M/C — Dia. Of Boring / Drilling :. 150 mm

Casing Lowered : 20 — Date: From 12-10-14 to 12-10-14

Date (dd/ mm)	Elevation (m)	Depth/ RUN (m) From	To	Length (m)	Nature of Sampling	SPT: No. of blows 0-15 cm	15-30 cm	30-45 cm	N Value	Time Taken (min)	Total length of Core Pieces (m)	Core Recovery (%)	R. Q. D. (%)	Description
		1.00	1.45	045	U	—	—	—						Clay Soil
		1.50	1.95	"	DS	2	3	4	7					"
		2.50	2.95	"	U	—	—	—						"
		3.00	3.45	"	DS	3	4	5	9					"
		4.50	4.95	"	DS	3	4	7	11					"
		5.00	5.45	"	U	—	—	—						"
		6.00	6.45	"	DS	5	7	10	17					Clay Gravel Soil
		7.50	7.95	"	DS	4	6	8	14					"
		8.00	8.45	"	U	—	—	—						"
		9.00	9.45	"	DS	6	9	11	20					"
		10.50	10.95	"	DS	5	10	12	22					"
		11.00	11.45	"	U	—	—	—						"
		12.00	12.45	"	DS	7	12	14	26					"
		13.50	13.95	"	DS	10	16	24	40					"
		14.00	14.45	"	U	—	—	—						"
		15.00	15.45	"	DS	13	20	28	48					Clay Soil
		16.50	16.95	"	DS	18	24	33	57					"
		17.00	17.45	"	U	—	—	—						"
		18.00	18.45	"	DS	16	28	37	65					"
		19.50	19.95	"	DS	20	29	39	68					"
		20.00	20.45	"	U	—	—	—						"

For Techpro Engineers Pvt. Ltd.
Pankaj
Site Supervisor
12/10/14

Abbreviation Used: U - Undisturbed Sample C-Core Sample D- Disturbed Sample P - Standard Penetration Test
R: Refusal (Standard Penetration Test (N) >100)

APPENDIX- C
CHART 4: - BORE LOG CHART (BH-4)

Techpro EngineersPvt. Ltd. Bore/ Drill Log

Project:. Geo Tech Inv. for. Nalanda University. Rajgir. Bihar — Bore Hole No.: 04

Location:. Nalanda University. Rajgir. Bihar — Ground Elevation:

Method of Boring/ Drilling: Auger Shill — Water Level (Static): 1.20 mt

Boring/ Drilling Equipments: Power winch M/C — Dia. Of Boring / Drilling :. 150 mm

Casing Lowered : 20 — Date: From 13-10-14 to 13-10-14

Date (dd/ mm)	Elevation (m)	Depth/ RUN (m) From	To	Length (m)	Nature of Sampling	SPT: No. of blows 0-15 cm	15-30 cm	30-45 cm	N Value	Time Taken (min)	Total length of Core Pieces (m)	Core Recovery (%)	R. Q. D. (%)	Description
		1.00	1.45	0.45	U	—	—	—						Clay Soil
		1.50	1.95	"	DS	2	3	4	7					"
		2.50	2.95	"	U	—	—	—						"
		3.00	3.45	"	DS	3	4	6	10					"
		4.50	4.95	"	DS	3	5	6	11					"
		5.00	5.45	"	U	—	—	—						"
		6.00	6.45	"	DS	4	6	9	15					"
		7.50	7.95	"	DS	3	6	11	17					"
		8.00	8.45	"	U	—	—	—						"
		9.00	9.45	"	DS	6	7	13	20					Clay Gravel Soil
		10.50	10.95	"	DS	7	11	12	23					"
		11.00	11.45	"	U	—	—	—						"
		12.00	12.45	"	DS	6	10	12	22					"
		13.50	13.95	"	DS	10	14	17	31					"
		14.00	14.45	"	U	—	—	—						"
		15.00	15.45	"	DS	13	19	21	40					"
		16.50	16.95	"	DS	9	16	24	40					"
		17.00	17.45	"	U	—	—	—						"
		18.00	18.45	"	DS	12	19	27	46					"
		19.50	19.95	"	DS	17	23	35	58					"
		20.00	20.00	"	U	—	—	—						"

For Techpro Engineers Pvt. Ltd.
Site Supervisor
13/10/14

Abbreviation Used: U - Undisturbed Sample C-Core Sample D- Disturbed Sample P - Standard Penetration Test
R: Refusal (Standard Penetration Test (N) >100)

APPENDIX- C
CHART 5: - BORE LOG CHART (BH-5)

Techpro EngineersPvt. Ltd. — **Bore/ Drill Log**

Project:. GeoTechInvfor Nalanda University Rajgir. Bihar
Location:. Firestation- Nalanda. University Rajgir. Bihar
Method of Boring/ Drilling: Augor Shill
Boring/ Drilling Equipments: Power winch M/C
Casing Lowered : 20

Bore Hole No.: 05 BHA-3
Ground Elevation:
Water Level (Static): 1.mt
Dia. Of Boring / Drilling :. 150 mm
Date: From 14-10-14 to 14-10-14

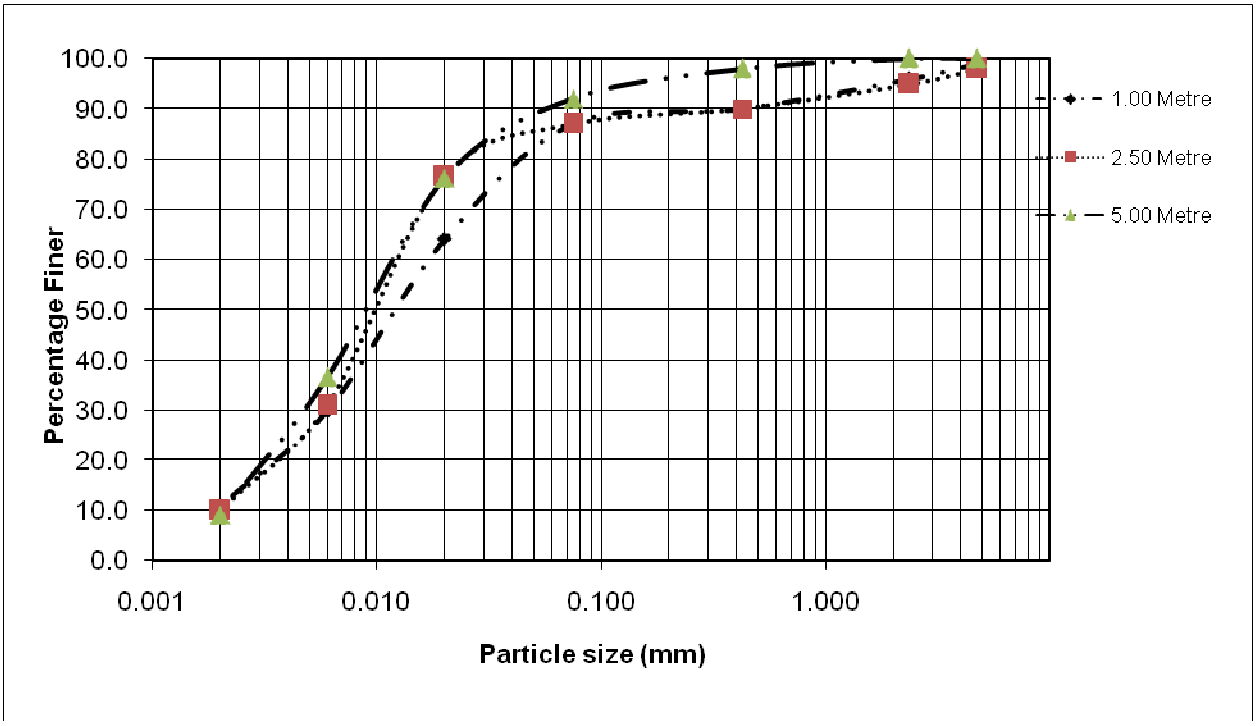
Date (dd/ mm)	Elevation (m)	Depth/ RUN (m) From	To	Length (m)	Nature of Sampling	SPT: No. of blows 0-15 cm	15-30 cm	30-45 cm	N Value	Time Taken (min)	Total length of Core Pieces (m)	Core Recovery (%)	R. Q. D. (%)	Description
		1.00	1.45	0.45	U									clay Soil
		1.50	1.95	"	DS	3	4	6	10					"
		2.50	2.95	"	U									"
		3.00	3.45	"	DS	2	4	5	9					"
		4.50	4.95	"	DS	4	6	8	14					"
		5.00	5.45	"	U									"
		6.00	6.45	"	DS	4	7	6	13					MooRam Soil
		7.50	7.95	"	DS	4	6	9	15					clay Soil
		8.00	8.45	"	U									"
		9.00	9.45	"	DS	5	7	9	16					"
		10.50	10.95	"	DS	7	8	10	18					"
		11.00	11.45	"	U									"
		12.00	12.45	"	DS	8	10	13	23					"
		13.50	13.95	"	DS	9	12	19	31					"
		14.00	14.45	"	U									Clay Gravel
		15.00	15.45	"	DS	10	21	23	44					"
		16.50	16.95	"	DS	11	23	26	49					"
		17.00	17.45	"	U									"
		18.00	18.45	"	DS	13	24	35	59					clay MooRam Soil
		19.50	19.95	"	DS	16	26	41	67					"
		20.00	20.00	"	U									"

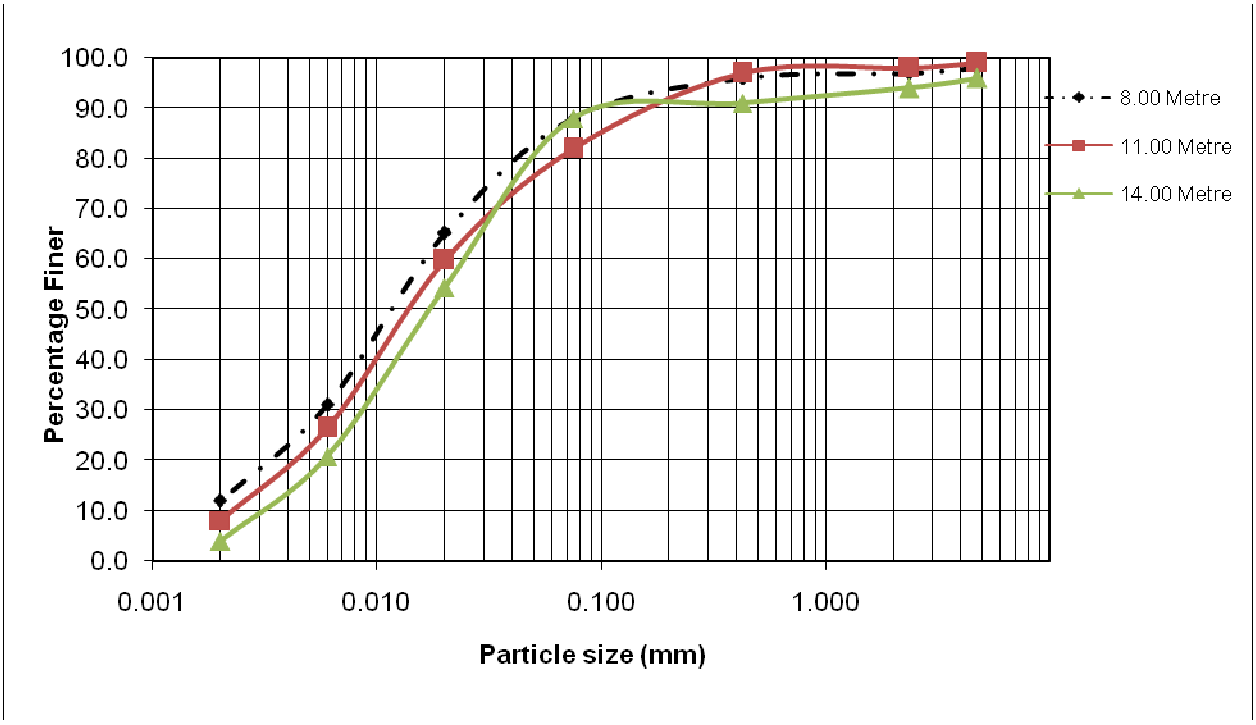
For Techpro Engineers Pvt. Ltd.
Site Supervisor

Abbreviation Used: U - Undisturbed Sample C-Core Sample D- Disturbed Sample P - Standard Penetration Test
R: Refusal (Standard Penetration Test (N) >100)

APPENDIX 'D'

GRAPH 1: PARTICLE GRADATION CURVE (BH-1)

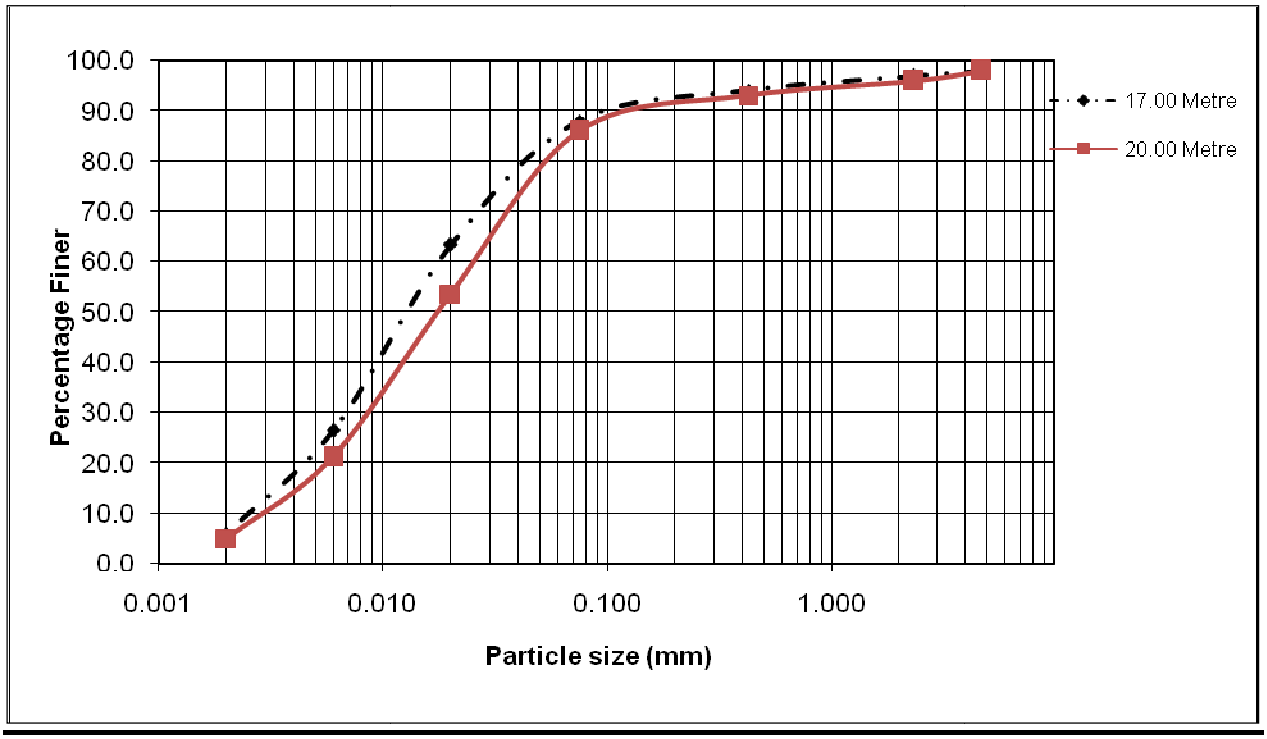




Note: - These are software generated curve

APPENDIX 'D'

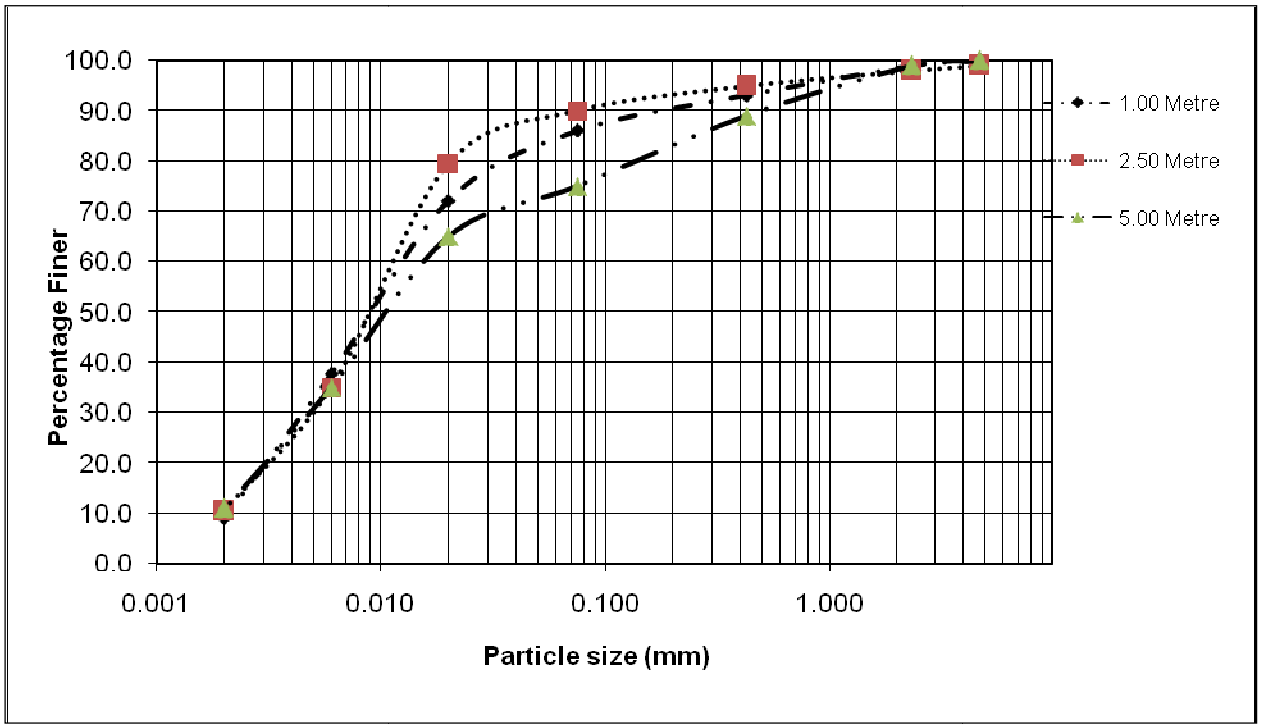
GRAPH 2: PARTICLE GRADATION CURVE (BH-1)

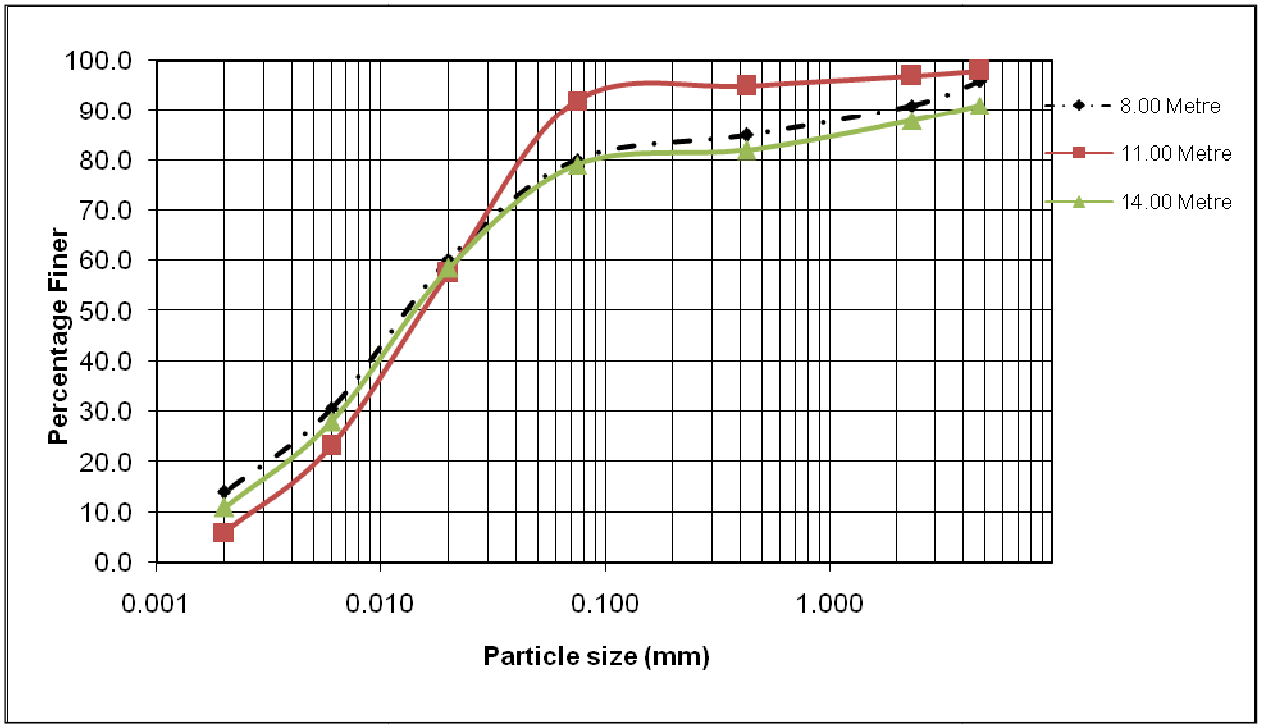


Note: - These are software generated curve

APPENDIX 'D'

GRAPH 3: PARTICLE GRADATION CURVE (BH-2)

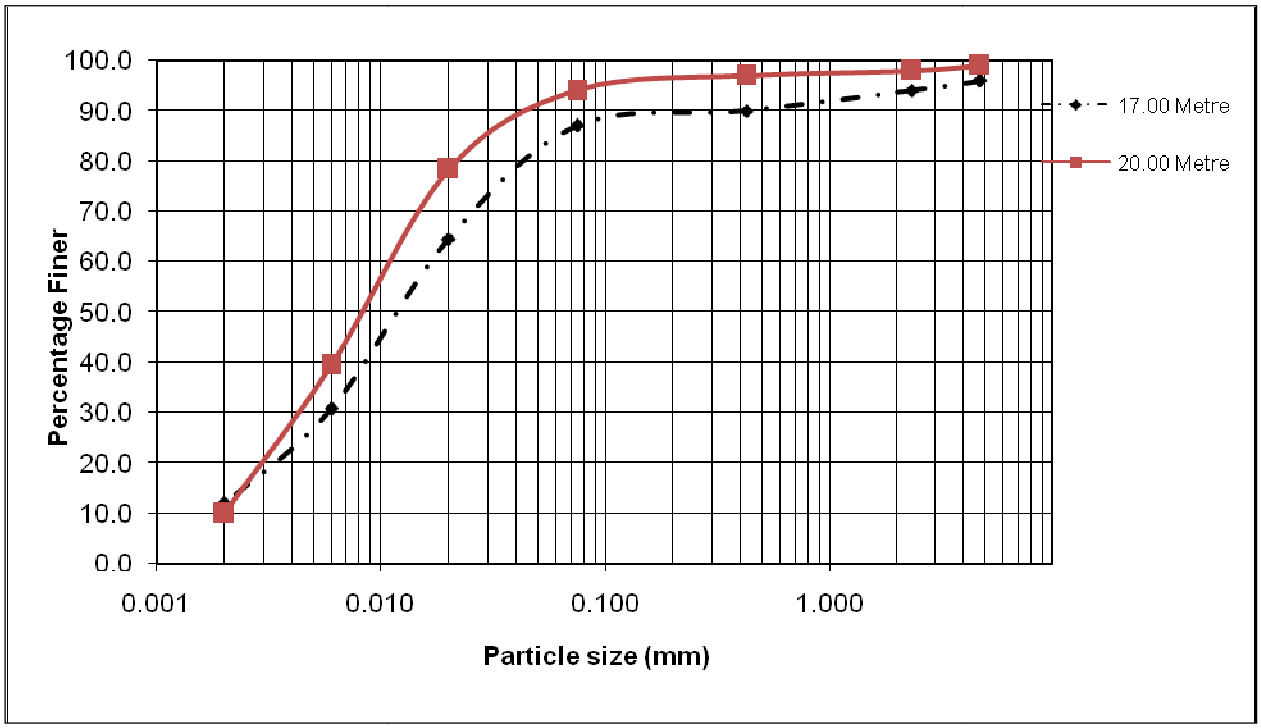




Note: - These are software generated curve

APPENDIX 'D'

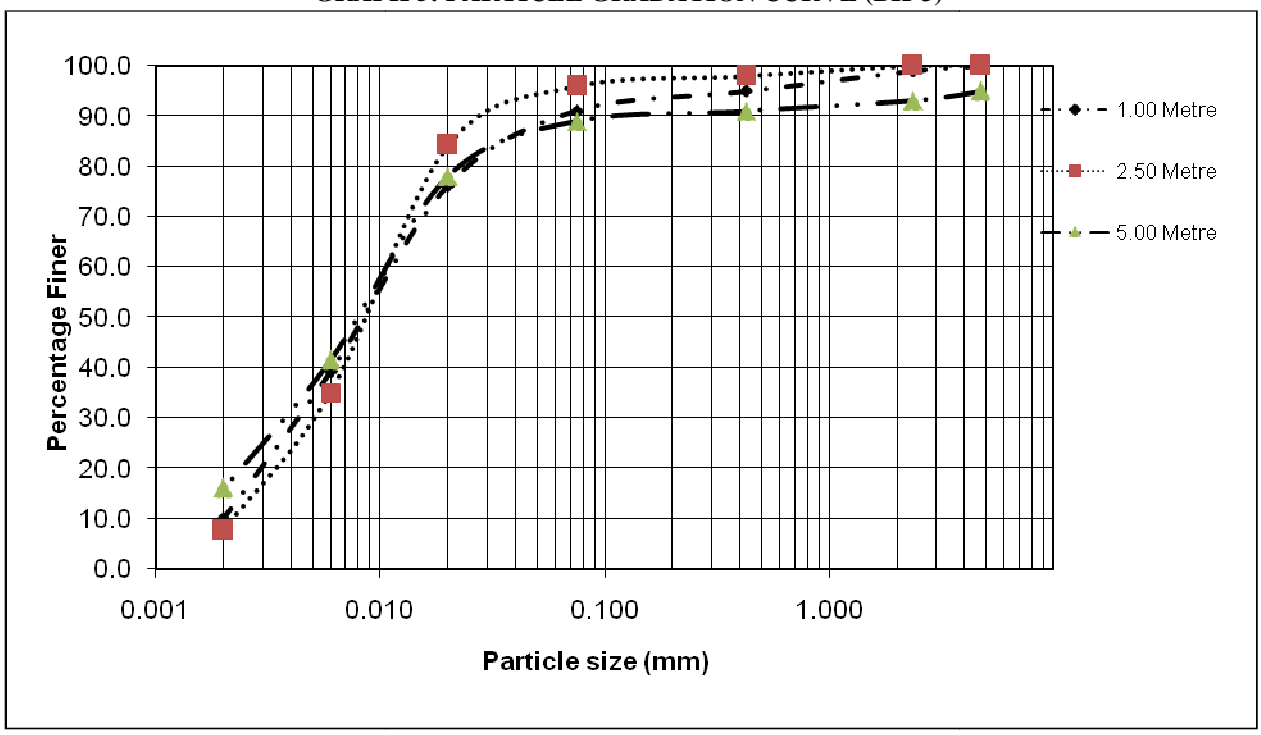
GRAPH 4: PARTICLE GRADATION CURVE (BH-2)

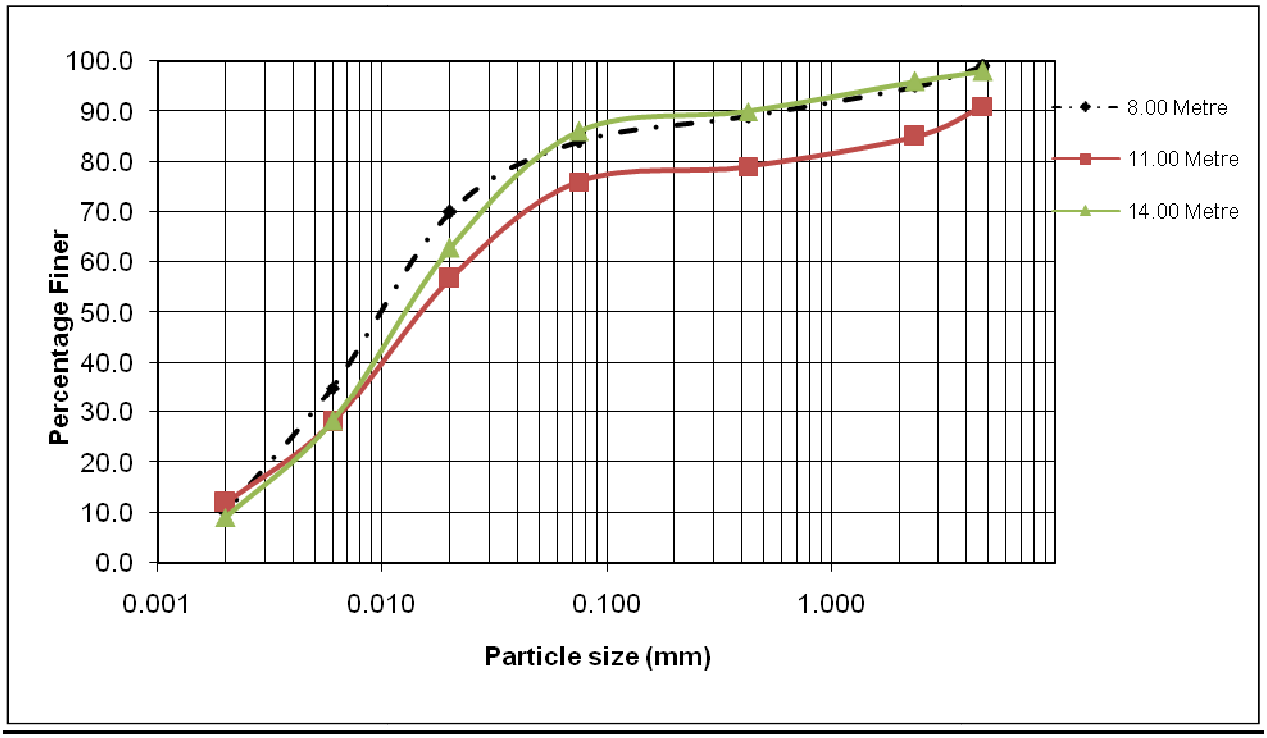


Note: - These are software generated curve

APPENDIX 'D'

GRAPH 5: PARTICLE GRADATION CURVE (BH-3)

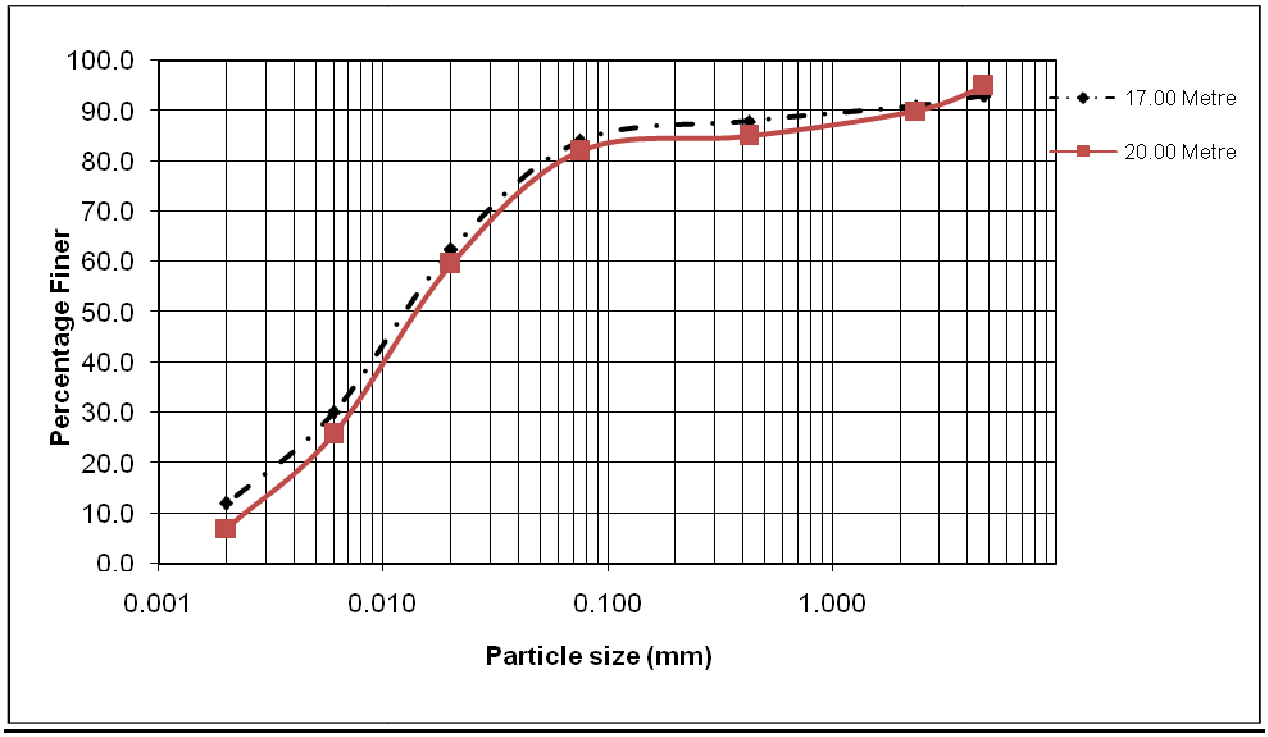




Note: - These are software generated curve

APPENDIX 'D'

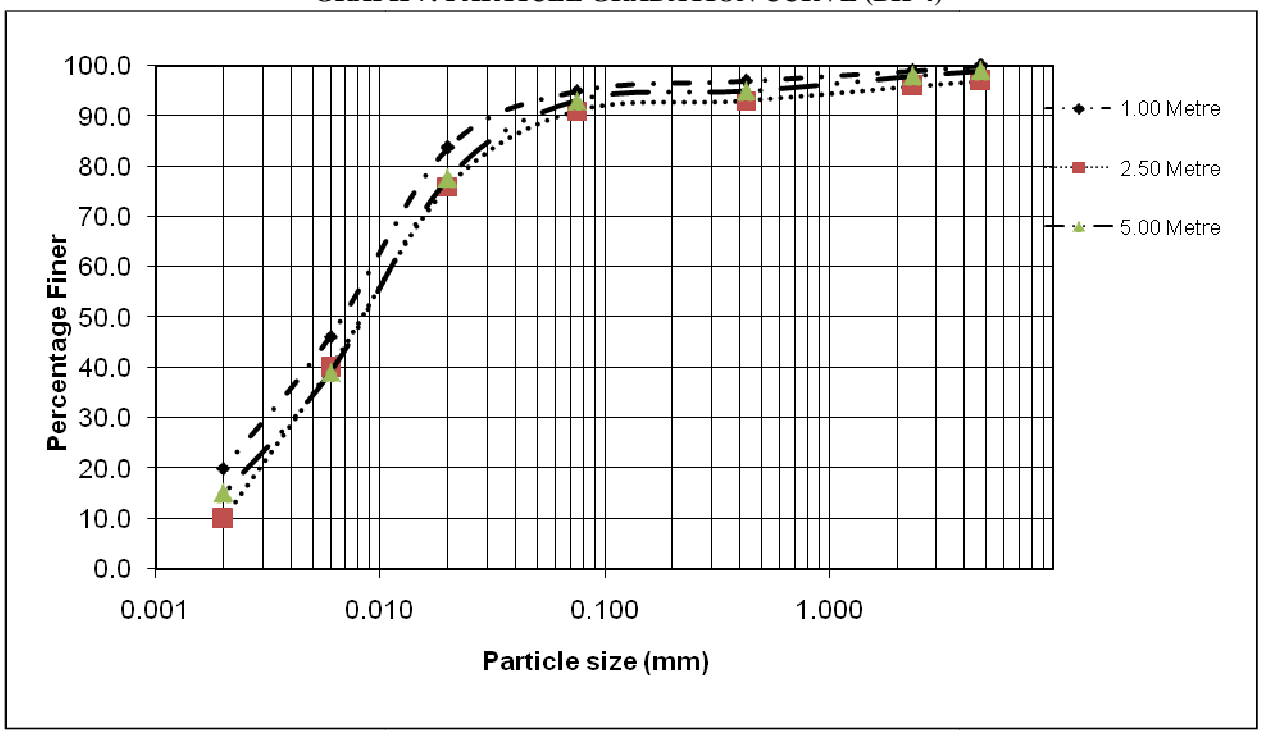
GRAPH 6: PARTICLE GRADATION CURVE (BH-3)

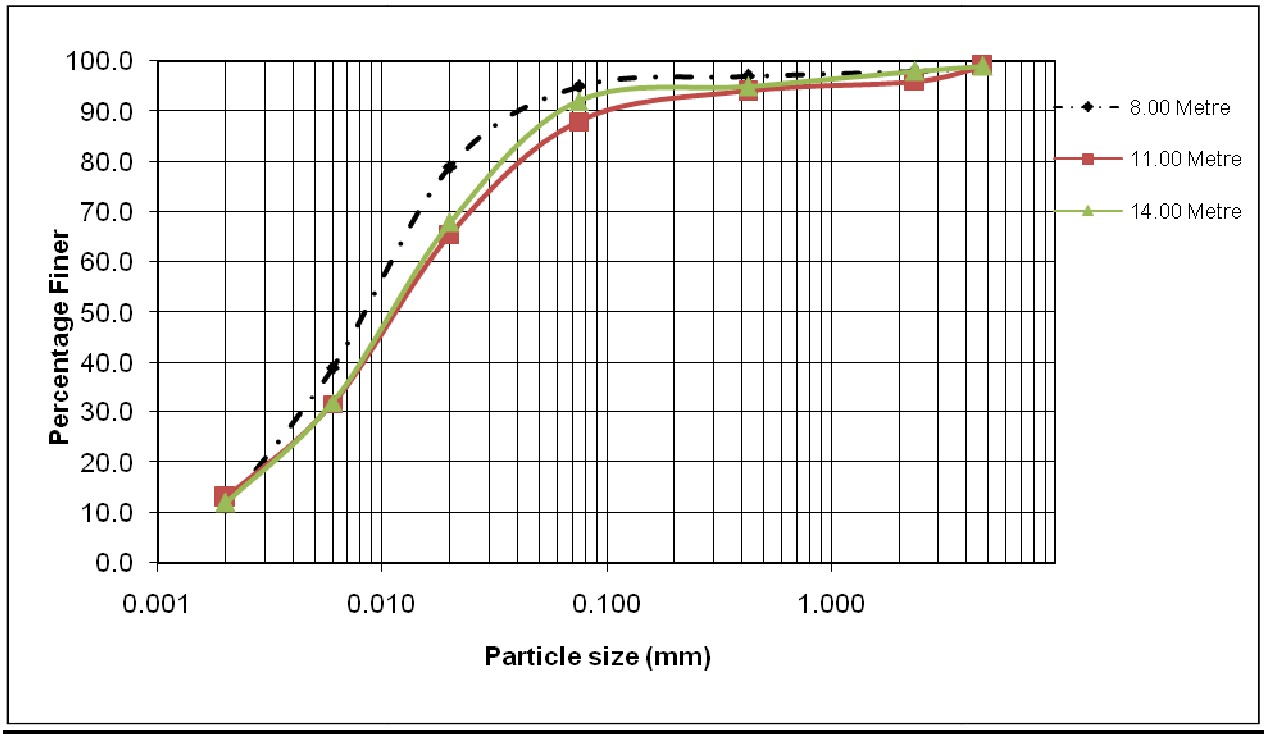


Note: - These are software generated curve

APPENDIX 'D'

GRAPH 7: PARTICLE GRADATION CURVE (BH-4)

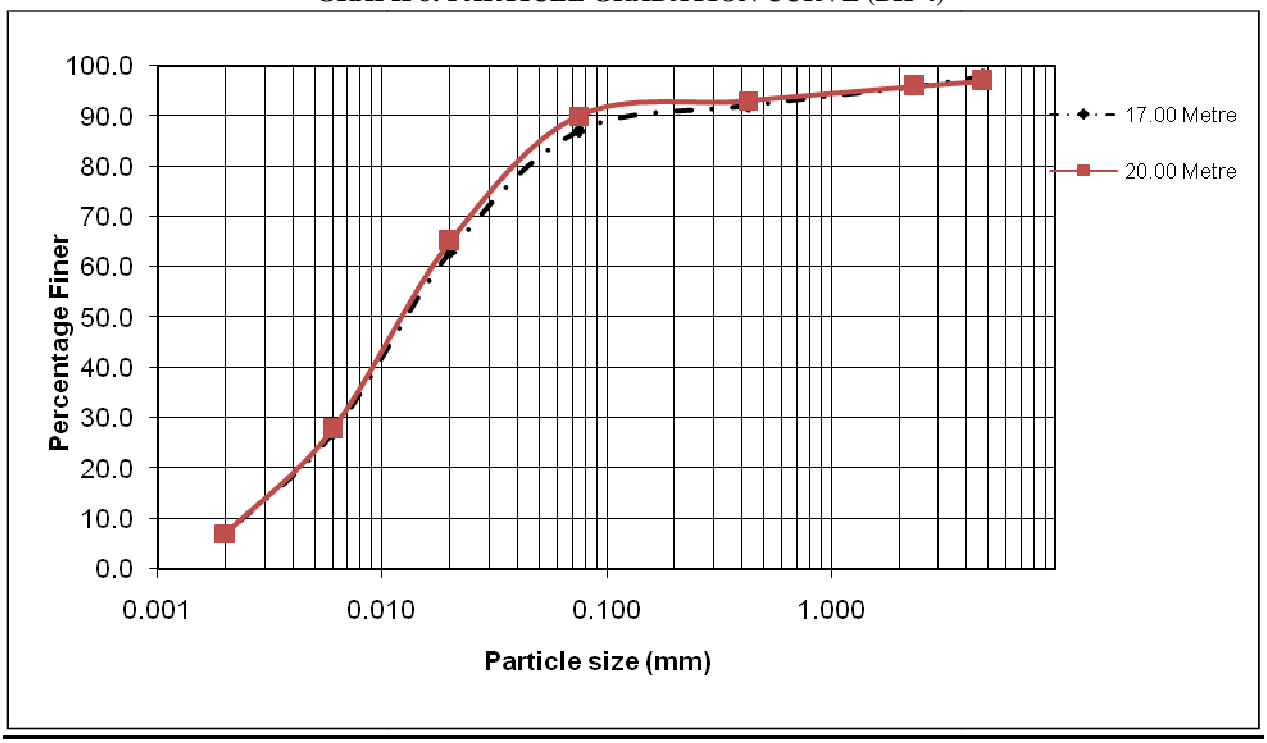




Note: - These are software generated curve

APPENDIX 'D'

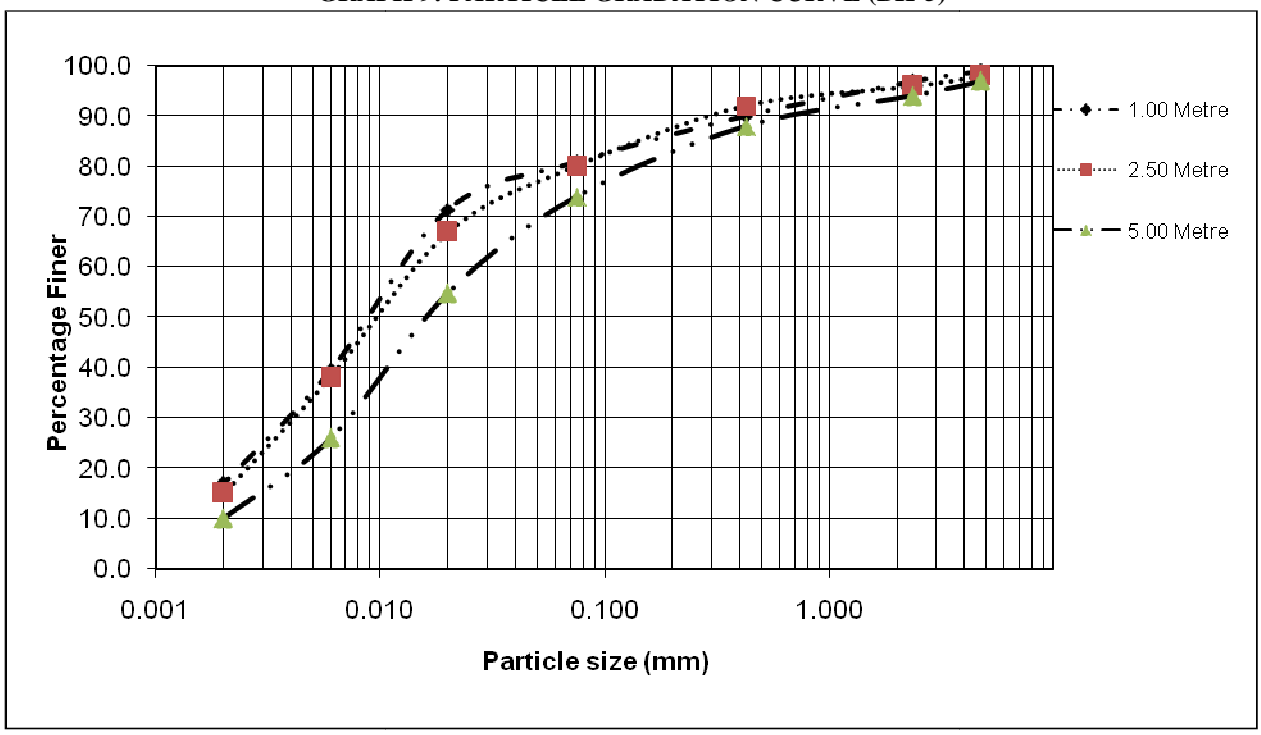
GRAPH 8: PARTICLE GRADATION CURVE (BH-4)

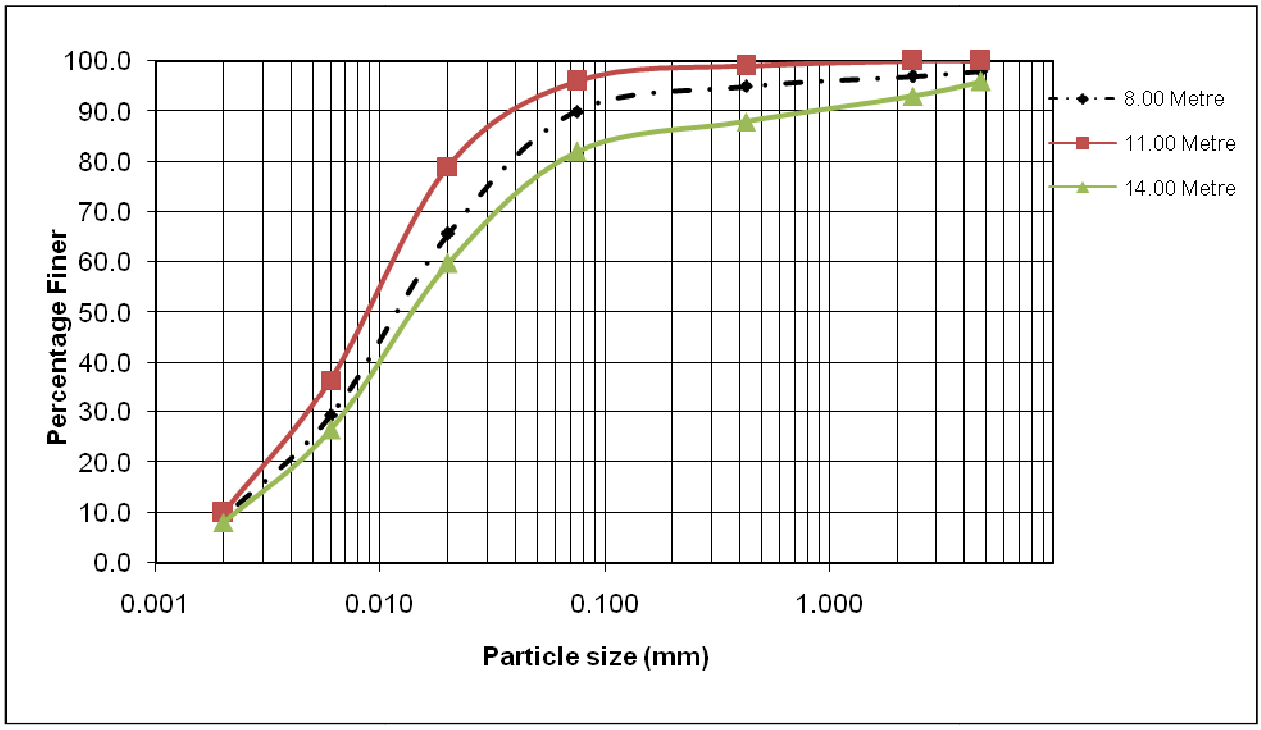


Note: - These are software generated curve

APPENDIX 'D'

GRAPH 9: PARTICLE GRADATION CURVE (BH-5)

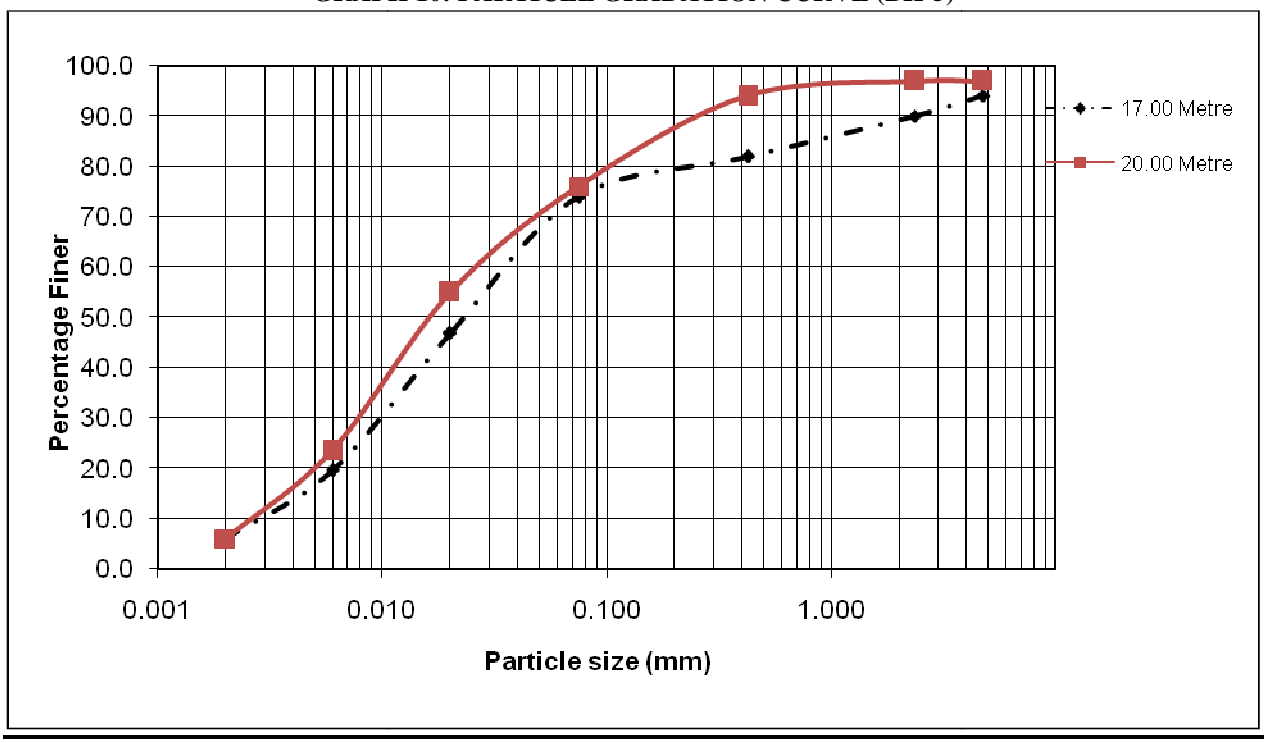




Note: - These are software generated curve

APPENDIX 'D'

GRAPH 10: PARTICLE GRADATION CURVE (BH-5)



Note: - These are software generated curve

APPENDIX 'D'
CALCULATIONS AND RESULTS

Looking at the site condition, sub soil stratification and type of proposed structure, calculations have been done for both shallow footings and deep foundation**.**

1. SHALLOW FOUNDATION:

The safe allowable bearing capacity of the foundation for the proposed building structures has been calculated on the shear failure criteria suggested as per IS 6403-1981, IS: 1904-1978: Settlement Criteria as per IS: 8009 (part-I)-1976 and Design of Pile foundations as per IS 2911(Part 1/Sec 2) 2010.

1.1 SHEAR FAILURE CRITERIA:

Based on C-ϕ values:

Type of shear failure = Mixed (Interpolation in between General and Local shear failure)

Factor of safety (F.S.) = 3.00

Depth of critical water table = 0.00 meter

Net allowable bearing capacity: = q_{na} (kN/m^2)

$$q_{na} = (1 / F.S.) [0.667c N_c S_c d_c + q (N_q - 1) S_q d_q + 0.5 B \gamma N_\gamma S_\gamma d_\gamma W']$$

Where,

B = Width of foundation (metre)

D = Depth of foundation (metre)

ϕ = Angle of shearing resistance (degree)

c = Cohesion intercept (kN/m^2)

γ = Bulk density of soil above the base of footing (kN/m^3)

q = Effective overburden (kN/m^2)

N_c, N_q, N_γ = Bearing capacity coefficient based on initial void ratio e_0

d_c, d_q, d_γ = depth factors

W' = Water table correction factor

1.1.1 Isolated footing

Shape Factors:

$S_c = 1.30$

$S_q = 1.20$

$S_\gamma = 0.80$

Substituting the values, the value of q_{na} can be calculated as per table below:

Bore Hole No.	B	D	ϕ	c	e_o	γ	q	N_c	N_q	N_γ	d_c	d_q	d_γ	W'	q_{na}
BH-1	2.00	1.50	11	30.0	0.727	18.400	12.60	7.55	2.09	0.90	1.13	1.07	1.07	0.50	82.20
BH-1	2.00	2.00	11	30.0	0.727	18.400	16.80	7.55	2.09	0.90	1.18	1.09	1.09	0.50	87.22
BH-1	2.00	2.50	8	40.0	0.777	19.240	23.10	6.62	1.63	0.50	1.22	1.11	1.11	0.50	101.48
BH-2	2.00	1.50	7	38.0	0.611	20.080	15.12	6.98	1.81	0.66	1.13	1.07	1.07	0.50	93.89
BH-2	2.00	2.00	7	38.0	0.611	20.080	20.16	6.98	1.81	0.66	1.18	1.09	1.09	0.50	99.20
BH-2	2.00	2.50	6	45.0	0.667	20.490	26.23	6.49	1.58	0.46	1.22	1.11	1.11	0.50	111.30
BH-3	2.00	1.50	7	40.0	0.672	19.700	14.55	6.73	1.69	0.55	1.13	1.07	1.07	0.50	93.92
BH-3	2.00	2.00	7	40.0	0.672	19.700	19.40	6.73	1.69	0.55	1.18	1.09	1.09	0.50	98.95
BH-3	2.00	2.50	6	42.0	0.654	19.800	24.50	6.53	1.60	0.48	1.22	1.11	1.11	0.50	104.79
BH-4	2.00	1.50	7	45.0	0.739	18.450	12.68	6.45	1.56	0.44	1.13	1.07	1.07	0.50	99.23

Bore Hole No.	B	D	ϕ	c	e_o	γ	q	N_c	N_q	N_γ	d_c	d_q	d_γ	W'	q_{na}
BH-4	2.00	2.00	7	45.0	0.739	18.450	16.90	6.45	1.56	0.44	1.18	1.09	1.09	0.50	104.08
BH-4	2.00	2.50	9	41.0	0.733	19.370	23.43	6.97	1.80	0.65	1.22	1.11	1.11	0.50	110.95
BH-5	2.00	1.50	10	35.0	0.712	19.100	13.65	7.36	1.99	0.81	1.13	1.07	1.07	0.50	92.15
BH-5	2.00	2.00	10	35.0	0.712	19.100	18.20	7.36	1.99	0.81	1.18	1.09	1.09	0.50	97.54
BH-5	2.00	2.50	10	35.0	0.679	19.210	23.03	7.56	2.09	0.89	1.22	1.11	1.11	0.50	106.81

1.1.2 Strip footing:

Shape Factors:

$S_c = 1.00$

$S_q = 1.00$

$S_\gamma = 1.00$

Substituting the values, the value of q_{na} can be calculated as per table below

Bore Hole No.	B	D	ϕ	c	e_o	γ	q	N_c	N_q	N_γ	d_c	d_q	d_γ	W'	q_{na}
BH-1	1.50	1.00	11	30.0	0.727	18.400	8.40	7.55	2.09	0.90	1.12	1.06	1.06	0.50	61.61
BH-1	1.50	1.25	11	30.0	0.727	18.400	10.50	7.55	2.09	0.90	1.15	1.07	1.07	0.50	63.97
BH-1	1.50	1.50	11	30.0	0.727	18.400	12.60	7.55	2.09	0.90	1.18	1.09	1.09	0.50	66.35

Bore Hole No.	B	D	ϕ	c	e_o	γ	q	N_c	N_q	N_γ	d_c	d_q	d_γ	W'	q_{na}
BH-2	1.50	1.00	7	38.0	0.611	20.080	10.08	6.98	1.81	0.66	1.12	1.06	1.06	0.50	70.52
BH-2	1.50	1.25	7	38.0	0.611	20.080	12.60	6.98	1.81	0.66	1.15	1.07	1.07	0.50	73.06
BH-2	1.50	1.50	7	38.0	0.611	20.080	15.12	6.98	1.81	0.66	1.18	1.09	1.09	0.50	75.61
BH-3	1.50	1.00	7	40.0	0.672	19.700	9.70	6.73	1.69	0.55	1.12	1.06	1.06	0.50	70.68
BH-3	1.50	1.25	7	40.0	0.672	19.700	12.13	6.73	1.69	0.55	1.15	1.07	1.07	0.50	73.10
BH-3	1.50	1.50	7	40.0	0.672	19.700	14.55	6.73	1.69	0.55	1.18	1.09	1.09	0.50	75.54
BH-4	1.50	1.00	7	45.0	0.739	18.450	8.45	6.45	1.56	0.44	1.12	1.06	1.06	0.50	74.90
BH-4	1.50	1.25	7	45.0	0.739	18.450	10.56	6.45	1.56	0.44	1.15	1.07	1.07	0.50	77.28
BH-4	1.50	1.50	7	45.0	0.739	18.450	12.68	6.45	1.56	0.44	1.18	1.09	1.09	0.50	79.67
BH-5	1.50	1.00	10	35.0	0.712	19.100	9.10	7.36	1.99	0.81	1.12	1.06	1.06	0.50	69.15
BH-5	1.50	1.25	10	35.0	0.712	19.100	11.38	7.36	1.99	0.81	1.15	1.07	1.07	0.50	71.70
BH-5	1.50	1.50	10	35.0	0.712	19.100	13.65	7.36	1.99	0.81	1.18	1.09	1.09	0.50	74.28

1.1.3 Raft Foundation:

Shape Factors:

$S_c = 1.00$

$S_q = 1.00$

$S_\gamma = 1.00$

Substituting the values, the value of q_{na} can be calculated as per table below:

Bore Hole No.	B	D	ϕ	c	e_o	γ	q	N_c	N_q	N_γ	d_c	d_q	d_γ	W'	q_{na}
BH-1	10.00	1.50	11	30.0	0.727	18.400	12.60	7.55	2.09	0.90	1.03	1.01	1.01	0.50	84.24
BH-1	10.00	2.00	11	30.0	0.727	18.400	16.80	7.55	2.09	0.90	1.04	1.02	1.02	0.50	86.72
BH-1	10.00	2.50	8	40.0	0.777	19.240	23.10	6.62	1.63	0.50	1.04	1.02	1.02	0.50	89.67
BH-2	10.00	1.50	7	38.0	0.611	20.080	15.12	6.98	1.81	0.66	1.03	1.01	1.01	0.50	90.91
BH-2	10.00	2.00	7	38.0	0.611	20.080	20.16	6.98	1.81	0.66	1.04	1.02	1.02	0.50	93.27
BH-2	10.00	2.50	6	45.0	0.667	20.490	26.23	6.49	1.58	0.46	1.04	1.02	1.02	0.50	97.20
BH-3	10.00	1.50	7	40.0	0.672	19.700	14.55	6.73	1.69	0.55	1.03	1.01	1.01	0.50	88.76
BH-3	10.00	2.00	7	40.0	0.672	19.700	19.40	6.73	1.69	0.55	1.04	1.02	1.02	0.50	90.83
BH-3	10.00	2.50	6	42.0	0.654	19.800	24.50	6.53	1.60	0.48	1.04	1.02	1.02	0.50	92.04
BH-4	10.00	1.50	7	45.0	0.739	18.450	12.68	6.45	1.56	0.44	1.03	1.01	1.01	0.50	90.54
BH-4	10.00	2.00	7	45.0	0.739	18.450	16.90	6.45	1.56	0.44	1.04	1.02	1.02	0.50	92.24

Bore Hole No.	B	D	ϕ	c	e_o	γ	q	N_c	N_q	N_γ	d_c	d_q	d_γ	W'	q_{na}
BH-4	10.00	2.50	9	41.0	0.733	19.370	23.43	6.97	1.80	0.65	1.04	1.02	1.02	0.50	100.02
BH-5	10.00	1.50	10	35.0	0.712	19.100	13.65	7.36	1.99	0.81	1.03	1.01	1.01	0.50	91.61
BH-5	10.00	2.00	10	35.0	0.712	19.100	18.20	7.36	1.99	0.81	1.04	1.02	1.02	0.50	94.13
BH-5	10.00	2.50	10	35.0	0.679	19.210	23.03	7.56	2.09	0.89	1.04	1.02	1.02	0.50	101.40

1.2 SETTLEMENT CRITERIA:

Settlement of the soil layer below the base of footing is given by;

$$S_i = [\{H_t/(1 + e_0)\}C_c \log_{10}\{(p_0 + \Delta p)/p_0\}]$$

Where

z = Mid depth of clay layer considered (metre)

p_0 = Effective overburden at depth z (kN/m^2)

e_0 = Void ratio at depth z corresponding to p_0

Δp = Pressure increment (kN/m^2) = (I_B x q)

I_B = Boussinesq coefficient

C_c = Compression Index

H_t = Thickness of clay layer considered (mm)

S_t = Total settlement of all layers

Final corrected settlement:

$S = \lambda . D_f . S_i . R_f$

λ = Field settlement correction factor = 0.70

D_f = Depth factor

q_s = Safe bearing pressure (kN/m^2)

R_f = Rigidity factor = 1.00 for Isolated and strip footings and 0.8 for Raft

The settlement of various footing at different depth and base width can be calculated as per the following table:

1.2.1 Isolated Footing:

BORE NO.	B	L	D	Q_{na}	LAYER		Ht	z	γ	p_0	e_0	C_c	I_b	Δp	S_i	D_f	S
BH-1	2.00	2.00	1.50	82.20	1.50	4.50	3000	3.00	10.00	30.00	0.777	0.135	0.180	14.80	40	0.770	21
BH-1	2.00	2.00	2.00	87.22	2.00	5.00	3000	3.50	10.00	35.00	0.777	0.135	0.180	15.70	37	0.740	19
BH-1	2.00	2.00	2.50	101.48	2.50	5.50	3000	4.00	10.00	40.00	0.777	0.135	0.180	18.27	37	0.720	19
BH-2	2.00	2.00	1.50	93.89	1.50	4.50	3000	3.00	10.00	30.00	0.667	0.140	0.180	16.90	49	0.770	26
BH-2	2.00	2.00	2.00	99.20	2.00	5.00	3000	3.50	10.00	35.00	0.667	0.140	0.180	17.86	45	0.740	23
BH-2	2.00	2.00	2.50	111.30	2.50	5.50	3000	4.00	10.00	40.00	0.667	0.140	0.180	20.03	44	0.720	22
BH-3	2.00	2.00	1.50	93.92	1.50	4.50	3000	3.00	10.00	30.00	0.654	0.122	0.180	16.91	43	0.770	23
BH-3	2.00	2.00	2.00	98.95	2.00	5.00	3000	3.50	10.00	35.00	0.654	0.122	0.180	17.81	40	0.740	20
BH-3	2.00	2.00	2.50	104.79	2.50	5.50	3000	4.00	10.00	40.00	0.654	0.122	0.180	18.86	37	0.720	19
BH-4	2.00	2.00	1.50	99.23	1.50	4.50	3000	3.00	10.00	30.00	0.733	0.120	0.180	17.86	42	0.770	23
BH-4	2.00	2.00	2.00	104.08	2.00	5.00	3000	3.50	10.00	35.00	0.733	0.120	0.180	18.73	39	0.740	20
BH-4	2.00	2.00	2.50	110.95	2.50	5.50	3000	4.00	10.00	40.00	0.733	0.120	0.180	19.97	37	0.720	18
BH-5	2.00	2.00	1.50	92.15	1.50	4.50	3000	3.00	10.00	30.00	0.679	0.118	0.180	16.59	40	0.770	22
BH-5	2.00	2.00	2.00	97.54	2.00	5.00	3000	3.50	10.00	35.00	0.679	0.118	0.180	17.56	37	0.740	19
BH-5	2.00	2.00	2.50	106.81	2.50	5.50	3000	4.00	10.00	40.00	0.679	0.118	0.180	19.23	36	0.720	18

1.2.2 Strip Footing:

BORE NO.	B	L	D	Qna	LAYER		Ht	z	γ	p0	e0	Cc	Ib	Δp	Si	Df	S
BH-1	1.50	1.50	1.00	61.61	1.00	3.25	2250	2.13	10.00	21.25	0.727	0.120	0.460	28.34	58	0.670	27
BH-1	1.50	1.50	1.25	63.97	1.25	3.50	2250	2.38	10.00	23.75	0.727	0.120	0.460	29.43	55	0.640	25
BH-1	1.50	1.50	1.50	66.35	1.50	3.75	2250	2.63	10.00	26.25	0.777	0.135	0.460	30.52	57	0.630	25
BH-2	1.50	1.50	1.00	70.52	1.00	3.25	2250	2.13	10.00	21.25	0.611	0.120	0.460	32.44	67	0.670	32
BH-2	1.50	1.50	1.25	73.06	1.25	3.50	2250	2.38	10.00	23.75	0.611	0.120	0.460	33.61	64	0.640	29
BH-2	1.50	1.50	1.50	75.61	1.50	3.75	2250	2.63	10.00	26.25	0.667	0.140	0.460	34.78	69	0.630	31
BH-3	1.50	1.50	1.00	70.68	1.00	3.25	2250	2.13	10.00	21.25	0.672	0.120	0.460	32.51	65	0.670	31
BH-3	1.50	1.50	1.25	73.10	1.25	3.50	2250	2.38	10.00	23.75	0.672	0.120	0.460	33.63	62	0.640	28
BH-3	1.50	1.50	1.50	75.54	1.50	3.75	2250	2.63	10.00	26.25	0.611	0.115	0.460	34.75	59	0.630	26
BH-4	1.50	1.50	1.00	74.90	1.00	3.25	2250	2.13	10.00	21.25	0.739	0.135	0.460	34.46	73	0.670	34
BH-4	1.50	1.50	1.25	77.28	1.25	3.50	2250	2.38	10.00	23.75	0.739	0.135	0.460	35.55	69	0.640	31
BH-4	1.50	1.50	1.50	79.67	1.50	3.75	2250	2.63	10.00	26.25	0.733	0.120	0.460	36.65	59	0.630	26
BH-5	1.50	1.50	1.00	69.15	1.00	3.25	2250	2.13	10.00	21.25	0.712	0.120	0.460	31.81	63	0.670	29
BH-5	1.50	1.50	1.25	71.70	1.25	3.50	2250	2.38	10.00	23.75	0.712	0.120	0.460	32.98	60	0.640	27
BH-5	1.50	1.50	1.50	74.28	1.50	3.75	2250	2.63	10.00	26.25	0.670	0.118	0.460	34.17	58	0.630	25

1.2.3 Raft Foundations:

BORE NO.	B	L	D	Qna	LAYER		Ht	z	γ	p0	e0	Cc	Ib	Δp	Si	Df	S	S_t
BH1	10.00	10.00	1.50	73.00	1.50	3.50	2000	2.50	10.00	25.00	0.778	0.135	0.780	56.94	78	0.970	43	
BH1	10.00	10.00	1.50	73.00	3.50	6.50	3000	5.00	10.00	50.00	0.619	0.125	0.590	43.07	63	0.970	34	
BH1	10.00	10.00	1.50	73.00	6.50	9.50	3000	8.00	10.00	80.00	0.612	0.122	0.340	24.82	27	0.970	14	
BH1	10.00	10.00	1.50	73.00	9.50	12.50	3000	11.00	10.00	110.00	0.588	0.110	0.180	13.14	10	0.970	6	
BH1	10.00	10.00	1.50	73.00	12.50	15.50	3000	14.00	10.00	140.00	0.574	0.105	0.100	7.30	4	0.970	2	
BH1	10.00	10.00	1.50	73.00	15.50	18.50	3000	17.00	10.00	170.00	0.569	0.107	0.050	3.65	2	0.970	1	100
BH1	10.00	10.00	2.00	86.72	2.00	3.50	1500	2.75	10.00	27.50	0.778	0.135	0.780	67.65	61	0.970	33	
BH1	10.00	10.00	2.00	86.72	3.50	6.50	3000	5.00	10.00	50.00	0.619	0.125	0.590	51.17	71	0.970	39	
BH1	10.00	10.00	2.00	86.72	6.50	9.50	3000	8.00	10.00	80.00	0.612	0.122	0.340	29.49	31	0.970	17	
BH1	10.00	10.00	2.00	86.72	9.50	12.50	3000	11.00	10.00	110.00	0.588	0.110	0.180	15.61	12	0.970	7	
BH1	10.00	10.00	2.00	86.72	12.50	15.50	3000	14.00	10.00	140.00	0.574	0.105	0.100	8.67	5	0.970	3	
BH1	10.00	10.00	2.00	86.72	15.50	18.50	3000	17.00	10.00	170.00	0.569	0.107	0.050	4.34	2	0.970	1	99
BH1	10.00	10.00	2.50	89.67	2.50	3.50	1000	3.00	10.00	30.00	0.778	0.135	0.780	69.95	40	0.970	22	
BH1	10.00	10.00	2.50	89.67	3.50	6.50	3000	5.00	10.00	50.00	0.619	0.125	0.590	52.91	73	0.970	39	

BORE NO.	B	L	D	Qna	LAYER		Ht	z	γ	p0	e0	Cc	Ib	Δp	Si	Df	S	S_t
BH1	10.00	10.00	2.50	89.67	6.50	9.50	3000	8.00	10.00	80.00	0.612	0.122	0.340	30.49	32	0.970	17	
BH1	10.00	10.00	2.50	89.67	9.50	12.50	3000	11.00	10.00	110.00	0.588	0.110	0.180	16.14	12	0.970	7	
BH1	10.00	10.00	2.50	89.67	12.50	15.50	3000	14.00	10.00	140.00	0.574	0.105	0.100	8.97	5	0.970	3	
BH1	10.00	10.00	2.50	89.67	15.50	18.50	3000	17.00	10.00	170.00	0.569	0.107	0.050	4.48	2	0.970	1	89

2. DEEP FOUNDATION:

2.1 PILE LOAD CAPACITY IN COMPRESSION & UPLIFT:

Calculations have been made for cast-in-situ bored RCC piles as per IS 2911 (part-1, section -2)-2010.

2.1.1 Design parameter for pile:

Material	: RCC
Type	: Cast-in-situ bored pile
Diameter	: 0.45 metre
Length	: 15.00 meter
Cut off length	: 2.00 meter

2.1.2 Design parameter of soils:

Coefficient of earth pressure K_a	= 1.00
Max. Depth for overburden	= 15 x Dia.
Factor of safety (FS)	= 2.50
Critical Depth of water table	= 0.00 meter

2.1.3 Notations and symbols:

Q_{uc} = Ultimate load carrying capacity of pile in compression (kN)

Q_{ut} = Ultimate load carrying capacity of pile in Uplift (kN)

Q_{ac} = Net allowable load capacity of the pile in compression (kN)

Q_{at} = Net allowable load capacity of the pile in Uplift (kN)

Q_b = Ultimate bearing capacity in End Bearing resistance (kN)

Q_f = Ultimate bearing capacity in stem friction (kN)

Qc = Ultimate bearing capacity in cohesion (kN)

Qw = Gross weight of pile (kN)

FS = Factor of safety

$Q_{uc} = Q_b + Q_f + Q_c$

$Q_{ut} = Q_w + Q_f + Q_c$

$Q_{ac} = Q_{uc}/FS$

$Q_{at} = Q_{ut}/FS$

2.1.4 End bearing resistance of pile

$$Q_b = A_p (q N_q + 0.5. \gamma. D. N_\gamma) + A_p N_c C_p$$

Where,

A_p = Cross sectional area of the pile toe (m^2)

D = Stem diameter

L = Distance of pile tip from top (metre)

ϕ = Angle of shearing resistance

γ = Bulk density (kN/m^3)

q = Effective overburden pressure at pile toe (kN/m^2)

N_q = Bearing capacity factors

N_c = Bearing Capacity factor

C_p= cohesion at pile tip (kN/m^2)

End bearing resistance of the pile can be calculated as per table below

Bore No.	D (m)	L (m)	Pile Length	A_p	ϕ	γ_2	N_q	N_y	C_P	q	Q_b
BH-1	0.45	17.00	15.00	0.1591	16.00	19.50	4.43	3.20	20.00	64.80	75.42
BH-2	0.45	17.00	15.00	0.1591	16.00	20.37	4.43	3.20	29.00	67.84	90.55
BH-3	0.45	17.00	15.00	0.1591	18.00	21.72	5.42	4.29	35.00	74.93	116.49
BH-4	0.45	17.00	15.00	0.1591	15.00	19.68	3.94	2.65	20.00	62.10	68.49
BH-5	0.45	17.00	15.00	0.1591	18.00	21.99	5.42	4.29	16.00	74.93	89.32

2.1.5 Frictional resistance along the stem of pile

$$Q_f = \sum K_i . qi . \tan \delta_i . A_{si}$$

Where,

$\sum$ = Sum of frictional resistance of all layers considered

K_i = Coefficient of earth pressure

q_i = Effective overburden pressure in KN/m^2 at mid depth of i^{th} layer

δ_i = Angle of wall friction between pile and soil of i^{th} layer
(Taken equal to ϕ)

A_{si} = Surface area of pile stem in i^{th} layer

The frictional resistance of pile stem can be calculated as per the table below

Bore Hole No.	Layer (m)		Mean Depth (m)	Length	Cumulative length	γ_1	γ_2	q_i	A_{si}	ϕ	δ_i	K_i	Q_i	$\sum Q_i$
BH-1	2.00	5.00	3.50	3.00	3.00	19.24	9.24	32.34	4.24	8.00	8.00	1.50	28.93	28.93
	5.00	8.00	6.50	3.00	6.00	20.10	10.10	62.64	4.24	9.00	9.00	1.50	63.14	92.07
	8.00	11.00	9.50	3.00	9.00	19.40	9.40	62.64	4.24	10.00	10.00	1.50	70.29	162.36
	11.00	14.00	12.50	3.00	12.00	19.68	9.68	62.64	4.24	13.00	13.00	1.50	92.04	254.40
	14.00	17.00	15.50	3.00	15.00	19.48	9.48	62.64	4.24	18.00	18.00	1.50	129.53	383.93
BH-2	2.00	5.00	3.50	3.00	3.00	20.49	10.49	36.72	4.24	6.00	6.00	1.50	24.56	24.56
	5.00	8.00	6.50	3.00	6.00	18.84	8.84	63.24	4.24	24.00	24.00	1.50	179.18	203.74
	8.00	11.00	9.50	3.00	9.00	20.52	10.52	63.24	4.24	18.00	18.00	1.50	130.76	334.50
	11.00	14.00	12.50	3.00	12.00	20.33	10.33	63.24	4.24	14.00	14.00	1.50	100.34	434.84
	14.00	17.00	15.50	3.00	15.00	20.11	10.11	63.24	4.24	20.00	20.00	1.50	146.48	581.32
BH-3	2.00	5.00	3.50	3.00	3.00	19.80	9.80	34.30	4.24	6.00	6.00	1.50	22.94	22.94
	5.00	8.00	6.50	3.00	6.00	20.10	10.10	64.60	4.24	16.00	16.00	1.50	117.89	140.83
	8.00	11.00	9.50	3.00	9.00	21.29	11.29	64.60	4.24	12.00	12.00	1.50	87.39	228.22
	11.00	14.00	12.50	3.00	12.00	21.51	11.51	64.60	4.24	20.00	20.00	1.50	149.64	377.86
	14.00	17.00	15.50	3.00	15.00	21.47	11.47	64.60	4.24	14.00	14.00	1.50	102.51	480.37
BH-4	2.00	5.00	3.50	3.00	3.00	19.37	9.37	32.80	4.24	9.00	9.00	1.50	33.06	33.06
	5.00	8.00	6.50	3.00	6.00	18.95	8.95	59.65	4.24	11.00	11.00	1.50	73.79	106.84

Bore Hole No.	Layer (m)		Mean Depth (m)	Length	Cumulative length	γ_1	γ_2	q_i	A_{si}	ϕ	δ_i	K_i	Q_i	$\sum Qi$
	8.00	11.00	9.50	3.00	9.00	19.45	9.45	59.65	4.24	12.00	12.00	1.50	80.69	187.53
	11.00	14.00	12.50	3.00	12.00	19.46	9.46	59.65	4.24	11.00	11.00	1.50	73.79	261.32
	14.00	17.00	15.50	3.00	15.00	19.81	9.81	59.65	4.24	12.00	12.00	1.50	80.69	342.00
BH-5	2.00	5.00	3.50	3.00	3.00	19.21	9.21	32.24	4.24	10.00	10.00	1.50	36.17	36.17
	5.00	8.00	6.50	3.00	6.00	19.74	9.74	61.46	4.24	16.00	16.00	1.50	112.15	148.33
	8.00	11.00	9.50	3.00	9.00	22.06	12.06	61.46	4.24	15.00	15.00	1.50	104.80	253.12
	11.00	14.00	12.50	3.00	12.00	21.50	11.50	61.46	4.24	13.00	13.00	1.50	90.30	343.42
	14.00	17.00	15.50	3.00	15.00	21.57	11.57	61.46	4.24	16.00	16.00	1.50	112.15	455.57

2.1.6 Cohesion along the stem of pile

$$Q_c = \sum c_i . A_{si} . \alpha$$

Where,

$\sum$ = Sum of frictional resistance of all layers considered

c_i = Average cohesion in i^{th} layer

A_{si} = Surface area of pile stem in i^{th} layer

α = Reduction factor = 0.5

The resistance due to cohesion along the pile stem can be calculated as per the table below:

Bore hole No.	Layer (m)		Mean Depth	Length (m)	Cumulative length	c_i	A_{si}	α	q_{ci}	$\sum Qi$
BH-1	2.00	5.00	3.50	3.00	3.00	40.00	4.24	0.50	84.86	84.86
	5.00	8.00	6.50	3.00	6.00	30.00	4.24	0.50	63.64	148.50
	8.00	11.00	9.50	3.00	9.00	27.00	4.24	0.50	57.28	205.78
	11.00	14.00	12.50	3.00	12.00	22.00	4.24	0.50	46.67	252.45
	14.00	17.00	15.50	3.00	15.00	17.00	4.24	0.50	36.06	288.51
BH-2	2.00	5.00	3.50	3.00	3.00	45.00	4.24	0.50	95.46	95.46
	5.00	8.00	6.50	3.00	6.00	0.00	4.24	0.50	0.00	95.46
	8.00	11.00	9.50	3.00	9.00	30.00	4.24	0.50	63.64	159.11
	11.00	14.00	12.50	3.00	12.00	25.00	4.24	0.50	53.04	212.14
	14.00	17.00	15.50	3.00	15.00	28.00	4.24	0.50	59.40	271.54
BH-3	2.00	5.00	3.50	3.00	3.00	42.00	4.24	0.50	89.10	89.10
	5.00	8.00	6.50	3.00	6.00	42.00	4.24	0.50	89.10	178.20
	8.00	11.00	9.50	3.00	9.00	40.00	4.24	0.50	84.86	263.06
	11.00	14.00	12.50	3.00	12.00	38.00	4.24	0.50	80.61	343.67
	14.00	17.00	15.50	3.00	15.00	35.00	4.24	0.50	74.25	417.92

Bore hole No.	Layer (m)		Mean Depth	Length (m)	Cumulative length	c_i	A_{si}	α	q_{ci}	$\sum$ Qi
BH-4	2.00	5.00	3.50	3.00	3.00	41.00	4.24	0.50	86.98	86.98
	5.00	8.00	6.50	3.00	6.00	45.00	4.24	0.50	95.46	182.44
	8.00	11.00	9.50	3.00	9.00	40.00	4.24	0.50	84.86	267.30
	11.00	14.00	12.50	3.00	12.00	38.00	4.24	0.50	80.61	347.91
	14.00	17.00	15.50	3.00	15.00	39.00	4.24	0.50	82.74	430.65
BH-5	2.00	5.00	3.50	3.00	3.00	35.00	4.24	0.50	74.25	74.25
	5.00	8.00	6.50	3.00	6.00	28.00	4.24	0.50	59.40	133.65
	8.00	11.00	9.50	3.00	9.00	26.00	4.24	0.50	55.16	188.81
	11.00	14.00	12.50	3.00	12.00	29.00	4.24	0.50	61.52	250.33
	14.00	17.00	15.50	3.00	15.00	20.00	4.24	0.50	42.43	292.76

2.1.7 Self weight of pile

Self weight of pile (Depth 15.00 metre) (Q_w) = (π/4) x $(0.45)^2$ x 15.00 x (25-10) = 35.80 kN

2.2 Lateral Load Capacity of Piles:

Factor $T = \sqrt[5]{(EI/k_1)}$

Where,

E= Modulus of elasticity of RCC in piles (kg/cm^2)

I = Moment of inertia of pile section = $(\pi/64).\ D^4$ (cm^4)

D = Diameter of pile (cm)

k_1 = Coefficient based on soil properties (from Table 1 as IS 2911 (part-1, section -2)2010 = 0.500

Total embedded length of pile = L (cm)

Cantilever length of pile = L1 = 0.00 cm

For a Pile with fixed head,

Permissible deflection (y) = $QL_f^3/12EI$ = 5 mm = 0.50 cm

Or, Ultimate lateral load capacity of pile (Q) = $6EI/ L_f^3$ (kg)

The values of lateral load capacities of piles have been computed as per the table below:

D (cm)	L (mm)	E	I	T	L1	L_1/T	L_f/T	L_f	Q (kg)
45	1500	250000	201186.91	158.677	0	0	2.18	345.92	7290.88
50	1500	250000	306640.63	172.6315	0	0	2.18	376.34	8629.62
60	1500	250000	635850.00	199.7399	0	0	2.18	435.43	11552.65
45	1800	250000	201186.91	158.677	0	0	2.18	345.92	7290.88
50	1800	250000	306640.63	172.6315	0	0	2.18	376.34	8629.62
60	1800	250000	635850.00	199.7399	0	0	2.18	435.43	11552.65

Values of lateral load capacities of piles of other length will remain same for the corresponding diameter.

APPENDIX 'E'
COMPUTATIONS OF LIQUIFACTION POTENTIAL

Bore Hole No. : BH-1

Reference: "*Semi-Emperical Procedures for Evaluating Liquefaction Potential During Earthquakes*" by I.M. Idriss and R.W. Boulanger (2004), Proceedings, 11th Int'l Conf. On Soil Dynamics & Earthquake Engg

Maximum Shear Stress at depth "h" during earthquake τ_{max} $= \frac{\gamma h}{g} a_{max}$

where

γ = bulk density of soil

h = depth

g = acceleration due to gravity

a_{max} = peak ground acceleration

γh = Total Overburden presure

Since soil column acts as a deformable body, actual shear stress at depth h, $(\tau_{max})_{act}$ is taken as

$$(\tau_{max})_{act} = r_d \frac{\gamma h}{g} a_{max}$$

r_d = stress reduction factor, to be computed using the following correlation :

For z <= 34 m,

$$Ln(r_d) = \alpha(z) + \beta(z) M$$

$$\alpha(z) = -1.012 - 1.126 \sin[(z/11.73) + 5.133]$$

$$\beta(z) = 0.106 + 0.118 \sin[(z/11.28) + 5.142]$$

For z > 34 m,

$$r_d = 0.12 e^{0.22M}$$

Average equivalent uniform shear stress, τ_{av} = Cycic Stress Ratio =

$$\tau_{av} = 0.65 r_d \frac{\gamma h}{g} a_{max}$$

Cyclic Stress Ratio, CSR $= \frac{\tau_{av}}{\sigma_v'}$

Depth of Water Table = 0.0 m

Depth, m		Soil Classification	SoilType* C,G or H	Density T/m^3
From	To			
0.0	20.0	Silts	C	1.90

* For "Soil Type", Enter : **C** (Cohesive soil), **G** (Granular soil) or **H** (Hard soils/Dense Sands/Rock) or **F**(Heterogeneous Fill)

Surcharge Load at Ground Level : Nil

Design Earthquake Magnitude, M = 7.0 on Richter scale

Peak ground acceleration, a_{max} = 0.18 g

Magnitude Scaling Factor, MSF = $6.9\, e^{-M/4} - 0.058$ = 1.141

Cyclic Stress Ratio at M = 7.5 = CSR / MSF = $\frac{r_d}{MSF} \frac{\gamma h}{g} \frac{a_{max}}{\sigma_v'}$

$(N_1)_{60} = C_N N_{60}$

where:

N_{60} = SPT value for 60% hammer efficiency

$(N_1)_{60}$ is normalized N_{60} to equivalent overburden pressure of 1 atmosphere

C_N = correction factor for normalizing N_{60} = $(P_a/\sigma'_v)^{\alpha}$

P_a = atmospheric pressure, taken as 10.33 T/m^2

σ'_v = effective overburden pressure

$\alpha = 0.784 - 0.0768\, (N_1)_{60}^{0.5}$

Solving for C_N requires iteration because $(N_1)_{60}$ depends on C_N and C_N depends on $(N_1)_{60}$

The SPT penetration resistance has to be adjusted to an Equivalent Clean Sand value to account for the soil gradation and fines content

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

where:

$\Delta(N1)60 = \exp\{1.63 + 9.7/FC - (15.7/FC)^2\}$

FC = Fines Content

$$C_\sigma = \frac{1}{18.9 - 2.55\,(N_1)_{60CS}^{0.5}}$$

$K_\sigma = 1 - C_\sigma \ln(\sigma'_v / P_a) \quad <= 1$

Cyclic Resistance Ratio

$$CRR = \exp\left\{ \frac{(N_1)_{60CS}}{14.1} + \left(\frac{(N_1)_{60CS}}{126} \right)^2 - \left(\frac{(N_1)_{60CS}}{23.6} \right)^3 + \left(\frac{(N_1)_{60CS}}{25.4} \right)^4 - 2.8 \right\} K_\sigma$$

Design Earthquake Magnitude, M = 7.0 on Richter scale

Peak ground acceleration, a_{max} = 0.18 g

Depth m	Corrected N Value, N_{60}	Fines Content (FC), %	Total Overburden Pressure, σ_{tot}, T/m^2	Effective Overburden Pressure, $\sigma_{v'}$, T/m^2	C_N	α	C_N	$(N_1)_{60}$	$\Delta(N_1)_{60\,cs}$	$(N_1)_{60\,cs}$
1.95	6.379	87	3.71	1.76	1.700	0.565	1.700	8.13	5.523	13.66
3.45	9.214	89	6.56	3.11	1.700	0.480	1.700	15.66	5.5172	21.18
4.95	13.655	77	9.41	4.46	1.450	0.442	1.450	19.81	5.5533	25.36
6.45	15.262	83	12.26	5.81	1.291	0.443	1.291	19.70	5.535	25.24
7.95	19.751	90	15.11	7.16	1.165	0.416	1.165	23.01	5.5143	28.52
9.45	29.626	85	17.96	8.51	1.071	0.351	1.071	31.72	5.529	37.25
10.95	32.130	82	20.81	9.86	1.016	0.345	1.016	32.66	5.538	38.19
12.45	30.240	87	23.66	11.21	0.971	0.368	0.971	29.35	5.523	34.87
13.95	39.690	88	26.51	12.56	0.940	0.315	0.940	37.33	5.5201	42.85
15.45	42.525	80	29.36	13.91	0.913	0.305	0.913	38.84	5.5441	44.38
16.95	35.910	88	32.21	15.26	0.871	0.355	0.871	31.27	5.5201	36.79
18.45	39.690	86	35.06	16.61	0.852	0.337	0.852	33.82	5.526	39.34
19.95	53.865	88	37.91	17.96	0.866	0.259	0.866	46.67	5.5201	52.19

Values computed by iterative process

Design Earthquake Magnitude, M = 7.0 on Richter scale

Peak ground acceleration, a_{max} = 0.18 g

Depth m	Soil Type	r_d	Cyclic Stress Ratio	Cyclic Stress Ratio, at M = 7.5	Factor of Safety against Liquefaction	Remarks
1.95	C	0.9871	0.244	0.2137	NA	Cohesive Soil
3.45	C	0.9684	0.239	0.2096	NA	Cohesive Soil
4.95	C	0.9472	0.234	0.205	NA	Cohesive Soil
6.45	C	0.9238	0.228	0.2	NA	Cohesive Soil
7.95	C	0.8988	0.222	0.1946	NA	Cohesive Soil
9.45	C	0.8724	0.215	0.1889	NA	Cohesive Soil

10.95	C	0.8453	0.209	0.183	NA	Cohesive Soil
12.45	C	0.8179	0.202	0.177	NA	Cohesive Soil
13.95	C	0.7904	0.195	0.1711	NA	Cohesive Soil
15.45	C	0.7634	0.1886	0.1652	NA	Cohesive Soil
16.95	C	0.7371	0.1821	0.1596	NA	Cohesive Soil
18.45	C	0.7118	0.1758	0.1541	NA	Cohesive Soil
19.95	C	0.6878	0.1699	0.1489	NA	Cohesive Soil

In Granular soils / sands, If Factor of Safety < 1, **Liquefiable**

In Granular soils / sands, If Factor of Safety >= 1.0, **No Liquefaction**

End of report