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Foundation characteristics of the soils of different parts of Nepal

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ABSTRACT

This paper deals with foundation characteristics of the soils of different parts of Nepal. In this paper, multiple approaches were adopted to explore foundation characteristics of the soil. In this study 14 sites from different parts of the country were selected; 2 sites from the hilly region, 2 sites from the inner Terai and 10 sites from the Terai. In each site two test sites were selected. In each test site simplified penetration apparatus (SPA) tests were carried out and were accompanied by the auger tests. Soil samples from different depths in each site were collected for the direct shear test, soil classification, LL-PL test, density and other tests and these tests were carried out in laboratory. Bearing capacity of the soils thus obtained from the laboratory was compared with the soil types of certain depth and the Nc value at that depth. From the study it was found that the Nc value depends upon the types of the soil and the compactness of the soils. This study showed that Nc value can be converted in to the ultimate bearing capacity by multiplying the obtained Nc value by the factor of 35 within 80% confidence. Resistivity measurements were carried out only to explore the suitability of the sites for the purposed construction of substations in terms of earthing. Resistivity measurement showed that the sites are suitable for the construction of purposed substations.

Keywords: SPA, bearing capacity, subsurface soil, foundation, Nepal

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INTRODUCTION

This paper presents the results of the subsurface investigation works carried out for the proposed substation at different parts of Nepal (Fig. 1). Foundation characteristics of the soil depends upon the soil properties such as soil type, grading, liquid limit, plastic limit, density, cohesion, compactness of the soil in the layer, friction angle, etc. In this study a total of 14 sites were selected; 2 sites from the hilly region, 2 sites from the inner Terai and 10 sites from the Terai. In each site, two test sites were selected. In each test site simplified penetration apparatus (SPA) tests were carried out. This is the simple instrument designed for the shallow soil investigation. Here, this instrument was used to characterize the subsurface soil horizons using the Nc number (the no. of blows required to penetrate 10 cm. depth). For each of the site two tests were carried out so that direct comparison can be done. Each site is accompanied by the auger test so that direct observation of the soil at depth of penetration can be done. Cross litholog of each site along with the Nc value was used to prepare the detailed subsurface soil horizons. Soil samples from different depths in each site were collected for laboratory test. Undisturbed soil samples were collected for the direct shear test and disturbed samples were collected for the soil classification, LL- PL test, density and other tests. Bearing capacity of the soil thus obtained from the laboratory was compared with the soil type of certain depth and the Nc value at that depth.

The proposed substation sites are as follows; 1. Bhiman Substation (Sindhuli), 2. Simroungadha Substation (Bara), 3. Katari Substation (Udayapur), 4. Yedukuwa Substation (Dhanusha), 5. Aurahai Substation (Mahotari), 6. Amuwa Substation (Kapilbastu), 7. Devdaha Substation (Rupandehi), 8. Mukundapur Substation (Nawalparasi), 9. Milan Chowk Substation (Parabat), 10. Jitpur Substation (Rupandehi), 11. Biratchowk Substation (Morang District), 12. Rangeli Substation (Morang District), 13. Phattepur (Balardaha) Substation (Saptari District), and 14. Phikal Substation (Ilam District).

For each substation, two sites - one for the control building and another for the Switchyard (Transformer Site) were selected. Wherever possible and necessary, both field test and laboratory test were conducted for each site. The objectives of this investigation are to study the subsurface character of the site and type, and loading intensity on the foundation for the proposed structure.

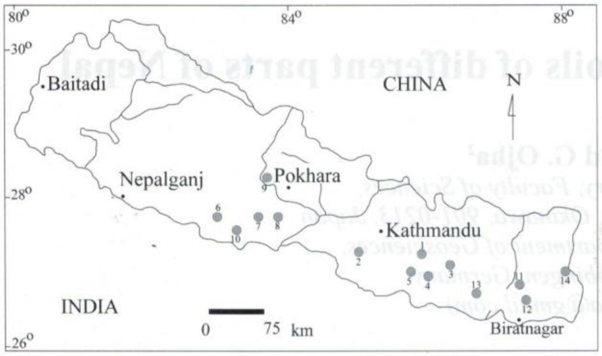


Fig. 1: Location map of the study sites

DETAILED METHODOLOGY

The field work is comprised of the following components; detail survey, preparation of the site map, simplified penetration test up to the depth of 6 m if possible, preparation of litholog of Hand Auger holes up to the depth of 6 m if possible, location of sites on the prepared maps, collection of samples for the laboratary test, measurement of resistivity of the site and water table measurement. Similarly, the laboratory tests comprise the following tests; moisture content, sieve analysis, Liquid Limit (LL) - Plastic Limit (PL), classification of the soil (UCS Classification), specific gravity, Direct Shear Test, and calculation of bearing capacity.

After careful study of both the data collected during the field investigation and the results obtained from the laboratory tests, strength and other soil properties were determined for the design of the foundation. Furthermore, the paper gives the soil properties of the each layer of subsurface deposits.

The permissible loading intensity for most suitable type of foundation has been evaluated. From the field data and the laboratory results, the safe bearing capacity in general for the strip 1.2 m wide, isolated 2 m x 2 m, Raft 5 m x 5 m for all the sites are calculated and are documented in the chapter "bearing capacity of the soil".

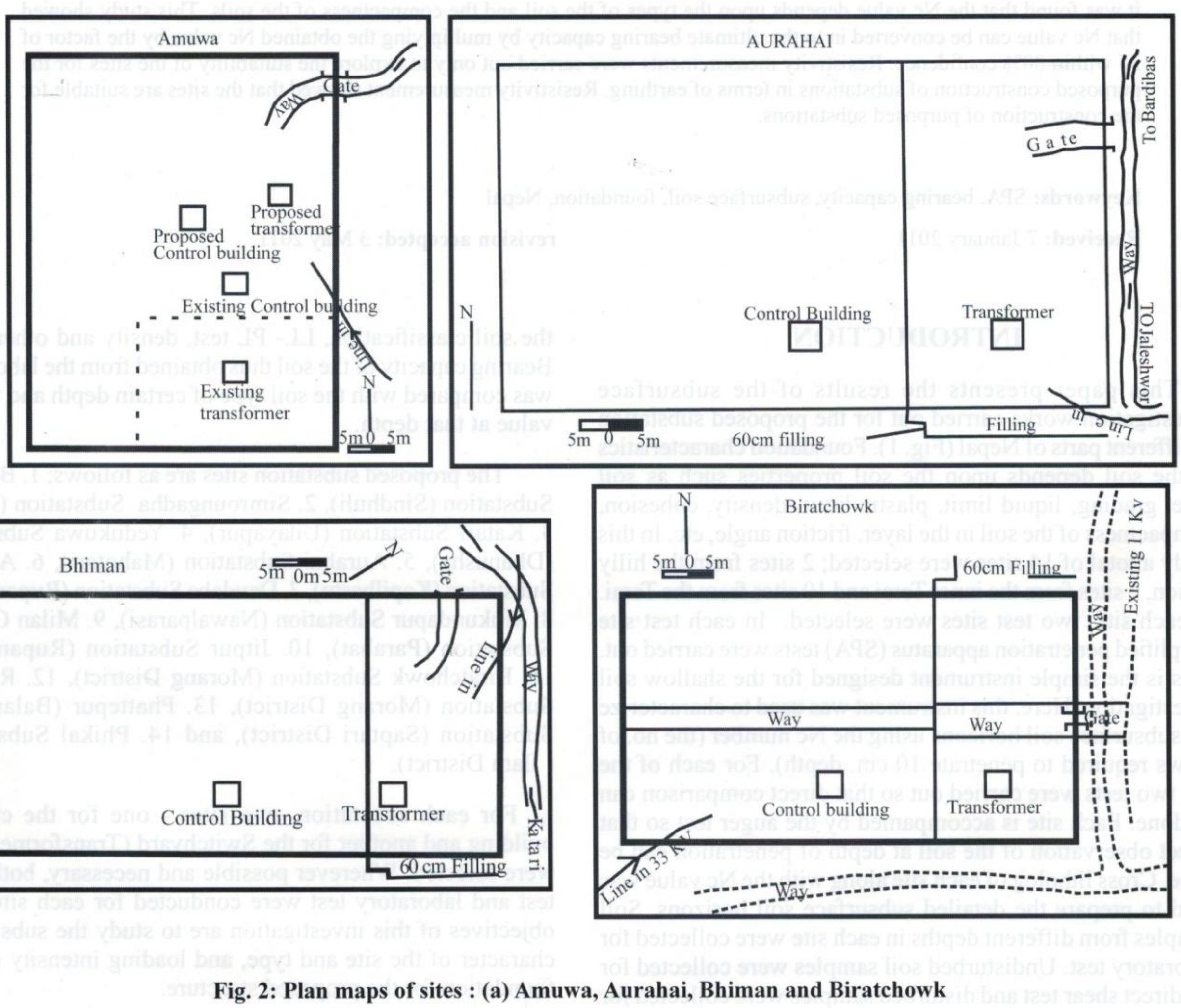


Fig. 2: Plan maps of sites : (a) Amuwa, Aurahai, Bhiman and Biratchowk

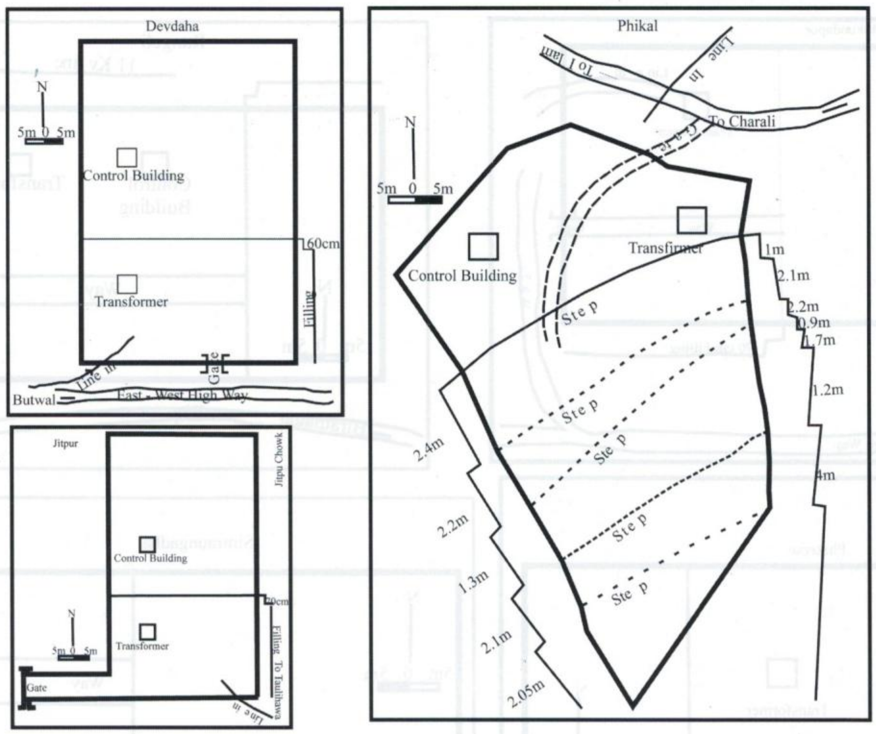


Fig. 2: Plan maps of sites : (b) Devdaha, Jitpur, and Phikal

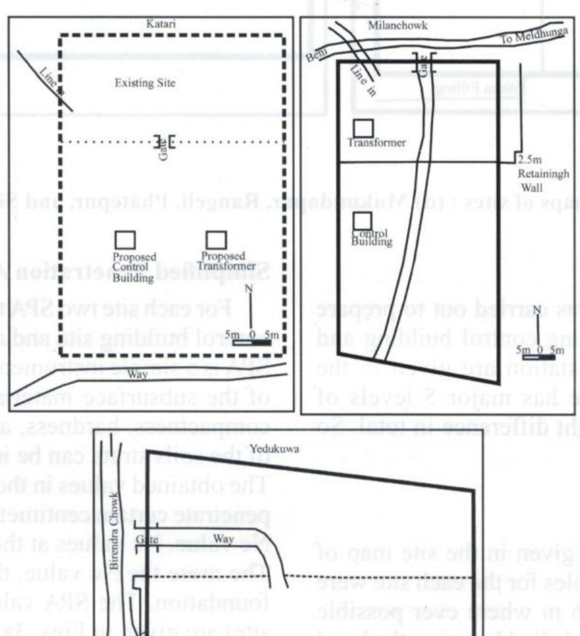


Fig. 2: Plan maps of sites : (c) Katari, Milanchowk and Yedukuwa

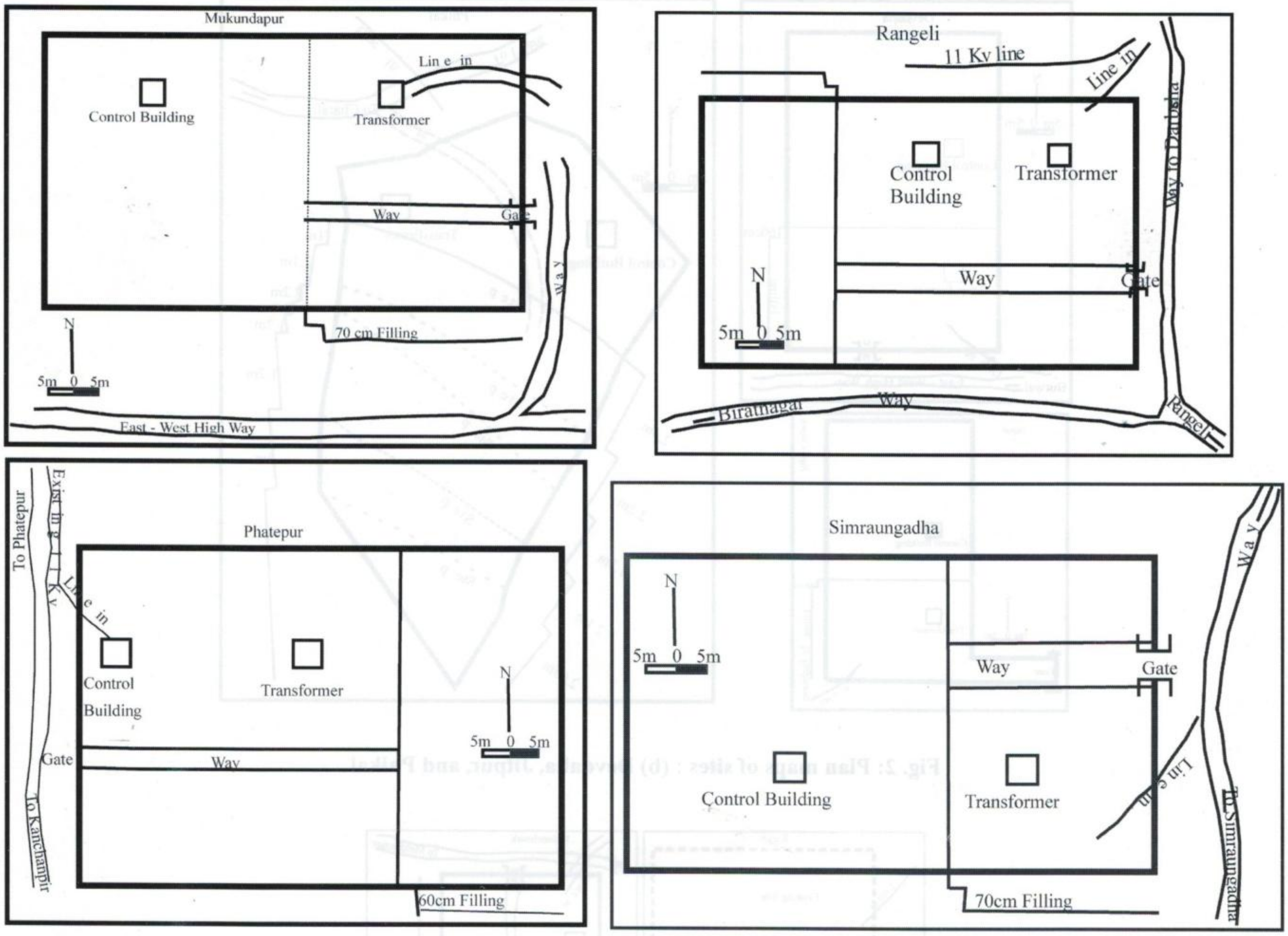


Fig. 2: Plan maps of sites : (d) Mukundapur, Rangeli, Phatepur, and Simraungadha

Detail survey

Detail survey of all the sites was carried out to prepare the site map. The site maps showing control building and switchyard position for each substation are given in the Fig. 2. The Phikal substation site has major 5 levels of terraces with more than 10 m height difference in total. So it should be leveled.

Boreholes

Location of the bore holes are given in the site map of each substation. A total of 2 bore holes for the each site were drilled at the maximum depth of 6 m where ever possible and necessary. Each bore hole was drilled by using the hand auger and using soil sample thus collected, litholog for each site were prepared. The litholog of each site are given in the Figs. 3a to 3z. These litholog are incorporated with Nc value verses depth curves. Water table and major types of soil horizons are described in the litholog.

Simplified Penetration Apparatus (SPA) test

For each site two SPA tests were carried out; one test at the control building site and another test at the switchyard area. SPA is a simple instrument for the continuous measurements of the subsurface material. The differences in the density, compactness, hardness, and other important characteristics of the soils strata can be interpreted by using the SPA value. The obtained values in the field, i. e., the number of blows to penetrate certain centimeter at certain depth are converted as Nc value. Nc values at the given depth are then interpreted. The more the Nc value, the layer of the soil is good for the foundation. The SPA values of each bore hole (2 for each site) are given in Figs. 3a to 3z. The Nc value thus obtained also depends upon the type of the soil but generally, higher values are indicative of good layer for the foundation. The Nc value can be converted in to the ultimate bearing capacity by multiplying the obtained Nc value by the factor of 35 within 80% confidence. The correlation coefficient between the Nc value and the ultimate bearing capacity is 0.829522. Therefore, the safe bearing capacity can be obtained from the converted Nc value by dividing them by the factor of safety (3). The SPA tests should be repeated to as to obtain unbiased values. Results of the bearing capacity from the Nc value are given in Table 1.

Soil sampling

Two types of the sampling were done; disturbed sampling and undisturbed sampling. The laboratory test includes the following; sieve analysis, LL – PL test, natural moisture content, specific gravity, and direct shear test. Disturbed samples were collected for laboratory tests such as sieve analysis, LL-PL test, moisture content, and specific gravity. Undisturbed samples were collected for direct shear test. The undisturbed samples were collected in the tube by hammering the tube on the material in the boreholes. The sample lifted from the depth is sealed with the wax at the both ends of the tube to prevent the moisture loss and taken to the laboratory for the testing.

In-situ testing

The in-situ testing was performed by the SPA test. For each site, it was continuously done down to the depth of 6 m if it is possible and necessary. The SPA data shows that the soil at the Phikal site is very loose up to the depth of 1 m. Thus the first 1 m soil should be removed totally and due consideration should be given during detail design stage. The SPA test data can be used to compare the bearing capacity of the soil further down to the depth of 6 m.

Ground water table

For each site the ground water table in each bore hole is carefully recorded and is shown in the litholog presented in Figs. 3a to 3z. The ground water table in most of the places is due to unconfined shallow aquifers. Except at Biratchowk the ground water table is generally below 3 m from the surface. At Biratchowk it is 90 cm below the surface and should be considered while designing the foundation.

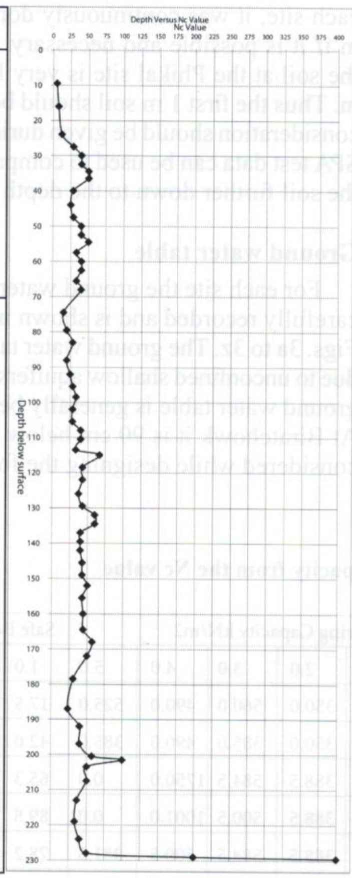
Table 1: Results of bearing capacity from the Nc value

	Minimum average Nc					Bearing Capacity kN/m2					Safe Bearing Capacity kN/m2				
Location / Depth (m)	1.0	2.0	3.0	4.0	5.0	1.0	2.0	3.0	4.0	5.0	1.0	2.0	3.0	4.0	5.0
Phikal Transformer Site	1.5	10.0	16.0	14.0	15.0	52.5	350.0	560.0	490.0	525.0	17.5	116.7	186.7	163.3	175.0
Phikal Control Building Site	3.6	10.0	11.0	14.0	11.0	126.0	350.0	385.0	490.0	385.0	42.0	116.7	128.3	163.3	128.3
Aurahai Control Building	5.6	11.1	16.7	50.0		196.0	388.5	584.5	1750.0	0.0	65.3	129.5	194.8	583.3	
Aurahai Transformer	7.7	11.1	14.3	28.6		269.5	388.5	500.5	1001.0	0.0	89.8	129.5	166.8	333.7	
Devdaha Control Building	6.7	11.1	16.7	14.3	10.9	234.5	388.5	584.5	500.5	381.5	78.2	129.5	194.8	166.8	127.2
Devdaha Transformer	6.7	11.5	23.1	14.3	30.0	234.5	402.5	808.5	500.5	1050.0	78.2	134.2	269.5	166.8	350.0
Simraungadha Transformer	5.3	12.5	16.7	22.0		185.5	437.5	584.5	770.0	0.0	61.8	145.8	194.8	256.7	
Simraungadha Control Building	8.3	10.5	12.5	16.7	20.0	290.5	367.5	437.5	584.5	700.0	96.8	122.5	145.8	194.8	233.3
Jitpur Transformer	6.3	17.9				220.5	626.5	0.0	0.0	0.0	73.5	208.8			
Jitpur Control Building	14.0	16.0	22.2			490.0	560.0	777.0	0.0	0.0	163.3	186.7	259.0		
Mukundapur Transformer	5.0	10.5	14.3	16.7	27.0	175.0	367.5	500.5	584.5	945.0	58.3	122.5	166.8	194.8	315.0
Mukundapur control Building	5.6	13.3	10.5	22.2	28.6	196.0	465.5	367.5	777.0	1001.0	65.3	155.2	122.5	259.0	333.7
Amuwa Transformer Site	5.3	23.5				185.5	822.5	0.0	0.0	0.0	61.8	274.2			
Rangeli Transformer	8.3	10.0	16.7	22.2	16.7	290.5	350.0	584.5	777.0	583.5	96.8	116.7	194.8	259.0	194.5
Rangeli control Building	6.3	10.2	16.0	20.0	25.0	220.5	357.0	560.0	700.0	875.0	73.5	119.0	186.7	233.3	291.7
Phatepur Transformer	5.7	11.1	16.7	20.0	25.0	199.5	388.5	584.5	700.0	875.0	66.5	129.5	194.8	233.3	291.7
Phatepur Control building	8.3	12.5	16.7	28.6	33.3	290.5	437.5	584.5	1001.0	1166.6	96.8	145.8	194.8	333.7	388.9
Biratchowk Transformer	6.3	11.1	20.0	40.0	50.0	220.5	388.5	700.0	1400.0	1750.0	73.5	129.5	233.3	466.7	583.3
Biratchowk Control Building	3.7	11.0	25.0	40.0		129.5	385.0	875.0	1400.0		43.2	128.3	291.7	466.7	
Yedukuwa Control Building	10.0	11.1	16.7	28.6		350.0	388.5	584.5	1000.0	0.0	116.7	129.5	194.8	333.3	
Yedukuwa Transformer	9.1	11.1	16.7	25.0		318.5	388.5	584.5	875.0	0.0	106.2	129.5	194.8	291.7	
Bhiman Control Building	7.1	25.0				248.5	875.0	0.0	0.0	0.0	82.8	291.7	0.0	0.0	0.0
Bhiman Transformer	2.9	20.0				101.5	700.0	0.0	0.0	0.0	33.8	233.3			
Milanchowk Control Building	8.3	16.7	25.0			290.5	584.5	875.0	0.0	0.0	96.8	194.8	291.7		
Milanchowk Transformer	8.3	18.2				290.5	637.0	0.0	0.0	0.0	96.8	212.3			
Katari	15.4	33.3				539.0	1165.5	0.0	0.0	0.0	179.7	388.5			

(a)

Amuwa Sub Station Transformer Site
SPA Test Data

No. of Blows	Depth	Depth Below Surface	Nc	Litholog	Remarks
5	9.5	9.5	5.3	Silty clay	
5	6.5	16	7.7		
10	8	24	12.5		
10	3.5	27.5	28.6	Gravelly sand	Filling
10	2.5	30	40.0		
10	2.5	32.5	40.0		
10	2	34.5	50.0		
10	2	36.5	50.0		
10	3.5	40	28.6		
10	4	44	25.0		
10	3.5	47.5	28.6		
10	2.5	50	40.0		
10	2.5	52.5	40.0		
10	2	54.5	50.0		
10	3	57.5	33.3		
10	2.5	60	40.0		
10	2.5	62.5	40.0		
10	3	65.5	33.3		
10	2.5	68	40.0		
10	6.5	74.5	15.4	Brown Silty clay (Dry)	
10	5	79.5	20.0		
10	3.5	83	28.6		
10	5	88	20.0		
10	4	92	25.0		
10	3.5	95.5	28.6		
10	3	98.5	33.3		
10	3.5	102	28.6		
10	3.5	105.5	28.6		
10	2.5	108	40.0		
10	2.5	110.5	40.0		
10	3	113.5	33.3		
10	1.5	115	66.7		
15	3.5	118.5	42.9		
15	3.5	122	42.9		
15	4	126	37.5		
15	3.5	129.5	42.9		
15	2.5	132	60.0		
15	2.5	134.5	60.0		
10	2.5	137	40.0		
10	2.5	139.5	40.0		
10	2.5	142	40.0		
15	3.5	145.5	42.9		
15	3.5	149	42.9		
15	3	152	50.0		
15	3.5	155.5	42.9		
20	4.5	160	44.4		
20	4.5	164.5	44.4		
20	3.5	168	57.1		
20	4	172	50.0		
20	6.5	178.5	30.8		
20	8.5	187	23.5		
20	5	192	40.0		
20	5	197	40.0		
20	3.5	200.5	57.1	Grey silty clay	
10	1	201.5	100.0		
10	2	203.5	50.0		
20	4	207.5	50.0		
20	5.5	213	36.4		
20	6	219	33.3		
20	5	224	40.0		
20	4	228	50.0		
20	1	229	200.0		
20	0.5	229.5	400.0		



(b)

Aurahai Sub Station Control Building Site
SPA Test Data

No. of Blows	Depth	Depth Below Surface	Nc	Litholog	Remarks
0	0.5	0.5	0.0	Clay	
5	12.5	13	4.0		
5	9	22	5.6		
5	6	28	8.3		
5	6	34	8.3		
5	10	44	5.0		
6	16	60	3.8		
5	16	76	3.1		
5	15	91	3.3		
5	9	100	5.6		
5	10	110	5.0		
5	10.5	120.5	4.8		
5	18.5	139	2.7		
5	9	148	5.6		
5	8	156	6.3		
5	6	162	8.3		
5	5.5	167.5	9.1		
5	4.5	172	11.1	Silty clay	
5	4	176	12.5		
5	4	180	12.5		
5	4	184	12.5		
5	4	188	12.5		
5	3	191	16.7		
5	3	194	16.7		
5	3	197	16.7		
5	3	200	16.7		
5	3	203	16.7		
5	3	206	16.7		
5	3	209	16.7		
5	3.5	212.5	14.3		
5	3	215.5	16.7		
5	2	217.5	25.0	Silt	
5	2	219.5	25.0		
5	2.5	222	20.0		
5	1.5	223.5	33.3		
5	2.5	226	20.0		
5	2	228	25.0		
5	2	230	25.0		
5	1	231	50.0	Silty Sand	
5	3	234	16.7		
5	2	236	25.0		
5	2	238	25.0		
5	1.5	239.5	33.3		
5	1.5	241	33.3		
5	2	243	25.0		
5	2	245	25.0		
5	1	246	50.0		
5	2	248	25.0		
5	1.5	249.5	33.3		
5	1.5	251	33.3		
5	3	254	16.7		
5	1	255	50.0	Sand	
5	1	256	50.0		
5	2	258	25.0		
5	1	259	50.0		
10	3.5	262.5	28.6		
10	3	265.5	33.3		
10	2.5	268	40.0		
10	3	271	33.3		
10	3	274	33.3		
10	2	276	50.0		Water Table
10	3	279	33.3		
10	2	281	50.0		
10	2.5	283.5	40.0		
10	2.5	286	40.0		
10	3	289	33.3		
10	2	291	50.0		
10	2	293	50.0		
10	3	296	33.3		
10	2	298	50.0		
15	3	301	50.0		
15	5	306	30.0		
15	3	309	50.0		
15	4	313	37.5		
15	4	317	37.5		
10	2.5	319.5	40.0		
15	5	324.5	30		
15	4.5	329	33.3		
15	4	333	37.5		
15	3	336	50		
15	3	339	50		
15	4	343	37.5		
15	3	346	50		
15	2	348	75		
15	3	351	50		
15	2	353	75		
15	2.5	355.5	60		
20	4	359.5	50		
15	3	362.5	50		
15	3.5	366	42.9		
15	4.5	370.5	33.3		
15	2	372.5	75		
15	3.5	376	42.9		
15	3	379	50		
15	2	381	75		
15	3	384	50		
15	2.5	386.5	60		
15	2	388.5	75		
15	2	390.5	75		
15	2	392.5	75		
15	3	395.5	50		
10	2	397.5	50		
10	1.5	399	66.7		
10	2	401	50		
10	2	403	50		
10	2	405	50		
10	2	407	50		

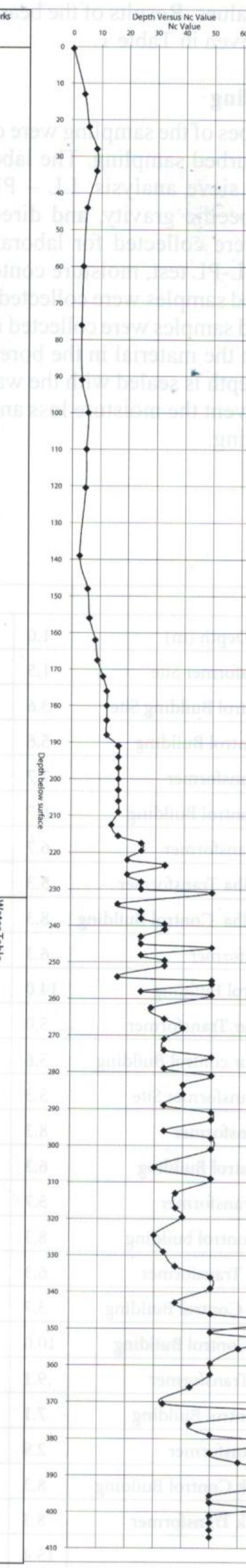
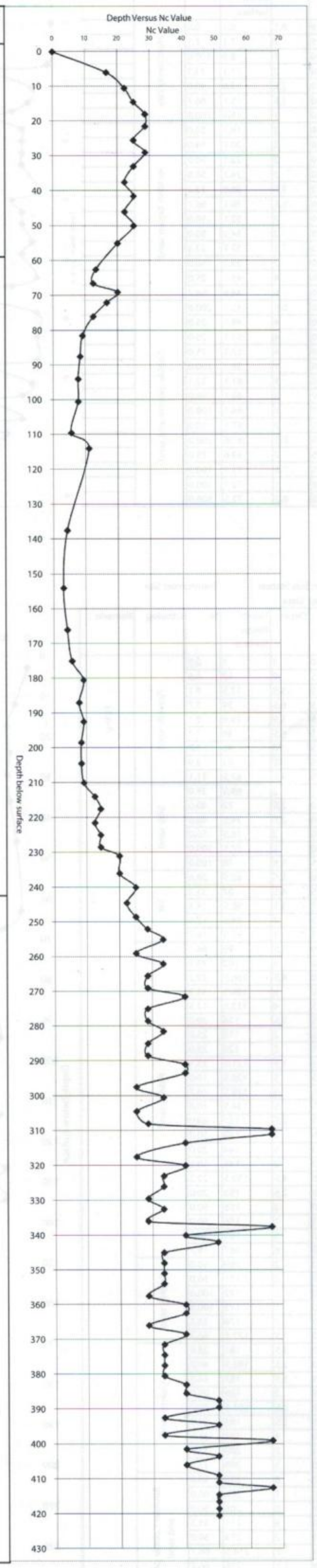


Fig. 3: Litholog, SPA test data, Nc value, Nc value Vs depth curve:
(a) Amuwa Substation Transformer Site, (b) Aurahai Substation, (c) Aurahai Substation Transformer Site, (d) Phattepur (Balardaha) Substation Control Building Site, (e) Phattepur (Balardaha) Substation Transformer Site, (f) Bhiman Substation Control Building Site, (g) Bhiman Substation Transformer Site, (h) Biratchowk Substation Control Building Site, (i) Biratchowk Substation Transformer Site, (j) Devdaha Substation Control Building Site, (k) Devdaha Substation Transformer Site, (l) Phikal Substation Control Building Site, (m) Phikal Substation Transformer Site, (n) Jitpur Substation Control Building Site, (o) Jitpur Substation Transformer Site, (p) Katari Substation Transformer Site, (q) Milan Chowk Substation Control Building Site, (r) MilanChowk Substation, (s) Mukundapur Substation Control Building Site, (t) Mukundapur Substation Transformer Site, (u) Rangeli Substation Control Building Site, (v) Rangeli Substation Transformer Site, (w) Simroungadha Substation Control Building Site, (x) Simroungadha Substation Transformer site, (y) Yedukuwa Substation Control Building Site, and (z) Yedukuwa Substation Transformer Site

(c)

Aurahai Sub Station Transformer Site
SPA Test Data

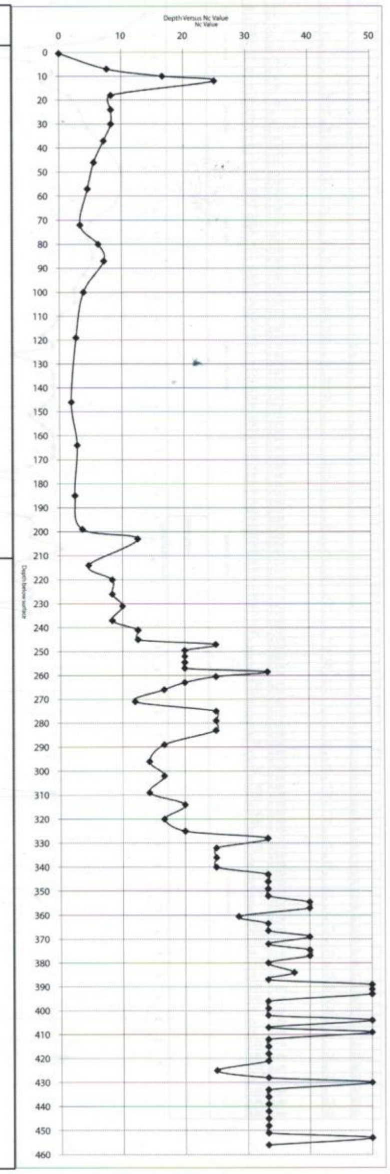
No. of Blows	Depth	Depth Below	Nc	Litholog	Remarks
0	0.1	0.1	0.0	Gravel, sand and silt	Filling
10	6	6.1	16.7		
10	4.5	10.6	22.2		
10	4	14.6	25.0		
10	3.5	18.1	28.6		
10	3.5	21.6	28.6		
10	4	25.6	25.0		
10	3.5	29.1	28.6		
10	4	33.1	25.0		
10	4.5	37.6	-22.2		
10	4	41.6	25.0		
10	4.5	46.1	22.2		
10	4	50.1	25.0		
10	5	55.1	20.0		
10	7.5	62.6	13.3	Clay	
5	4	66.6	12.5		
5	2.5	69.1	20.0		
5	3	72.1	16.7		
5	4	76.1	12.5		
5	5.5	81.6	9.1	Silty clay	
5	6	87.6	8.3		
5	6.5	94.1	7.7		
5	6.5	100.6	7.7		
5	9	109.6	5.6		
5	4.5	114.1	11.1		
10	23.5	137.6	4.3		
5	16.5	154.1	3.0		
5	12	166.1	4.2		
5	9	175.1	5.6		
5	5.5	180.6	9.1		
5	6.5	187.1	7.7		
5	5.5	192.6	9.1		
5	6	198.6	8.3		
5	6	204.6	8.3		
5	5.5	210.1	9.1		
5	4	214.1	12.5		
5	3.5	217.6	14.3		
5	4	221.6	12.5		
5	3.5	225.1	14.3		
5	3.5	228.6	14.3		
5	2.5	231.1	20.0	Silty Sand	
10	5	236.1	20.0		
10	4	240.1	25.0		
10	4.5	244.6	22.2		
10	4	248.6	25.0		
10	3.5	252.1	28.6		
10	3	255.1	33.3		
10	4	259.1	25.0		
10	3	262.1	33.3		
10	3.5	265.6	28.6		
10	3.5	269.1	28.6		
10	2.5	271.6	40.0		
10	3.5	275.1	28.6		
10	3.5	278.6	28.6		
10	3	281.6	33.3		
10	3.5	285.1	28.6		
10	3.5	288.6	28.6		
10	2.5	291.1	40.0		
10	2.5	293.6	40.0		
10	4	297.6	25.0		
10	3	300.6	33.3		Water Table
10	4	304.6	25.0		
10	3.5	308.1	28.6		
10	1.5	309.6	66.7	Sand	
10	1.5	311.1	66.7		
10	2.5	313.6	40.0		
10	4	317.6	25.0		
10	2.5	320.1	40.0		
10	3	323.1	33.3		
10	3	326.1	33.3		
10	3.5	329.6	28.6		
10	3	332.6	33.3		
10	3.5	336.1	28.6		
10	1.5	337.6	66.7		
10	2.5	340.1	40.0		
10	2	342.1	50.0		
10	3	345.1	33.3		
10	3	348.1	33.3		
10	3	351.1	33.3		
10	3	354.1	33.3		
10	3.5	357.6	28.6		
10	2.5	360.1	40		
10	2.5	362.6	40		
10	3.5	366.1	28.6		
10	2.5	368.6	40		
10	3	371.6	33.3		
10	3	374.6	33.3		
10	3	377.6	33.3		
10	3	380.6	33.3		
10	2.5	383.1	40		
10	2.5	385.6	40		
10	2	387.6	50		
10	2	389.6	50		
10	3	392.6	33.3		
10	2	394.6	50		
10	3	397.6	33.3		
10	1.5	399.1	66.7		
10	2.5	401.6	40		
10	2	403.6	50		
10	2.5	406.1	40		
15	3	409.1	50		
10	2	411.1	50		
10	1.5	412.6	66.7		
10	2	414.6	50		
10	2	416.6	50		
10	2	418.6	50		
10	2	420.6	50		



(d)

Balardha Sub Station Control Building Site
SPA Test Data

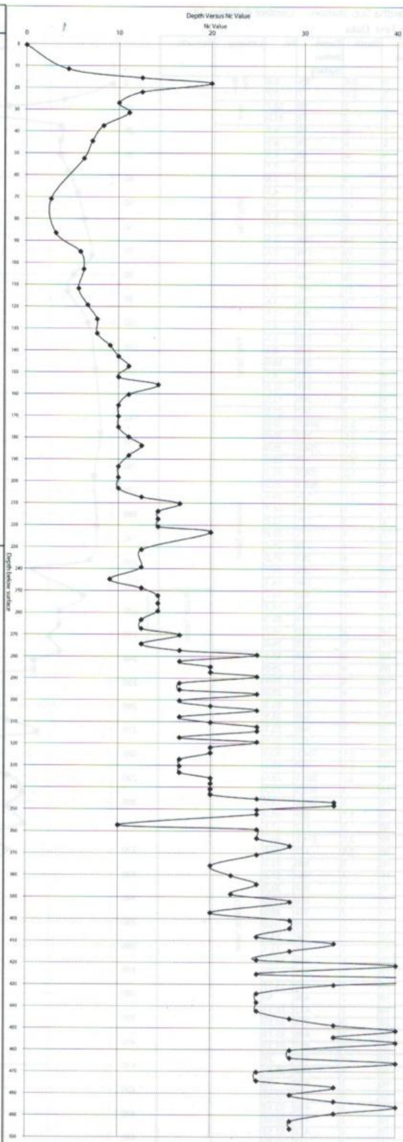
No. of Blows	Depth	Depth Below Surface	Nc	Litholog	Remarks
0	0.5	0.5	0.0	Black Clay	
5	6.5	7	7.7		
5	3	10	16.7	Sand	
5	2	12	25.0		
5	6	18	8.3	Silty Clay	
5	6	24	8.3		
5	6	30	8.3		
5	7	37	7.1		
5	9	46	5.6		
5	11	57	4.5		
5	15	72	3.3		
5	8	80	6.3		
5	7	87	7.1		
5	13	100	3.8		
5	19	119	2.6		
5	27	146	1.9		
5	18	164	2.8		
5	21	185	2.4		
5	14	199	3.6		
5	4	203	12.5	Fine Sand	
5	11	214	4.5		
5	6	220	8.3		
5	6	226	8.3		
5	5	231	10.0		
5	6	237	8.3		
5	4	241	12.5		
5	4	245	12.5		
5	2	247	25.0	Medium Sand	
5	2.5	249.5	20.0		
5	2.5	252	20.0		
5	2.5	254.5	20.0		
5	2.5	257	20.0		
5	1.5	258.5	33.3		
5	2	260.5	25.0		
5	2.5	263	20.0		
5	3	266	16.7		
6	5	271	12.0		
10	4	275	25.0		
10	4	279	25.0		
10	4	283	25.0		
10	6	289	16.7		
10	7	296	14.3		
10	6	302	16.7		Water Table
10	7	309	14.3		
10	5	314	20.0		
10	6	320	16.7		
10	5	325	20.0		
10	3	328	33.3	Coarse Sand	
10	4	332	25.0		
10	4	336	25.0		
10	4	340	25.0		
10	3	343	33.3		
10	3	346	33.3		
10	3	349	33.3		
10	3	352	33.3		
10	2.5	354.5	40.0		
10	2.5	357	40.0		
10	3.5	360.5	28.6		
10	3	363.5	33.3		
10	3	366.5	33.3		
10	2.5	369	40.0		
10	3	372	33.3		
10	2.5	374.5	40.0		
10	2.5	377	40.0		
10	3	380	33.3		
15	4	384	37.5		
10	3	387	33.3		
10	2	389	50.0		
10	2	391	50.0		
10	2	393	50.0		
10	3	396	33.3		
10	3	399	33.3		
10	3	402	33.33		
10	2	404	50		
10	3	407	33.33		
10	2	409	50		
10	3	412	33.33		
10	3	415	33.33		
10	3	418	33.33		
10	3	421	33.33		
10	4	425	25		
10	3	428	33.33		
10	2	430	50		
10	3	433	33.33		
10	3	436	33.33		
10	3	439	33.33		
10	3	442	33.33		
10	3	445	33.33		
10	3	448	33.33		
10	3	451	33.33		
10	2	453	50		
10	3	456	33.33		



(e)

Balardha Sub Station　　Transformer Site
SPA Test Data

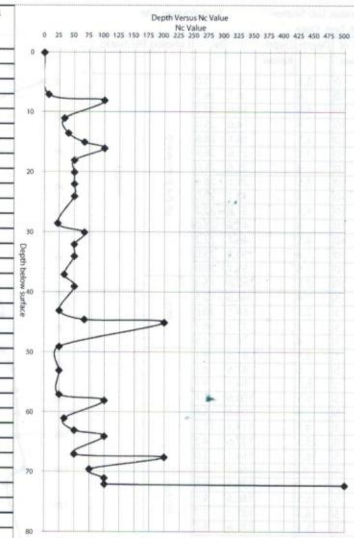
No. of Blows	Depth	Depth Below Surface	Nc	Litholog	Remarks
0	0.5	0.5	0.0	Clay	
5	11	11.5	4.5		
5	4	15.5	12.5	Fine Sand	
5	2.5	18	20.0		
5	4	22	12.5		
5	5	27	10.0		
5	4.5	31.5	11.1		
5	6	37.5	8.3	Grey Clay	
5	7	44.5	7.1		
5	8	52.5	6.3		
5	18.5	71	2.7		
5	15.5	86.5	3.2		
5	8.5	95	5.9		
5	8	103	6.3		
5	8.8	111.8	5.7		
5	7.5	119.3	6.7		
5	6.5	123.8	7.7		
5	6.5	132.3	7.7		
5	5.5	137.8	9.1		
5	5	142.8	10.0	Silty Clay	
5	4.5	147.3	11.1		
5	5	152.3	10.0		
5	3.5	155.8	14.3		
5	4.5	160.3	11.1		
5	5	165.3	10.0		
5	5	170.3	10.0		
5	5	175.3	10.0		
5	4.5	179.8	11.1		
5	4	183.8	12.5		
5	4.5	188.3	11.1		
5	5	193.3	10.0		
5	5	198.3	10.0		
5	5	203.3	10.0		
5	4	207.3	12.5	Clean Fine Sand	
5	3	210.3	16.7		
5	3.5	213.8	14.3		
5	3.5	217.3	14.3		
5	3.5	220.8	14.3		
5	2.5	223.3	20.0		
10	8	231.3	12.5		
10	8	239.3	12.5		
5	5.5	244.8	9.1		
5	4	248.8	12.5		
5	3.5	252.3	14.3		
5	3.5	255.8	14.3		
5	3.5	259.3	14.3		
5	4	263.3	12.5		
5	4	267.3	12.5		
5	3	270.3	16.7		
5	4	274.3	12.5		
5	3	277.3	16.7	Medium Sand	
5	2	279.3	25.0		
5	3	282.3	16.7		
5	2.5	284.8	20.0		
5	2.5	287.3	20.0		
5	2	289.3	25.0		
5	3	292.3	16.7		
5	3	295.3	16.7		
5	2	297.3	25.0		
5	3	300.3	16.7		Water Table
5	2.5	302.8	20.0		
5	2	304.8	25.0		
5	3	307.8	16.7		
5	2.5	310.3	20.0		
5	2	312.3	25.0		
5	2	314.3	25.0		
5	3	317.3	16.7		
5	2	319.3	25.0		
5	2.5	321.8	20.0		
5	2.5	324.3	20.0		
5	3	327.3	16.7		
5	3	330.3	16.7		
5	3	333.3	16.67		
5	2.5	335.8	20		
5	2.5	338.3	20		
5	2.5	340.8	20		
5	2.5	343.3	20		
5	2	345.3	25	Coarse Sand	
5	1.5	346.8	33.33		
5	1.5	348.3	33.33		
5	2	350.3	25		
5	2	352.3	25		
5	5	357.3	10		
5	2	359.3	25		
10	4	363.3	25		
10	3.5	366.8	28.57		
10	4	370.8	25		
10	5	375.8	20		
10	4.5	380.3	22.22		
10	4	384.3	25		
10	4.5	388.8	22.22		
10	3.5	392.3	28.57		
10	5	397.3	20		
10	3.5	400.8	28.57		
10	3.5	404.3	28.57		
10	4	408.3	25		
10	3	411.3	33.33		
10	3.5	414.8	28.57		
10	4	418.8	25		
10	2.5	421.3	40		
10	4	425.3	25		
10	2	427.3	50		
10	3	430.3	33.33		
10	4	434.3	25		
10	4	438.3	25		
10	4	442.3	25		
10	3.5	445.8	28.6		
10	3	448.8	33.3		
10	2.5	451.3	40		
10	3	454.3	33.3		
10	2.5	456.8	40		
10	3.5	460.3	28.6		
10	3.5	463.8	28.6		
10	2.5	466.3	40		
10	4	470.3	25		
10	4	474.3	25		
10	3	477.3	33.3		
10	3.5	480.8	28.6		
10	3	483.8	33.3		
10	2.5	486.3	40		
10	3	489.3	33.3		
10	3.5	492.8	28.6		
10	3.5	496.3	28.6		



(f)

Bhiman Sub Station　　Control building Site
SPA Test Data

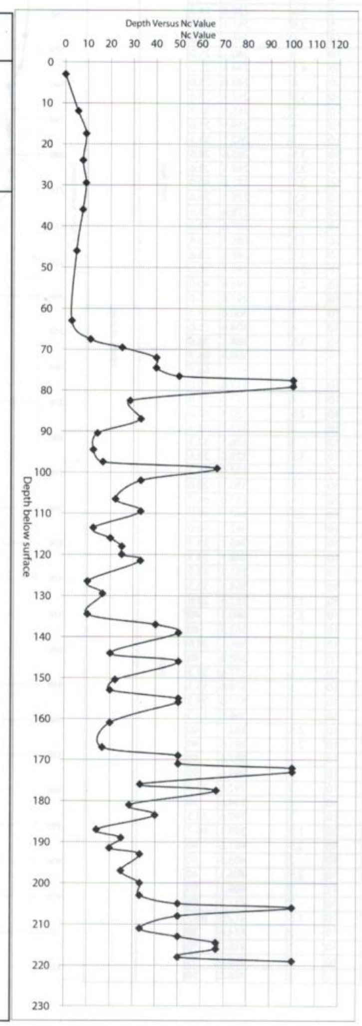
No. of Blows	Depth	Depth Below Surface	Nc	Litholog	Remarks
0	0.1	0.1	0.0	Hard sandy clay	
5	7	7.1	7.1		
10	1	8.1	100.0		
10	3	11.1	33.3		
10	2.5	13.6	40.0		
10	1.5	15.1	66.7		
10	1	16.1	100.0		
10	2	18.1	50.0	Redish brown sand	
10	2	20.1	50.0		
10	2	22.1	50.0		
10	2	24.1	50.0		
10	4.5	28.6	22.2		
10	1.5	30.1	66.7		
10	2	32.1	50.0		
10	2	34.1	50.0		
10	3	37.1	33.3		
10	2	39.1	50.0		
10	4	43.1	25.0		
10	1.5	44.6	66.7		
10	0.5	45.1	200.0	Cobble, pebble and sand	
10	4	49.1	25.0		
10	4	53.1	25.0		
10	4	57.1	25.0		
10	1	58.1	100.0		
10	3	61.1	33.3		
10	2	63.1	50.0		
10	1	64.1	100.0		
15	3	67.1	50.0		
10	0.5	67.6	200.0		
15	2	69.6	75.0		
15	1.5	71.1	100.0		
10	1	72.1	100.0		
10	0.2	72.3	500.0		



(g)

Bhiman Sub Station　　Transformer Site
SPA Test Data

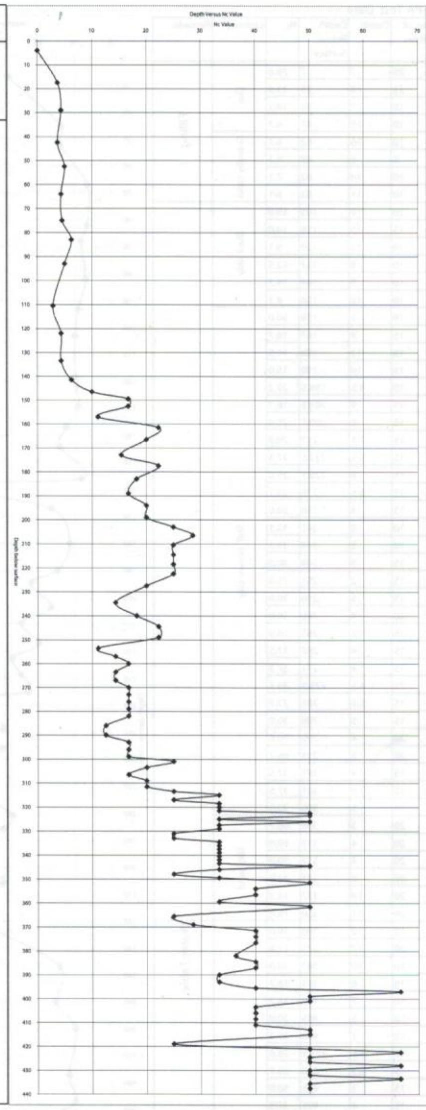
No. of Blows	Depth	Depth Below Surface	Nc	Litholog	Remarks
0	3	3	0.0	Gravelly sand	Filling
5	9	12	5.6		
5	5.5	17.5	9.1		
5	6.5	24	7.7		
5	5.5	29.5	9.1		
5	6.5	36	7.7		
5	10	46	5.0		
5	17	63	2.9		
5	4.5	67.5	11.1		
5	2	69.5	25.0	Silty sand	
10	2.5	72	40.0		
10	2.5	74.5	40.0		
10	2	76.5	50.0		
10	1	77.5	100.0		
15	1.5	79	100.0		
10	3.5	82.5	28.6	Silt	
15	4.5	87	33.3		
5	3.5	90.5	14.3		
5	4	94.5	12.5		
5	3	97.5	16.7		
10	1.5	99	66.7	Pebbly sand	
10	3	102	33.3		
10	4.5	106.5	22.2		
10	3	109.5	33.3		
5	4	113.5	12.5		
5	2.5	116	20.0		
5	2	118	25.0		
5	2	120	25.0		
5	1.5	121.5	33.3		
5	5	126.5	10.0		
5	3	129.5	16.7		
5	5	134.5	10.0		
10	2.5	137	40.0		
10	2	139	50.0		
10	5	144	20.0		
10	2	146	50.0		
10	4.5	150.5	22.2		
5	2.5	153	20.0		
10	2	155	50.0		
5	1	156	50.0		
10	5	161	20.0		
10	6	167	16.7		
10	2	169	50.0	Cobbly sand	
10	2	171	50.0		
10	1	172	100.0		
10	1	173	100.0		
10	3	176	33.3		
10	1.5	177.5	66.7		
10	3.5	181	28.6	Coarse sand	
10	2.5	183.5	40.0		
5	3.5	187	14.3		
5	2	189	25.0		
5	2.5	191.5	20.0		
5	1.5	193	33.3		
10	4	197	25.0		
10	3	200	33.3		
10	3	203	33.3		
10	2	205	50.0	Boulder Cobble pebble and sand	
10	1	206	100.0		
10	2	208	50.0		
10	3	211	33.3		
10	2	213	50.0		
10	1.5	214.5	66.7		
10	1.5	216	66.7		
10	2	218	50.0		
10	1	219	100.0		



(h)

Biratchowk Sub Station Control Building Site
SPA Test Data

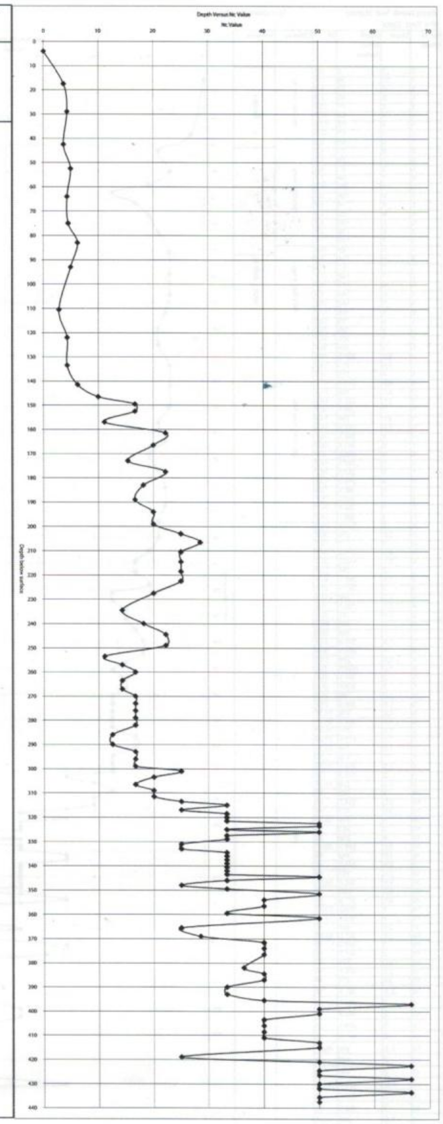
No. of Blows	Depth	Depth Below Surface	Nc	Litholog	Remarks
0	4	4	0.0	Top Soil, Silty Clay	
5	13.5	17.5	3.7		
5	11.5	29	4.3		
5	13.5	42.5	3.7		
5	10	52.5	5.0		
5	11.5	64	4.3		
5	11	75	4.5		
5	8	83	6.3		
5	10	93	5.0		
5	17.5	110.5	2.9		Water Table
5	11.5	122	4.3		
5	11.5	133.5	4.3		
5	8	141.5	6.3		
5	5	146.5	10.0	Silty Sand	
5	3	149.5	16.7		
5	3	152.5	16.7		
5	4.5	157	11.1		
10	4.5	161.5	22.2	Fine Sand, Silt	
10	5	166.5	20.0		
10	6.5	173	15.4		
10	4.5	177.5	22.2		
10	5.5	183	18.2		
10	6	189	16.7		
10	5	194	20.0		
10	5	199	20.0		
10	4	203	25.0		
10	3.5	206.5	28.6		
10	4	210.5	25.0		
10	4	214.5	25.0		
10	4	218.5	25.0		
10	4	222.5	25.0		
10	5	227.5	20.0		
10	7	234.5	14.3	Fine Sand	
10	5.5	240	18.2		
10	4.5	244.5	22.2		
10	4.5	249	22.2		
5	4.5	253.5	11.1		
5	3.5	257	14.3		
5	3	260	16.7		
5	3.5	263.5	14.3		
5	3.5	267	14.3		
5	3	270	16.7		
5	3	273	16.7		
5	3	276	16.7		
5	3	279	16.7		
5	3	282	16.7		
5	4	286	12.5		
5	4	290	12.5		
5	3	293	16.7		
5	3	296	16.7		
5	3	299	16.7		
5	2	301	25.0		
5	2.5	303.5	20.0		
5	3	306.5	16.7		
5	2.5	309	20.0		
5	2.5	311.5	20.0		
5	2	313.5	25.0	Medium Sand	
5	1.5	315	33.3		
5	2	317	25.0		
5	1.5	318.5	33.3		
5	1.5	320	33.3		
5	1.5	321.5	33.3		
5	1	322.5	50.0		
5	1	323.5	50.0		
5	1.5	325	33.3		
5	1	326	50.0		
5	1.5	327.5	33.3		
5	1.5	329	33.3		
5	2	331	25.0		
5	2	333	25.0		
5	1.5	334.5	33.3		
5	1.5	336	33.3		
5	1.5	337.5	33.33		
5	1.5	339	33.33		
5	1.5	340.5	33.33		
5	1.5	342	33.33		
5	1.5	343.5	33.33		
5	1	344.5	50		
5	1.5	346	33.33		
5	2	348	25		
5	1.5	349.5	33.33		
10	2	351.5	50		
10	2.5	354	40		
10	2.5	356.5	40		
10	3	359.5	33.33		
10	2	361.5	50		
10	4	365.5	25		
10	3.5	369	28.57		
10	2.5	371.5	40		
10	2.5	374	40		
10	2.5	376.5	40		
20	5.5	382	36.36		
10	2.5	384.5	40		
10	2.5	387	40		
10	3	390	33.33		
10	3	393	33.33		
10	2.5	395.5	40		
10	1.5	397	66.67		
10	2	399	50		
10	2	401	50		
10	2.5	403.5	40		
10	2.5	406	40		
10	2.5	408.5	40		
10	2.5	411	40		
10	2	413	50		
10	2	415	50		
10	4	419	25		
10	2	421	50	Coarse Sand	
10	1.5	422.5	66.67		
10	2	424.5	50		
10	2	426.5	50		
10	1.5	428	66.67		
10	2	430	50		
10	2	432	50		
10	1.5	433.5	66.67		
10	2	435.5	50		
10	2	437.5	50		



(i)

Biratchowk Sub Station Control Building Site
SPA Test Data

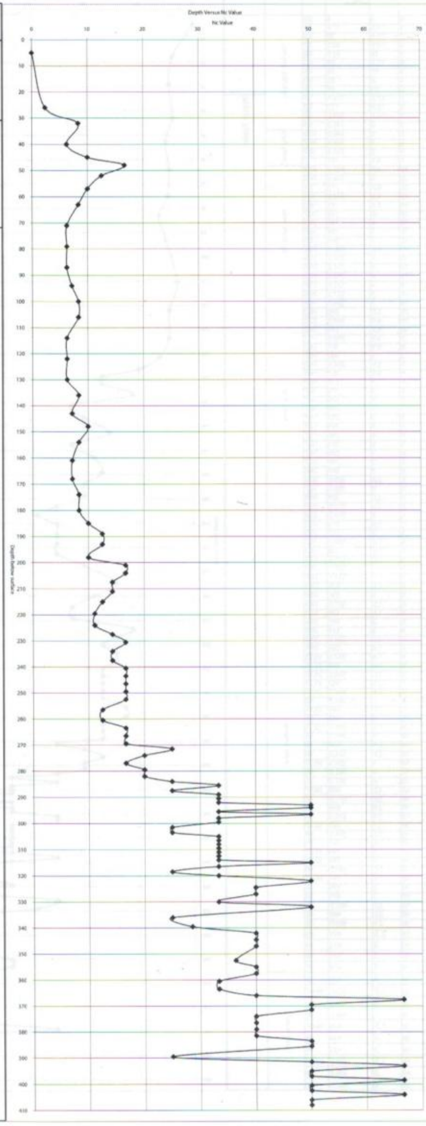
No. of Blows	Depth	Depth Below Surface	Nc	Litholog	Remarks
0	4	4	0.0	Top Soil, Silty Clay	
5	13.5	17.5	3.7		
5	11.5	29	4.3		
5	13.5	42.5	3.7		
5	10	52.5	5.0		
5	11.5	64	4.3		
5	11	75	4.5		
5	8	83	6.3		
5	10	93	5.0		
5	17.5	110.5	2.9		Water Table
5	11.5	122	4.3		
5	11.5	133.5	4.3		
5	8	141.5	6.3		
5	5	146.5	10.0	Silty Sand	
5	3	149.5	16.7		
5	3	152.5	16.7		
5	4.5	157	11.1		
10	4.5	161.5	22.2	Fine Sand, Silt	
10	5	166.5	20.0		
10	6.5	173	15.4		
10	4.5	177.5	22.2		
10	5.5	183	18.2		
10	6	189	16.7		
10	5	194	20.0		
10	5	199	20.0		
10	4	203	25.0		
10	3.5	206.5	28.6		
10	4	210.5	25.0		
10	4	214.5	25.0		
10	4	218.5	25.0		
10	4	222.5	25.0		
10	5	227.5	20.0		
10	7	234.5	14.3	Fine Sand	
10	5.5	240	18.2		
10	4.5	244.5	22.2		
10	4.5	249	22.2		
5	4.5	253.5	11.1		
5	3.5	257	14.3		
5	3	260	16.7		
5	3.5	263.5	14.3		
5	3.5	267	14.3		
5	3	270	16.7		
5	3	273	16.7		
5	3	276	16.7		
5	3	279	16.7		
5	3	282	16.7		
5	4	286	12.5		
5	4	290	12.5		
5	3	293	16.7		
5	3	296	16.7		
5	3	299	16.7		
5	2	301	25.0		
5	2.5	303.5	20.0		
5	3	306.5	16.7		
5	2.5	309	20.0		
5	2.5	311.5	20.0		
5	2	313.5	25.0	Medium Sand	
5	1.5	315	33.3		
5	2	317	25.0		
5	1.5	318.5	33.3		
5	1.5	320	33.3		
5	1.5	321.5	33.3		
5	1	322.5	50.0		
5	1	323.5	50.0		
5	1.5	325	33.3		
5	1	326	50.0		
5	1.5	327.5	33.3		
5	1.5	329	33.3		
5	2	331	25.0		
5	2	333	25.0		
5	1.5	334.5	33.3		
5	1.5	336	33.3		
5	1.5	337.5	33.33		
5	1.5	339	33.33		
5	1.5	340.5	33.33		
5	1.5	342	33.33		
5	1.5	343.5	33.33		
5	1	344.5	50		
5	1.5	346	33.33		
5	2	348	25		
5	1.5	349.5	33.33		
10	2	351.5	50		
10	2.5	354	40		
10	2.5	356.5	40		
10	3	359.5	33.33		
10	2	361.5	50		
10	4	365.5	25		
10	3.5	369	28.57		
10	2.5	371.5	40		
10	2.5	374	40		
10	2.5	376.5	40		
20	5.5	382	36.36		
10	2.5	384.5	40		
10	2.5	387	40		
10	3	390	33.33		
10	3	393	33.33		
10	2.5	395.5	40		
10	1.5	397	66.67		
10	2	399	50		
10	2	401	50		
10	2.5	403.5	40		
10	2.5	406	40		
10	2.5	408.5	40		
10	2.5	411	40		
10	2	413	50		
10	2	415	50		
10	4	419	25		
10	2	421	50	Coarse Sand	
10	1.5	422.5	66.67		
10	2	424.5	50		
10	2	426.5	50		
10	1.5	428	66.67		
10	2	430	50		
10	2	432	50		
10	1.5	433.5	66.67		
10	2	435.5	50		
10	2	437.5	50		



(j)

Biratchowk Sub Station Transformer Site
SPA Test Data

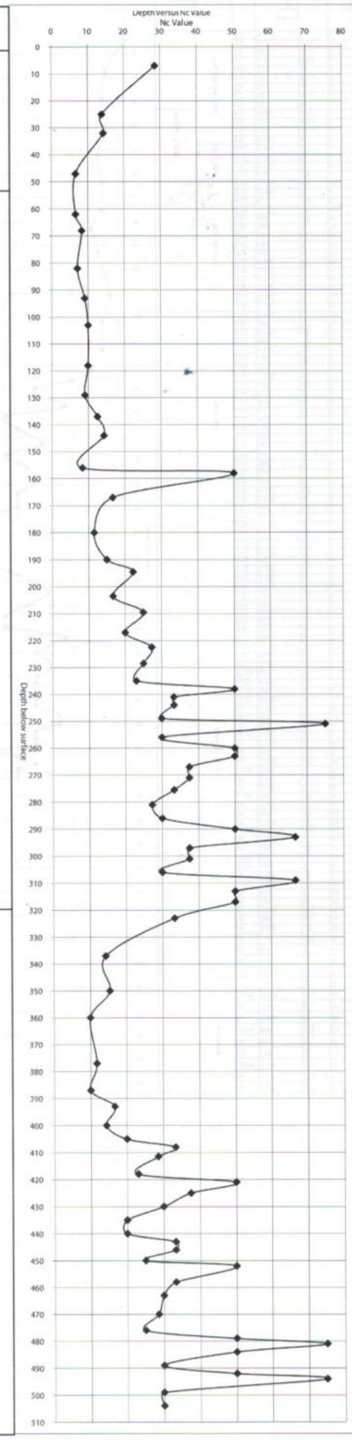
No. of Blows	Depth	Depth Below Surface	Nc	Litholog	Remarks
0	5	5	0.0	Top Soil, Silty Clay	Filling
5	21	26	2.4		
5	6	32	8.3		
5	8	40	6.3		
5	5	45	10.0		
5	3	48	16.7		
5	4	52	12.5		
5	5	57	10.0		
5	6	63	8.3	Grey Silty Clay	
5	8	71	6.3		
5	8	79	6.3		
5	8	87	6.3		
5	7	94	7.1		
5	6	100	8.3		
5	6	106	8.3		
5	8	114	6.3		
5	8	122	6.3		
5	8	130	6.3		
5	6	136	8.3		
5	7	143	7.1		
5	5	148	10.0	Black Silty Clay	
5	6	154	8.3		Water Table
5	7	161	7.1		
5	7	168	7.1		
5	6	174	8.3		
5	6	180	8.3		
5	5	185	10.0		
5	4	189	12.5		
5	4	193	12.5		
5	5	198	10.0		
5	3	201	16.7	Very Fine Sand, Silt	
5	3	204	16.7		
5	3.5	207.5	14.3		
5	3.5	211	14.3		
5	4	215	12.5		
5	4.5	219.5	11.1		
5	4.5	224	11.1		
5	3.5	227.5	14.3		
5	3	230.5	16.7		
5	3.5	234	14.3		
5	3.5	237.5	14.3		
5	3	240.5	16.7		
5	3	243.5	16.7		
5	3	246.5	16.7		
5	3	249.5	16.7		
5	3	252.5	16.7		
5	4	256.5	12.5		
5	4	260.5	12.5		
5	3	263.5	16.7		
5	3	266.5	16.7		
5	3	269.5	16.7		
5	2	271.5	25.0	Sand	
5	2.5	274	20.0		
5	3	277	16.7		
5	2.5	279.5	20.0		
5	2.5	282	20.0		
5	2	284	25.0		
5	1.5	285.5	33.3		
5	2	287.5	25.0		
5	1.5	289	33.3		
5	1.5	290.5	33.3		
5	1.5	292	33.3		
5	1	293	50.0		
5	1	294	50.0		
5	1.5	295.5	33.3		
5	1	296.5	50.0		
5	1.5	298	33.3		
5	1.5	299.5	33.3		
5	2	301.5	25.0		
5	2	303.5	25.0		
5	1.5	305	33.3		
5	1.5	306.5	33.3		
5	1.5	308	33.33		
5	1.5	309.5	33.33		
5	1.5	311	33.33		
5	1.5	312.5	33.33		
5	1.5	314	33.33		
5	1	315	50		
5	1.5	316.5	33.33		
5	2	318.5	25		
5	1.5	320	33.33		
10	2	322	50		
10	2.5	324.5	40		
10	2.5	327	40		
10	3	330	33.33		
10	2	332	50		
10	4	336	25		
10	3.5	339.5	28.57		
10	2.5	342	40		
10	2.5	344.5	40		
10	2.5	347	40		
20	5.5	352.5	36.36		
10	2.5	355	40		
10	2.5	357.5	40		
10	3	360.5	33.33		
10	3	363.5	33.33		
10	2.5	366	40		
10	1.5	367.5	66.67		
10	2	369.5	50		
10	2	371.5	50		
10	2.5	374	40		
10	2.5	376.5	40		
10	2.5	379	40		
10	2.5	381.5	40		
10	2	383.5	50		
10	2	385.5	50		
10	4	389.5	25		
10	2	391.5	50		
10	1.5	393	66.67		
10	2	395	50		
10	2	397	50		
10	1.5	398.5	66.67		
10	2	400.5	50		
10	2	402.5	50		
10	1.5	404	66.67		
10	2	406	50		
10	2	408	50		



(k)

Devdaha Sub Station Transformer Site
SPA Test Data

No. of Blows	Depth	Depth Below Surface	Nc	Litholog	Remarks
20	7	7	28.6	Clay	Filling
25	18	25	13.9		
10	7	32	14.3		
10	15	47	6.7		
10	15	62	6.7	Gravelly sand	
5	6	68	8.3		
10	14	82	7.1		
10	11	93	9.1		
10	10	103	10.0	Black clay	
15	15	118	10.0		
10	11	129	9.1		
10	8	137	12.5		
10	7	144	14.3		
10	12	156	8.3		
10	2	158	50.0	Stiff brown clay	
15	9	167	16.7		
15	13	180	11.5		
15	10	190	15.0		
10	4.5	194.5	22.2		
15	9	203.5	16.7		
15	6	209.5	25.0		
15	7.5	217	20.0		
15	5.5	222.5	27.3		
15	6	228.5	25.0		
15	6.5	235	23.1		
15	3	238	50.0		
10	3	241	33.3		
10	3	244	33.3		
15	5	249	30.0		
15	2	251	75.0		
15	5	256	30.0		
20	4	260	50.0		
15	3	263	50.0		
15	4	267	37.5		
15	4	271	37.5		
15	4.5	275.5	33.3		
15	5.5	281	27.3		
15	5	286	30.0		
20	4	290	50.0		
20	3	293	66.7		
15	4	297	37.5		
15	4	301	37.5		
15	5	306	30.0		
20	3	309	66.7	Silty sand	
20	4	313	50.0		
20	4	317	50.0		
20	6	323	33.3		
20	14	337	14.3		
20	13	350	15.4		
10	10	360	10.0	Sand	Water Table
20	17	377	11.8		
10	10	387	10.0		
10	6	393	16.7		
10	7	400	14.3		
10	5	405	20.0		
10	3	408	33.3		
10	3.5	411.5	28.6		
15	6.5	418	23.1		
15	3	421	50.0		
15	4	425	37.5		
15	5	430	30.0		
10	5	435	20.0		
10	5	440	20.0		
10	3	443	33.3		
10	3	446	33.3		
10	4	450	25.0		
10	2	452	50.0		
20	6	458	33.3		
15	5	463	30.0		
20	7	470	28.6		
15	6	476	25.0		
15	3	479	50.0		
15	2	481	75.0		
15	3	484	50.0		
15	5	489	30.0		
15	3	492	50.0		
15	2	494	75		
15	5	499	30		
15	5	504	30		

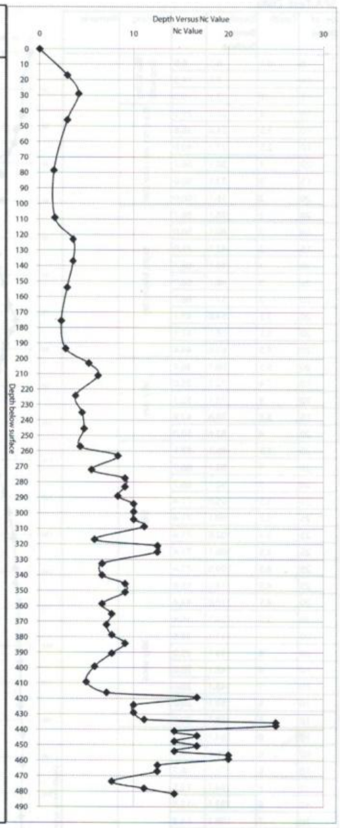


(l)

Phikal Sub Station — Control Building Site

SPA Test Data

No. of Blows	Depth	Depth Below Surface	Nc	Litholog	Remarks
0	0.1	0.1	0.0	Organic Clay, Clay	
5	17	17.1	2.9		
5	12	29.1	4.2		
5	17	46.1	2.9		
5	32.5	78.6	1.5		
5	30.5	109.1	1.6		
5	14	123.1	3.6		
5	14	137.1	3.6		
5	17	154.1	2.9		
5	21.5	175.6	2.3		
5	18	193.6	2.8		
5	9.5	203.1	5.3		
5	8	211.1	6.3		
5	13	224.1	3.8		
5	11	235.1	4.5		
5	10.5	245.6	4.8		
5	11.5	257.1	4.3		
5	6	263.1	8.3		
5	9	272.1	5.6		
5	5.5	277.6	9.1	Silty Clay	
5	5.5	283.1	9.1		
5	6	289.1	8.3		
5	5	294.1	10.0		
5	5	299.1	10.0		
5	5	304.1	10.0		
5	4.5	308.6	11.1		
5	8.5	317.1	5.9		
5	4	321.1	12.5		
5	4	325.1	12.5		
5	7.5	332.6	6.7	Brown Silty Clay	
5	7.5	340.1	6.7		
5	5.5	345.6	9.1		
5	5.5	351.1	9.1		
5	7.5	358.6	6.7		
5	6.5	365.1	7.7		
5	7	372.1	7.1		
5	6.5	378.6	7.7		
5	5.5	384.1	9.1		
5	6.5	390.6	7.7		
5	8.5	399.1	5.9		
5	10	409.1	5.0		
5	7	416.1	7.1		
5	3	419.1	16.7	Silt	
5	5	424.1	10.0		
5	5	429.1	10.0		
5	4.5	433.6	11.1		
5	2	435.6	25.0		
5	2	437.6	25.0		
5	3.5	441.1	14.3		
5	3	444.1	16.7		
5	3.5	447.6	14.3		
5	3	450.6	16.7		
5	3.5	454.1	14.3		
5	2.5	456.6	20.0		
5	2.5	459.1	20.0		
5	4	463.1	12.5		
5	4	467.1	12.5		
5	6.5	473.6	7.7		
5	4.5	478.1	11.1		
5	3.5	481.6	14.3		

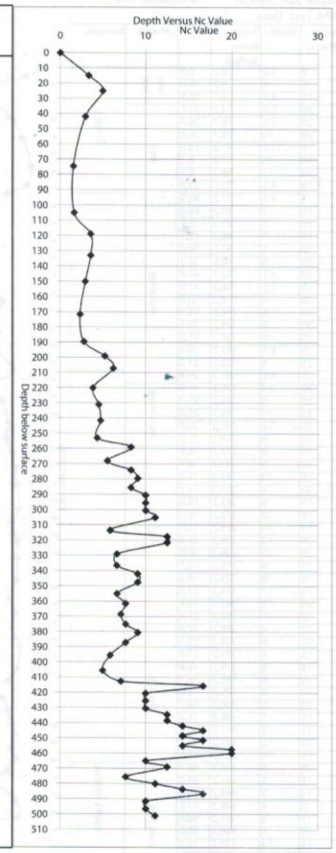


(m)

Phikal Sub Station — Transformer

Simplified Penetration Test Data

No. of Blows	Depth	Depth Below Surface	Nc	Litholog	Remarks
0	0.1	0.1	0.0	Organic Clay, Clay	
5	15	15.1	3.3		
5	10	25.1	5.0		
5	17	42.1	2.9		
5	32.5	74.6	1.5		
5	30.5	105.1	1.6		
5	14	119.1	3.6		
5	14	133.1	3.6		
5	17	150.1	2.9		
5	21.5	171.6	2.3		
5	18	189.6	2.8		
5	9.5	199.1	5.3		
5	8	207.1	6.3		
5	13	220.1	3.8		
5	11	231.1	4.5		
5	10.5	241.6	4.8		
5	11.5	253.1	4.3		
5	6	259.1	8.3		
5	9	268.1	5.6		
5	6	274.1	8.3	Silty Clay	
5	5.5	279.6	9.1		
5	6	285.6	8.3		
5	5	290.6	10.0		
5	5	295.6	10.0		
5	5	300.6	10.0		
5	4.5	305.1	11.1		
5	8.5	313.6	5.9		
5	4	317.6	12.5		
5	4	321.6	12.5		
5	7.5	329.1	6.7	Brown Silty Clay	
5	7.5	336.6	6.7		
5	5.5	342.1	9.1		
5	5.5	347.6	9.1		
5	7.5	355.1	6.7		
5	6.5	361.6	7.7		
5	7	368.6	7.1		
5	6.5	375.1	7.7		
5	5.5	380.6	9.1		
5	6.5	387.1	7.7		
5	8.5	395.6	5.9		
5	10	405.6	5.0		
5	7	412.6	7.1		
5	3	415.6	16.7	Silt	
5	5	420.6	10.0		
5	5	425.6	10.0		
5	5	430.6	10.0		
5	4	434.6	12.5		
5	4	438.6	12.5		
5	3.5	442.1	14.3		
5	3	445.1	16.7		
5	3.5	448.6	14.3		
5	3	451.6	16.7		
5	3.5	455.1	14.3		
5	2.5	457.6	20.0		
5	2.5	460.1	20.0		
5	5	465.1	10.0		
5	4	469.1	12.5		
5	6.5	475.6	7.7		
5	4.5	480.1	11.1		
5	3.5	483.6	14.3		
5	3	486.6	16.7		
5	5	491.6	10.0		
5	5	496.6	10.0		
5	4.5	501.1	11.1		

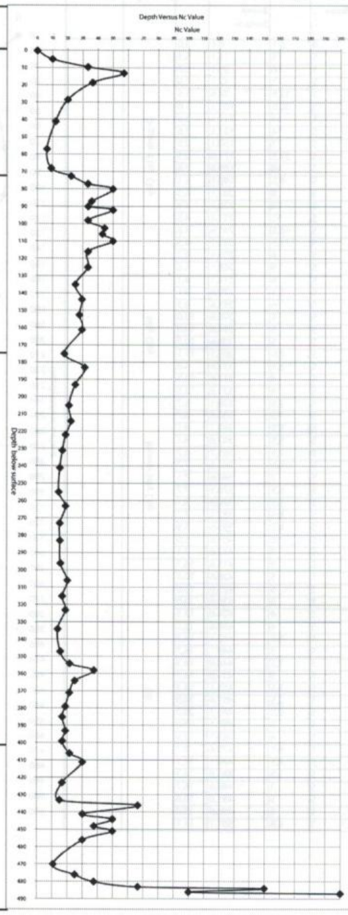


M. P. Koirala and G. Ojha

(n)

Jitpur Sub Station Transformer Site
SPA Test Data

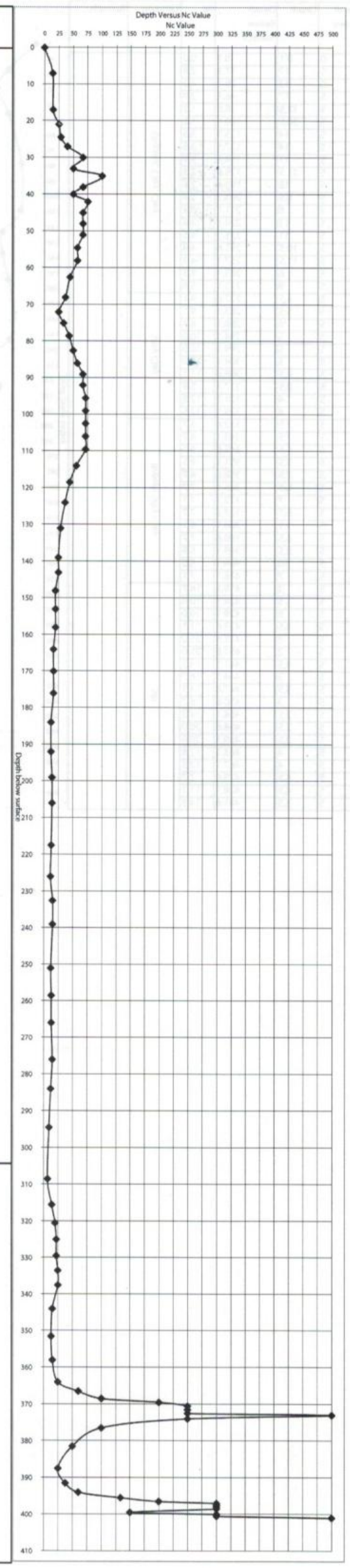
No. of Blows	Depth	Depth Below Surface	Nc	Litholog	Remarks
0	0.2	0.2	0.0	Silty clay	Filling
5	5	5.2	10.0		
15	4.5	9.7	33.3		
20	3.5	13.2	57.1	Clay	
20	5.5	18.7	36.4		
20	10	28.7	20.0		
15	12.5	41.2	12.0		
10	16	57.2	6.3		
10	11	68.2	9.1		
10	4.5	72.7	22.2		
15	4.5	77.2	33.3		
15	3	80.2	50.0	Black clay	
25	7	87.2	35.7		
10	3	90.2	33.3		
10	2	92.2	50.0		
20	6	98.2	33.3		
20	4.5	102.7	44.4		
15	3.5	106.2	42.9		
20	4	110.2	50.0		
20	6	116.2	33.3		
30	9	125.2	33.3		
25	10	135.2	25.0		
25	8.5	143.7	29.4		
25	9	152.7	27.8		
25	8.5	161.2	29.4		
25	14	175.2	17.9	Brown clay	
25	8	183.2	31.3		
25	10	193.2	25.0		
25	12	205.2	20.8		
20	9	214.2	22.2		
15	8	222.2	18.8	Clay	
15	9	231.2	16.7		
15	10	241.2	15.0		
20	14	255.2	14.3		
15	8	263.2	18.8		
15	10	273.2	15.0		
15	10	283.2	15.0		
20	13	296.2	15.4		
20	10	306.2	20.0		
15	9	315.2	16.7		
15	8	323.2	18.8		
15	11	334.2	13.6		
20	13	347.2	15.4		
15	7	354.2	21.4		
15	4	358.2	37.5	Silty clay	
15	6	364.2	25.0		
15	7	371.2	21.4		
15	8	379.2	18.8		
10	6	385.2	16.7		
15	8	393.2	18.8		
10	6	399.2	16.7		
15	7	406.2	21.4		
15	5	411.2	30.0		
20	12	423.2	16.7		
15	10	433.2	15.0		
20	3	436.2	66.7	Silty Sand	Water table
15	5	441.2	30.0		
15	3	444.2	50.0		
15	4	448.2	37.5		
15	3	451.2	50.0		
15	5	456.2	30.0		
15	14	470.2	10.7		
15	6	476.2	25.0		
15	4	480.2	37.5		
20	3	483.2	66.7		
15	1	484.2	150	Sand	
20	2	486.2	100		
20	1	487.2	200		



(o)

Jitpur Sub Station Control Building Site
SPA Test Data

No. of Blows	Depth	Depth Below Surface	Nc	Litholog	Remarks
0	0.1	0.1	0.0	Black clay (top soil)	
10	7	7.1	14.3		
15	10	17.1	15.0		
10	4	21.1	25.0	Hard dry ass color clay	
10	3.5	24.6	28.6		
10	2.5	27.1	40.0		
20	3	30.1	66.7		
15	3	33.1	50.0		
20	2	35.1	100.0		
20	3	38.1	66.7	Light black clay	
10	2	40.1	50.0		
15	2	42.1	75.0		
20	3	45.1	66.7		
20	3	48.1	66.7		
20	3	51.1	66.7		
20	3.5	54.6	57.1		
20	3.5	58.1	57.1		
20	4.5	62.6	44.4		
20	5.5	68.1	36.4	Silty clay	
10	4	72.1	25.0		
10	3	75.1	33.3		
15	3.5	78.6	42.9		
20	4	82.6	50.0		
20	3.5	86.1	57.1	Silt	
20	3	89.1	66.7		
20	3	92.1	66.7		
25	3.5	95.6	71.4		
25	3.5	99.1	71.4		
25	3.5	102.6	71.4		
25	3.5	106.1	71.4		
25	3.5	109.6	71.4		
25	4.5	114.1	55.6		
20	4.5	118.6	44.4	Silty sand	
20	5.5	124.1	36.4		
20	7	131.1	28.6		
20	8	139.1	25.0		
10	4	143.1	25.0		
10	5	148.1	20.0		
10	5	153.1	20.0		
10	5	158.1	20.0		
10	6	164.1	16.7	Fine sand	
10	6	170.1	16.7		
10	6	176.1	16.7		
10	8	184.1	12.5		
10	8	192.1	12.5		
10	7	199.1	14.3		
10	7	206.1	14.3		
15	11.5	217.6	13.0		
10	8.5	226.1	11.8		
10	6.5	232.6	15.4		
10	6.5	239.1	15.4		
15	12	251.1	12.5		
10	7.5	258.6	13.3		
10	7.5	266.1	13.3		
15	10	276.1	15.0		
10	8	284.1	12.5		
10	10.5	294.6	9.5		
10	14	308.6	7.1		
10	7	315.6	14.3		
10	5	320.6	20.0		
10	4.5	325.1	22.2		
10	4.5	329.6	22.2		
10	4	333.6	25.0		
10	4	337.6	25.0		
10	6.5	344.1	15.4		
10	7.5	351.6	13.3		
10	6.5	358.1	15.4		Water Table
15	6	364.1	25.0		
15	2.5	366.6	60.0	Gravelly sand	
20	2	368.6	100.0		
20	1	369.6	200.0		
25	1	370.6	250.0		
25	1	371.6	250.0		
25	1	372.6	250.0		
25	0.5	373.1	500.0		
25	1	374.1	250.0		
25	2.5	376.6	####		
25	5	381.6	50.0		
15	6	387.6	25.0		
15	4	391.6	37.5		
15	2.5	394.1	60.0		
20	1.5	395.6	####		
20	1	396.6	####		
15	0.5	397.1	####		
15	0.5	397.6	####		
15	0.5	398.1	####		
15	0.5	398.6	####		
15	1	399.6	####		
15	0.5	400.1	####		
15	0.5	400.6	####		
25	0.5	401.1	####		

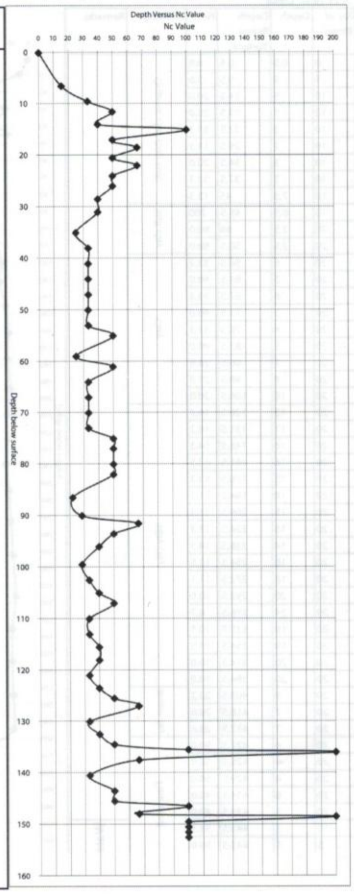


(p)

Katari Sub Station Transformer Site

SPA Test Data

No. of Blows	Depth	Depth Below Surface	Nc	Litholog	Remarks
0	0.1	0.1	0.0	Gravelly sand	Alluvium
10	6.5	6.6	15.4		
10	3	9.6	33.3		
10	2	11.6	50.0		
10	2.5	14.1	40.0		
10	1	15.1	100.0		
10	2	17.1	50.0	Medium sand	
10	1.5	18.6	66.7		
10	2	20.6	50.0		
10	1.5	22.1	66.7		
10	2	24.1	50.0		
10	2	26.1	50.0		
10	2.5	28.6	40.0		
10	2.5	31.1	40.0		
10	4	35.1	25.0	Coarse sand	
10	3	38.1	33.3		
10	3	41.1	33.3		
10	3	44.1	33.3		
10	3	47.1	33.3		
10	3	50.1	33.3		
10	3	53.1	33.3		
10	2	55.1	50.0		
10	4	59.1	25.0		
10	2	61.1	50.0		
10	3	64.1	33.3		
10	3	67.1	33.3		
10	3	70.1	33.3		
10	3	73.1	33.3		
10	2	75.1	50.0		
10	2	77.1	50.0		
15	3	80.1	50.0		
10	2	82.1	50.0		
10	4.5	86.6	22.2		
10	3.5	90.1	28.6		
10	1.5	91.6	66.7		
10	2	93.6	50.0		
10	2.5	96.1	40.0		
10	3.5	99.6	28.6		
10	3	102.6	33.3		
10	2.5	105.1	40.0		
10	2	107.1	50.0		
10	3	110.1	33.3		
10	3	113.1	33.3		
10	2.5	115.6	40.0	Gravelly sand	
10	2.5	118.1	40.0		
10	3	121.1	33.3		
10	2.5	123.6	40.0		
10	2	125.6	50.0		
10	1.5	127.1	66.7		
10	3	130.1	33.3		
10	2.5	132.6	40.0		
10	2	134.6	50.0		
10	1	135.6	100.0	Boulder, cobble pebble and sand	
10	0.5	136.1	200.0		
10	1.5	137.6	66.7		
10	3	140.6	33.3		
15	3	143.6	50.0		
10	2	145.6	50.0		
10	1	146.6	100.0		
10	1.5	148.1	66.7		
10	0.5	148.6	200.0		
10	1	149.6	100.0		
10	1	150.6	100.0		
10	1	151.6	100.0		
10	1	152.6	100.0		

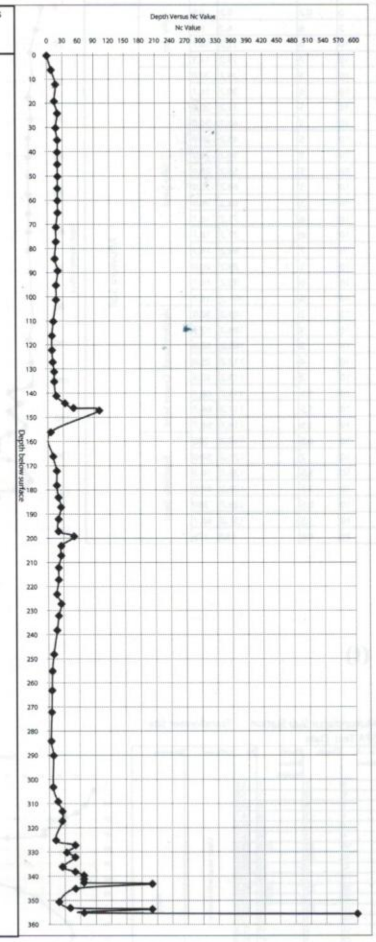


(q)

Milanchowk Sub Station Control Building Site

SPA Test Data

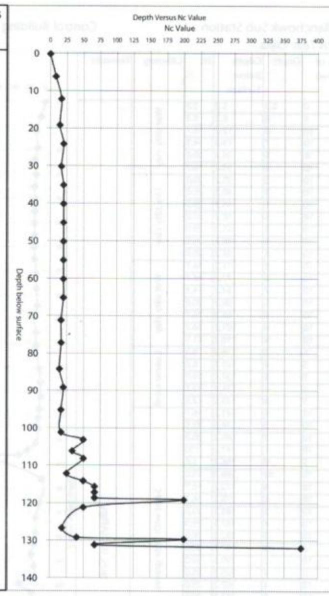
No. of Blows	Depth	Depth Below Surface	Nc	Litholog	Remarks
0	0.2	0.2	0.0	Wet silty clay	Alluvium Soil
5	6	6.2	8.3		
10	6	12.2	16.7		
10	7	19.2	14.3		
10	5	24.2	20.0		
10	6	30.2	16.7		
10	5	35.2	20.0	Dry silty clay	
10	5	40.2	20.0		
10	5	45.2	20.0		
10	5	50.2	20.0		
10	5	55.2	20.0		
10	5	60.2	20.0		
10	5	65.2	20.0		
10	6	71.2	16.7	Wet silty clay	
10	6	77.2	16.7		
10	7	84.2	14.3		
10	5	89.2	20.0		
10	6	95.2	16.7		
10	6	101.2	16.7		
10	9	110.2	11.1		
5	6	116.2	8.3	Coarse sand	
5	6	122.2	8.3		
5	5	127.2	10.0		
5	4	131.2	12.5		
5	4	135.2	12.5		
10	6	141.2	16.7	Sand with little gravel	
10	3	144.2	33.3		
10	2	146.2	50.0		
10	1	147.2	100		
5	9	156.2	5.6		
10	10	166.2	10.0		
10	6	172.2	16.7		
10	6	178.2	16.7		
10	5	183.2	20.0		
10	4	187.2	25.0		
10	5	192.2	20.0		
10	5	197.2	20.0		
10	2	199.2	50.0		
10	4	203.2	25.0		
10	4	207.2	25.0		
10	5	212.2	20.0		
10	5	217.2	20.0		
10	6	223.2	16.7		
10	4	227.2	25.0		
10	5	232.2	20.0		
10	6	238.2	16.7		
10	10	248.2	10.0	Fime sand	
5	7	255.2	7.1		
5	8	263.2	6.3		
5	9	272.2	5.6		
5	12	284.2	4.2		
5	6	290.2	8.3		
10	13	303.2	7.7		
10	6	309.2	16.7		
10	4	313.2	25.0		
10	4	317.2	25.0		
10	8	325.2	12.5		
10	2	327.2	50.0	Gravelly sand	
10	3	330.2	33.3		
10	2	332.2	50.0		
10	4	336.2	25.0		
10	2	338.2	50.0		
10	1.5	339.7	66.7		
10	1.5	341.2	66.7		
10	1.5	342.7	66.7		
10	0.5	343.2	200		
10	2	345.2	50.0		
10	5.5	350.7	18.2		
10	2.5	353.2	40.0		
10	0.5	353.7	200		
10	1.5	355.2	66.7		
30	0.5	355.7	600		



(r)

Milanchowk Sub Station Transformer Site
SPA Test Data

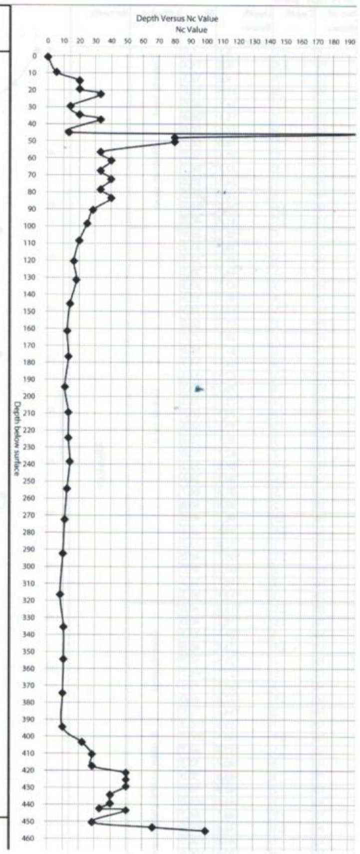
No. of Blows	Depth	Depth Below Surface	Nc	Litholog	Remarks
0	0.2	0.2	0.0	Silty clay	Alluvium Soil
5	6	6.2	8.3		
10	6	12.2	16.7		
10	7	19.2	14.3		
10	5	24.2	20.0	Silty Sand	
10	6	-30.2	16.7		
10	5	35.2	20.0		
10	5	40.2	20.0		
10	5	45.2	20.0		
10	5	50.2	20.0		
10	5	55.2	20.0		
10	5	60.2	20.0		
10	5	65.2	20.0		
10	6	71.2	16.7		
10	6	77.2	16.7		
10	7	84.2	14.3		
10	5	89.2	20.0		
10	6	95.2	16.7		
10	6	101.2	16.7		
10	2	103.2	50.0	Medium sand	
10	3	106.2	33.3		
10	2	108.2	50.0		
10	4	112.2	25.0		
10	2	114.2	50.0	Coarse Sand	
10	1.5	115.7	66.7		
10	1.5	117.2	66.7		
10	1.5	118.7	66.7		
10	0.5	119.2	200	Boulderly Sand	
10	2	121.2	50.0		
10	5.5	126.7	18.2		
10	2.5	129.2	40.0		
10	0.5	129.7	200		
10	1.5	131.2	66.7		
30	0.8	132	375		



(s)

Mukundapur Sub Station Control Building Site
SPA Test Data

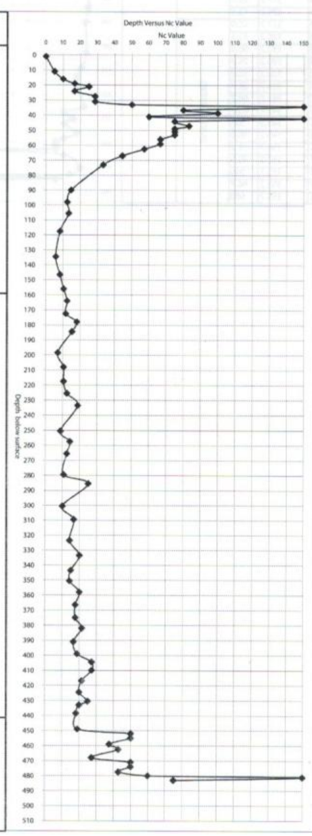
No. of Blows	Depth	Depth Below Surface	Nc	Litholog	Remarks
0	0.5	0.5	0.0	Organic clay (top soil)	
5	9	9.5	5.6		
10	5	14.5	20.0		
10	5	19.5	20.0		
10	3	22.5	33.3		
10	7	29.5	14.3		
10	5	34.5	20.0		
10	3	37.5	33.3		
10	7.5	45	13.3		
10	0.5	45.5	200	Stiff clay	
20	2.5	48	80.0		
20	2.5	50.5	80.0		
20	6	56.5	33.3	Clay	
20	5	61.5	40.0		
20	6	67.5	33.3		
20	5	72.5	40.0		
20	6	78.5	33.3		
20	5	83.5	40.0		
20	7	90.5	28.6		
20	8	98.5	25.0		
20	10	108.5	20.0		
20	12	120.5	16.7	Silty clay	
20	11	131.5	18.2		
20	14	145.5	14.3		
20	16	161.5	12.5		
20	15	176.5	13.3		
20	18	194.5	11.1		
20	15	209.5	13.3		
20	15	224.5	13.3		
20	14	238.5	14.3		
20	16	254.5	12.5		
20	18	272.5	11.1		
20	20	292.5	10.0		
20	24	316.5	8.3		
20	19	335.5	10.5		
20	19	354.5	10.5		
20	20	374.5	10.0		
20	20	394.5	10.0		
20	9	403.5	22.2	Brown clay	
20	7	410.5	28.6		
20	7	417.5	28.6		
20	4	421.5	50.0	Fine sand	
20	4	425.5	50.0		
20	4	429.5	50.0		
20	5	434.5	40.0		
20	5	439.5	40.0		
10	3	442.5	33.3		Wate
5	1	443.5	50.0		



(t)

Mukundapur Sub Station Transformer Site
SPA Test Data

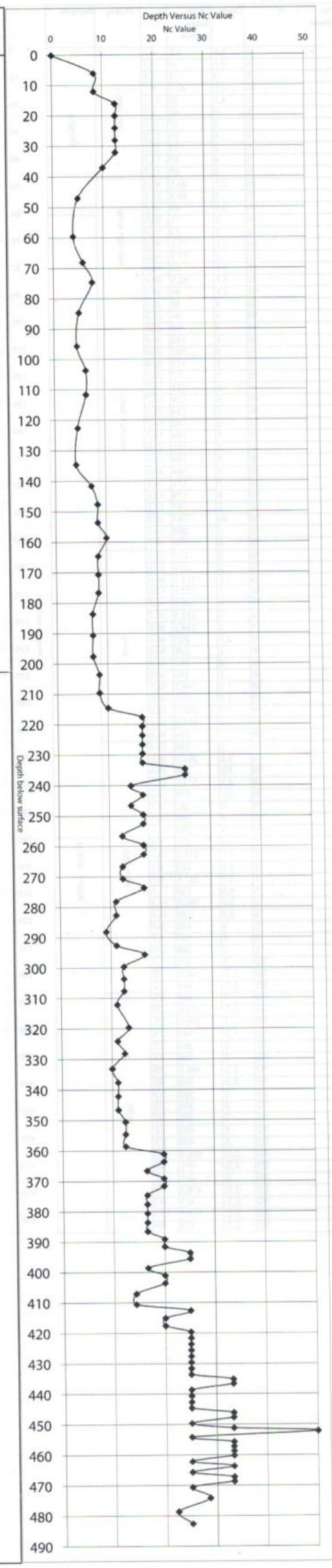
No. of Blows	Depth	Depth Below Surface	Nc	Litholog	Remarks
0	1	1	0.0	Clean sand with pebbles	Filling
5	10	11	5.0		
5	5	16	10.0		
5	3	19	16.7		
5	2	21	25.0		
5	3	24	16.7		
10	3.5	27.5	28.6		
10	3.5	31	28.6		
10	2	33	50.0		
15	1	34	150		
20	2.5	36.5	80.0		
20	2	38.5	100		
15	2.5	41	60.0		
15	1	42	150		
15	2	44	75.0		
25	3	47	83.3		
15	2	49	75.0		
15	2	51	75.0		
15	2	53	75.0		
20	3	56	66.7	Silty clay	
20	3	59	66.7		
20	3.5	62.5	57.1		
20	4.5	67	44.4		
20	6	73	33.3		
25	17	90	14.7	Stiff clay	
10	8	98	12.5		
10	7.5	105.5	13.3		
10	12	117.5	8.3	Black clay	
10	17	134.5	5.9		
10	12	146.5	8.3		
10	9.5	156	10.5	Brown clay	
10	8	164	12.5		
10	8.5	172.5	11.8		
10	5.5	178	18.2		
10	6.5	184.5	15.4		
10	14	198.5	7.1	Silty clay	
10	9.5	208	10.5		
10	9.5	217.5	10.5		
10	8	225.5	12.5		
15	8	233.5	18.8		
15	17	250.5	8.8		
10	7	257.5	14.3		
10	8	265.5	12.5		
15	14	279.5	10.7		
15	6	285.5	25.0		
15	15	300.5	10.0		
15	9	309.5	16.7		
20	14	323.5	14.3		
20	10	333.5	20.0	Silty Sand	
15	10	343.5	15.0		
10	7	350.5	14.3		
15	7.5	358	20.0		
15	8.5	366.5	17.6		
15	8.5	375	17.6		
15	7	382	21.4		
15	9	391	16.7		
15	8	399	18.8		
15	5.5	404.5	27.3		
15	5.5	410	27.3		
15	7	417	21.4		
15	7.5	424.5	20.0		
15	6	430.5	25.0		
5	2.5	433	20.0		
10	5.5	438.5	18.2		
20	10.5	449	19.0		
15	3	452	50.0	Fine sand	Water Table
15	3	455	50.0		
15	4	459	37.5		
15	3.5	462.5	42.9		
15	5.5	468	27.3		
15	3	471	50.0	Sand with gravel	
15	3	474	50.0		
15	3.5	477.5	42.9		
15	2.5	480	60.0		
15	1	481	150		
15	2	483	75.0		



(u)

Rangeli Sub Station Control Building Site
Simplified Penetration Test Data

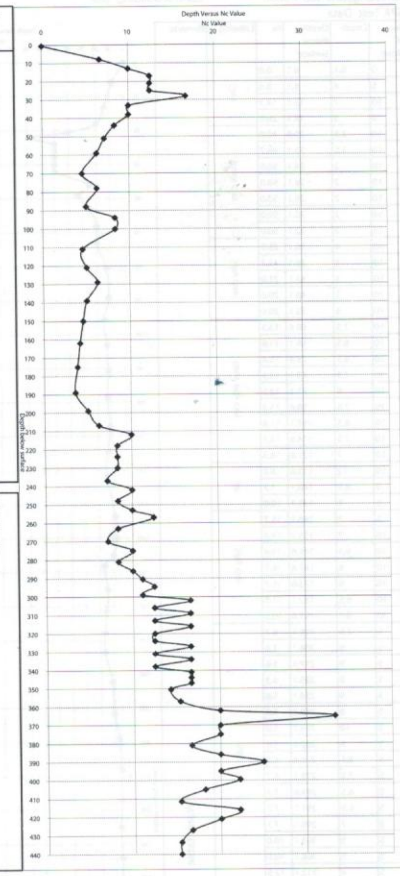
No. of Blows	Depth	Depth Below Surface	Nc	Litholog	Remarks
0	0.1	0.1	0.0	clay	
5	6	6.1	8.3		
5	6	12.1	8.3		
5	4	16.1	12.5	Silty clay	
5	4	20.1	12.5		
5	4	24.1	12.5		
5	4	28.1	12.5		
5	4	32.1	12.5		
5	5	37.1	10.0		
5	10	47.1	5.0	Wet Grey Silty Clay	
5	12.5	59.6	4.0		
5	8.5	68.1	5.9		
5	6.5	74.6	7.7		
5	10	84.6	5.0		
5	11	95.6	4.5		
5	8	103.6	6.3		
5	8	111.6	6.3		
5	11	122.6	4.5		
5	12	134.6	4.2		
5	7	141.6	7.1	Black Clay	
5	6	147.6	8.3		
5	6	153.6	8.3		
5	5	158.6	10.0		
5	6	164.6	8.3		
5	6	170.6	8.3		
5	6	176.6	8.3		
5	7	183.6	7.1		
5	7	190.6	7.1		
5	7	197.6	7.1		
5	6	203.6	8.3		
5	6	209.6	8.3		
5	5	214.6	10.0	Silty Sand	
5	3	217.6	16.7		
5	3	220.6	16.7		
5	3	223.6	16.7		
5	3	226.6	16.7		
5	3	229.6	16.7		
5	3	232.6	16.7		
5	2	234.6	25.0		
5	2	236.6	25.0		
5	3.5	240.1	14.3	Fine Sand	
5	3	243.1	16.7		
5	3.5	246.6	14.3		
5	3	249.6	16.7		
5	3	252.6	16.7		
5	4	256.6	12.5		
5	3	259.6	16.7		
5	3	262.6	16.7		
5	4	266.6	12.5		
5	4	270.6	12.5		
5	3	273.6	16.7		
5	4.5	278.1	11.1		
5	4.5	282.6	11.1		
5	5.5	288.1	9.1		
5	4.5	292.6	11.1		Water Table
5	3	295.6	16.7		
5	4	299.6	12.5		
5	4	303.6	12.5		
5	4	307.6	12.5		
5	4.5	312.1	11.1		
10	7.5	319.6	13.3		
5	4.5	324.1	11.1		
5	4	328.1	12.5		
5	5	333.1	10.0		
5	4.5	337.6	11.1		
5	4.5	342.1	11.1		
5	4.5	346.6	11.1		
5	4	350.6	12.5		
5	4	354.6	12.5		
5	4	358.6	12.5		
5	2.5	361.1	20.0	Medium sand	
5	2.5	363.6	20.0		
5	3	366.6	16.67		
5	2.5	369.1	20		
5	2.5	371.6	20		
5	3	374.6	16.67		
5	3	377.6	16.67		
5	3	380.6	16.67		
5	3	383.6	16.67		
5	3	386.6	16.67		
5	2.5	389.1	20		
5	2.5	391.6	20		
5	2	393.6	25		
5	2	395.6	25		
5	3	398.6	16.67		
5	2.5	401.1	20		
5	2.5	403.6	20		
5	3.5	407.1	14.29		
5	3.5	410.6	14.29		
5	2	412.6	25	Coarse Sand	
5	2.5	415.1	20		
5	2.5	417.6	20		
5	2	419.6	25		
5	2	421.6	25		
5	2	423.6	25		
5	2	425.6	25		
5	2	427.6	25		
5	2	429.6	25		
5	2	431.6	25		
5	2	433.6	25		
5	1.5	435.1	33.33		
5	1.5	436.6	33.33		
5	2	438.6	25		
5	2	440.6	25		
5	2	442.6	25		
5	2	444.6	25		
5	1.5	446.1	33.3		
5	1.5	447.6	33.3		
5	2	449.6	25		
5	1.5	451.1	33.3		
5	1	452.1	50		
5	2	454.1	25		
5	1.5	455.6	33.3		
5	1.5	457.1	33.3		
5	1.5	458.6	33.3		
5	1.5	460.1	33.3		
5	2	462.1	25		
5	1.5	463.6	33.3		
5	2	465.6	25		
5	1.5	467.1	33.3		
5	1.5	468.6	33.3		
5	2	470.6	25		
10	3.5	474.1	28.6		
10	4.5	478.6	22.2		
10	4	482.6	25		



(v)

Rangeli Sub Station Transformer Site
SPA Test Data

No. of Blows	Depth	Depth Below Surface	Nc	Litholog	Remarks
0	0.5	0.5	0.0	Org. Clay	
5	7.5	8	6.7		
5	5	13	10.0	Silty Clay	
5	4	17	12.5		
5	4	21	12.5		
5	4	25	12.5		
5	3	28	16.7		
5	5	33	10.0		
5	5	38	10.0		
5	6	44	8.3	Silt	
5	7	51	7.1		
5	8	59	6.3		
5	11	70	4.5		
5	8	78	6.3		
5	10	88	5.0		
5	6	94	8.3		
5	6	100	8.3		
5	11	111	4.5		
5	10	121	5.0		
5	8	129	6.3		
5	10	139	5.0		
5	11	150	4.5		
5	12	162	4.2		
5	13	175	3.8		
5	14	189	3.6		
5	10	199	5.0		
5	8	207	6.3		
5	5	212	10.0	Clay	
5	6	218	8.3		
5	6	224	8.3		
5	6	230	8.3		
5	7	237	7.1		
5	5	242	10.0		
5	6	248	8.3	Silty Sand	
5	5	253	10.0		
5	4	257	12.5		
5	6	263	8.3		
5	7	270	7.1		
5	5	275	10.0		
5	6	281	8.3		
5	5	286	10.0		
5	4.5	290.5	11.1		Water Table
5	4	294.5	12.5		
5	4.5	299	11.1		
5	3	302	16.7	Fine Sand	
5	4	306	12.5		
5	3	309	16.7		
5	4	313	12.5		
5	3	316	16.7		
5	4	320	12.5		
5	4	324	12.5		
5	3	327	16.7		
5	4	331	12.5		
5	3	334	16.7		
5	4	338	12.5		
5	3	341	16.7		
5	3	344	16.7		
5	3	347	16.7		
5	3.5	350.5	14.3		
10	6.5	357	15.4		
10	5	362	20.0	Medium Sand	
10	3	365	33.3		
10	5	370	20.0		
10	5	375	20.0		
10	6	381	16.7		
10	5	386	20.0		
10	4	390	25.0		
10	5	395	20.0		
10	4.5	399.5	22.2		
10	5.5	405	18.2		
10	6.5	411.5	15.4		
10	4.5	416	22.2		
10	5	421	20		
10	6	427	16.67		
10	6.5	433.5	15.38		
10	6.5	440	15.38		

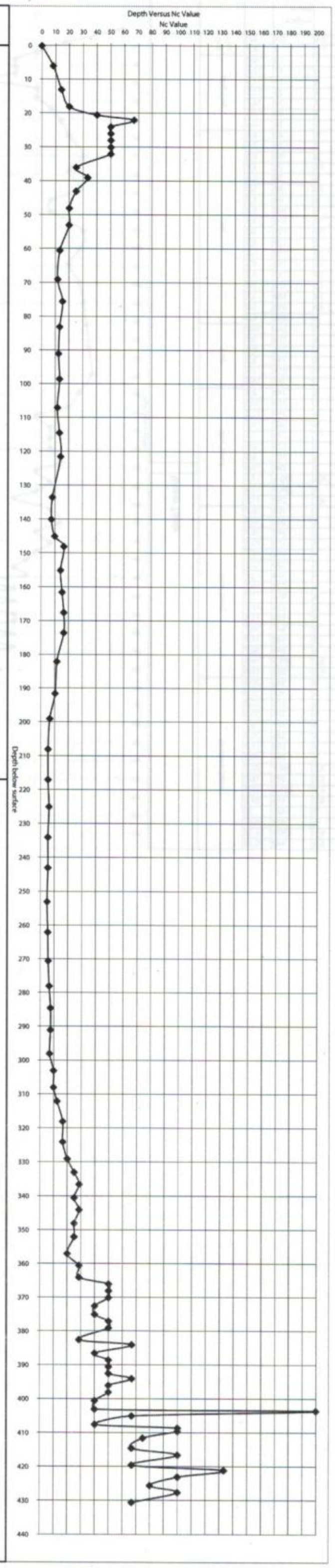


(w)

Simraungadha Sub Station — Control Building Site

SPA Test Data

No. of Blows	Depth	Depth Below Surface	Nc	Litholog	Remarks
0	0.1	0.1	0.0	Clay	
5	6	6.1	8.3		
10	7	13.1	14.3		
10	5	18.1	20.0		
10	2.5	20.6	40.0	Black clay	
10	1.5	22.1	66.7		
10	2	24.1	50.0		
10	2	26.1	50.0		
10	2	28.1	50.0		
10	2	30.1	50.0		
10	2	32.1	50.0		
10	4	36.1	25.0	Silty clay	
10	3	39.1	33.3		
10	4	43.1	25.0		
10	5	48.1	20.0		
10	5	53.1	20.0		
10	7.5	60.6	13.3	Grey silty clay	
10	8.5	69.1	11.8		
10	6.5	75.6	15.4		
10	7.5	83.1	13.3		
10	8	91.1	12.5		
10	7.5	98.6	13.3		
10	8.5	107.1	11.8		
10	7.5	114.6	13.3		
10	7	121.6	14.3		
10	12	133.6	8.3	Silt	
5	6.5	140.1	7.7		
5	5	145.1	10.0		
5	3	148.1	16.7	Silty clay	
10	7	155.1	14.3		
10	6.5	161.6	15.4		
10	6	167.6	16.7		
10	6	173.6	16.7		
10	8.5	182.1	11.8		
10	9.5	191.6	10.5		
5	7.5	199.1	6.7	Silt	
5	9	208.1	5.6		
5	9	217.1	5.6		
5	8	225.1	6.3		
5	9	234.1	5.6		
5	9	243.1	5.6		
5	10	253.1	5.0		
5	9	262.1	5.6		
5	8.5	270.6	5.9		
5	7.5	278.1	6.7		
5	6.5	284.6	7.7		
5	6.5	291.1	7.7		Water table
5	7	298.1	7.1		
5	5	303.1	10.0		
5	5	308.1	10.0		
5	4	312.1	12.5		
10	6	318.1	16.7	Silty sand	
10	6	324.1	16.7		
10	5	329.1	20.0		
10	4	333.1	25.0		
10	3.5	336.6	28.6		
10	4	340.6	25.0		
10	3.5	344.1	28.6		
10	4	348.1	25.0		
10	4	352.1	25.0		
10	5	357.1	20.0		
10	3.5	360.6	28.6		
10	3.5	364.1	28.6		
10	2	366.1	50.0	Sand	
10	2	368.1	50.0		
10	2	370.1	50.0		
10	2.5	372.6	40.0		
10	2.5	375.1	40.0		
10	2	377.1	50.0		
10	2	379.1	50.0		
10	3.5	382.6	28.6		
10	1.5	384.1	66.7		
10	2.5	386.6	40.0		
10	2	388.6	50.0		
10	2	390.6	50.0		
10	2	392.6	50.0		
10	1.5	394.1	67		
10	2	396.1	50		
10	2	398.1	50		
10	2.5	400.6	40		
10	2.5	403.1	40		
10	0.5	403.6	200		
10	1.5	405.1	67		
10	2.5	407.6	40		
10	1	408.6	100		
10	1	409.6	100		
15	2	411.6	75		
20	3	414.6	67		
20	2	416.6	100		
20	3	419.6	67		
20	1.5	421.1	133		
20	2	423.1	100		
20	2.5	425.6	80		
20	2	427.6	100		
20	3	430.6	67		

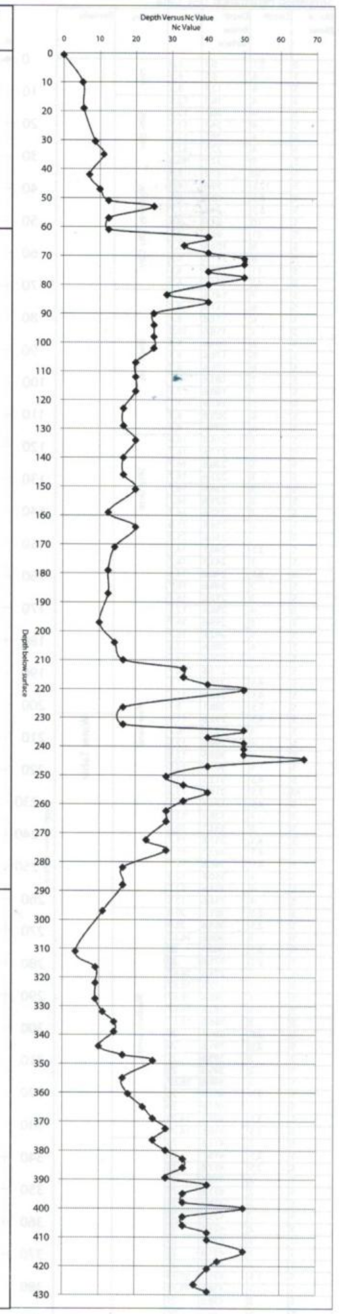


(x)

Simraungadha Sub Station — Transformer Site

SPA Test Data

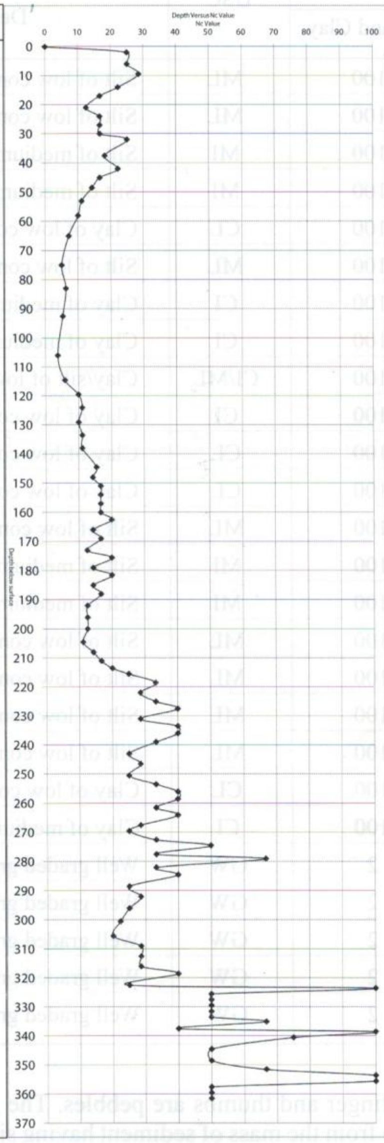
No. of Blows	Depth	Depth Below Surface	Nc	Litholog	Remarks
0	0.5	0.5	0.0	Silty clay	Filling
5	9.5	10	5.3		
5	9	19	5.6		
10	11.5	30.5	8.7		
5	4.5	35	11.1		
5	7	42	7.1		
5	5	47	10.0		
5	4	51	12.5		
5	2	53	25.0		
5	4	57	12.5		
5	4	61	12.5		
10	2.5	63.5	40.0	Black silty clay	
10	3	66.5	33.3		
10	2.5	69	40.0		
10	2	71	50.0		
10	2	73	50.0		
10	2.5	75.5	40.0		
10	2	77.5	50.0		
10	2.5	80	40.0		
10	3.5	83.5	28.6		
10	2.5	86	40.0		
10	4	90	25.0	Grey silty clay	
10	4	94	25.0		
10	4	98	25.0		
10	4	102	25.0		
10	5	107	20.0		
10	5	112	20.0		
10	5	117	20.0		
10	6	123	16.7		
10	6	129	16.7		
10	5	134	20.0		
10	6	140	16.7		
10	6	146	16.7		
10	5	151	20.0		
10	8	159	12.5		
10	5	164	20.0		
10	7	171	14.3		
10	8	179	12.5		
10	8	187	12.5		
10	10	197	10.0		
10	7	204	14.3		
10	6	210	16.7		
10	3	213	33.3	Sand	
10	3	216	33.3		
10	2.5	218.5	40.0		
10	2	220.5	50.0		
10	6	226.5	16.7		
10	6	232.5	16.7		
10	2	234.5	50.0		
10	2.5	237	40.0		
10	2	239	50.0		
10	2	241	50.0		
10	2	243	50.0		
10	1.5	244.5	66.7		
10	2.5	247	40.0		
10	3.5	250.5	28.6		
10	3	253.5	33.3		
10	2.5	256	40.0		
10	3	259	33.3	Silty sand	
10	3.5	262.5	28.6		
10	3.5	266	28.6		
15	6.5	272.5	23.1		
10	3.5	276	28.6		
10	6	282	16.7		
10	6	288	16.7		
10	9	297	11.1		
5	14	311	3.6		Water Table
5	5.5	316.5	9.1		
5	5.5	322	9.1		
5	5.5	327.5	9.1		
5	4.5	332	11.1		
5	3.5	335.5	14.3		
5	3.5	339	14.3		
5	5	344	10.0		
5	3	347	16.7		
5	2	349	25.0		
10	6	355	17		
10	5.5	360.5	18		
10	4.5	365	22		
10	4	369	25	Sand	
10	3.5	372.5	29		
10	4	376.5	25		
10	3.5	380	29		
10	3	383	33		
10	3	386	33		
10	3.5	389.5	29		
10	2.5	392	40		
10	3	395	33		
10	3	398	33		
10	2	400	50		
10	3	403	33		
10	3	406	33		
10	2.5	408.5	40		
10	2.5	411	40		
20	4	415	50		
15	3.5	418.5	43		
10	2.5	421	40		
20	5.5	426.5	36		
10	2.5	429	40		



(y)

Yedukuwa Sub Station Control Building Site
SPA Test Data

No. of Blows	Depth	Depth Below Surface	Nc	Litholog	Remarks
0	0.1	0.1	0.0	Silty clay	
5	2	2.1	25.0		
10	4	6.1	25.0		
10	3.5	9.6	28.6		
10	4.5	14.1	22.2		
5	3	17.1	16.7		
5	4	21.1	12.5		
5	3	24.1	16.7		
5	3	27.1	16.7		
5	3	30.1	16.7		
5	2	32.1	25.0		
10	5.5	37.6	18.2		
10	4.5	42.1	22.2		
5	3	45.1	16.7		
5	3.5	48.6	14.3		
5	4.5	53.1	11.1		
5	5	58.1	10.0		
5	7	65.1	7.1		
5	10	75.1	5.0	Black clay	
5	8	83.1	6.3		
5	9.5	92.6	5.3		
5	13.5	106.1	3.7	Light black clay	
5	8.5	114.6	5.9		
5	5	119.6	10.0		
5	4.5	124.1	11.1		
5	5	129.1	10.0		
5	4.5	133.6	11.1		
5	4.5	138.1	11.1	Grey clay	
10	6.5	144.6	15.4		
5	3.5	148.1	14.3		
5	3	151.1	16.7		
5	3	154.1	16.7		
5	3	157.1	16.7	Silty clay	
5	3	160.1	16.7		
5	2.5	162.6	20.0		
5	3.5	166.1	14.3		
5	3	169.1	16.7		
5	4	173.1	12.5		
5	2.5	175.6	20.0		
5	3.5	179.1	14.3		
5	2.5	181.6	20.0		
5	3.5	185.1	14.3		
5	3	188.1	16.7		
5	4	192.1	12.5		
5	4	196.1	12.5		
5	4	200.1	12.5		
5	4.5	204.6	11.1		
5	3.5	208.1	14.3	Clay	
5	3	211.1	16.7		
5	2.5	213.6	20.0		
5	2	215.6	25.0		
10	3	218.6	33.3		
10	3.5	222.1	28.6	Silty clay	
10	3	225.1	33.3		
10	2.5	227.6	40.0		
10	3.5	231.1	28.6		
10	2.5	233.6	40.0		
10	2.5	236.1	40.0		
10	3	239.1	33.3		
10	4	243.1	25.0		
10	3.5	246.6	28.6		
10	4	250.6	25.0		
10	3	253.6	33.3		
10	2.5	256.1	40.0		
10	2.5	258.6	40.0		
10	3	261.6	33.3		
10	2.5	264.1	40.0		
10	3.5	267.6	28.6		
5	2	269.6	25.0		
10	3	272.6	33.3		
10	2	274.6	50.0		
10	3	277.6	33.3		
10	1.5	279.1	66.67		
10	3	282.1	33.33		
10	2.5	284.6	40		
10	4	288.6	25		
10	3.5	292.1	28.57		
10	4	296.1	25		
10	4.5	300.6	22.22		
10	5	305.6	20		
10	3.5	309.1	28.57		
10	3.5	312.6	28.57		
10	3.5	316.1	28.57		
10	2.5	318.6	40		
10	4	322.6	25		
10	1	323.6	100		
10	2	325.6	50		
10	2	327.6	50		
10	2	329.6	50		
10	2	331.6	50	Sand	
10	2	333.6	50		
10	1.5	335.1	66.67		
10	2.5	337.6	40		
10	1	338.6	100		
15	2	340.6	75		
20	4	344.6	50		
20	4	348.6	50		
20	3	351.6	66.67		
20	2	353.6	100		
20	2	355.6	100		
10	2	357.6	50		
10	2	359.6	50		
10	2	361.6	50		



(z)

Yedukuwa Sub Station Transformer Site
SPA Test Data

No. of Blows	Depth	Depth Below Surface	Nc	Litholog	Remarks
0	0.1	0.1	0.0	Silty clay	
5	5.5	5.6	9.1		
5	1.5	7.1	33.3		
5	3.5	10.6	14.3		
5	4	14.6	12.5		
10	3.5	18.1	28.6		
10	4	22.1	25.0		
10	3.5	25.6	28.6		
10	4.5	30.1	22.2		
5	3	33.1	16.7		
5	4	37.1	12.5		
5	3	40.1	16.7		
5	3	43.1	16.7		
5	3	46.1	16.7		
5	2	48.1	25.0		
10	5.5	53.6	18.2		
10	4.5	58.1	22.2		
5	3	61.1	16.7		
5	3.5	64.6	14.3	Black clay	
5	4.5	69.1	11.1		
5	5	74.1	10.0		
5	7	81.1	7.1	Light black clay	
5	10	91.1	5.0		
5	8	99.1	6.3		
5	9.5	108.6	5.3		
5	13.5	122.1	3.7		
5	8.5	130.6	5.9		
5	5	135.6	10.0	Grey clay	
5	4.5	140.1	11.1		
5	5	145.1	10.0		
5	4.5	149.6	11.1		
5	4.5	154.1	11.1		
10	6.5	160.6	15.4	Silty clay	
5	3.5	164.1	14.3		
5	3	167.1	16.7		
5	3	170.1	16.7		
5	3	173.1	16.7		
5	3	176.1	16.7		
5	2.5	178.6	20.0		
5	3.5	182.1	14.3		
5	3	185.1	16.7		
5	4	189.1	12.5		
5	2.5	191.6	20.0		
5	3.5	195.1	14.3		
5	2.5	197.6	20.0		
5	3.5	201.1	14.3		
5	3	204.1	16.7		
5	4	208.1	12.5	Clay	
5	4	212.1	12.5		
5	4	216.1	12.5		
5	4.5	220.6	11.1		
5	3.5	224.1	14.3		
5	3	227.1	16.7		
5	2.5	229.6	20.0		
5	2	231.6	25.0	Silty clay	
10	3	234.6	33.3		
10	3.5	238.1	28.6		
10	3	241.1	33.3		
10	2.5	243.6	40.0		
10	3.5	247.1	28.6		
10	2.5	249.6	40.0		
10	2.5	252.1	40.0		
10	3	255.1	33.3		
10	4	259.1	25.0		
10	3.5	262.6	28.6		
10	4	266.6	25.0		
10	3	269.6	33.3		
10	2.5	272.1	40.0		
10	2.5	274.6	40.0		
10	3	277.6	33.3		
10	2.5	280.1	40.0		
10	3.5	283.6	28.6		
10	3	286.6	33.33		
5	2	288.6	25		
10	3	291.6	33.33		
10	2	293.6	50		
10	3	296.6	33.33		
10	1.5	298.1	66.67		
10	3	301.1	33.33		
10	2.5	303.6	40		
10	4	307.6	25		
10	3.5	311.1	28.57		
10	4	315.1	25		
10	4.5	319.6	22.22		
10	5	324.6	20		
10	3.5	328.1	28.57		
10	3.5	331.6	28.57		
10	3.5	335.1	28.57		
10	2.5	337.6	40		
10	4	341.6	25		
10	1	342.6	100	Sand	
10	2	344.6	50		
10	2	346.6	50		
10	2	348.6	50		
10	2	350.6	50		
10	2	352.6	50		
10	1.5	354.1	66.67		
10	2.5	356.6	40		
10	1	357.6	100		
15	2	359.6	75		
20	4	363.6	50		
20	4	367.6	50		
20	3	370.6	66.67		
20	2	372.6	100		
20	2	374.6	100		

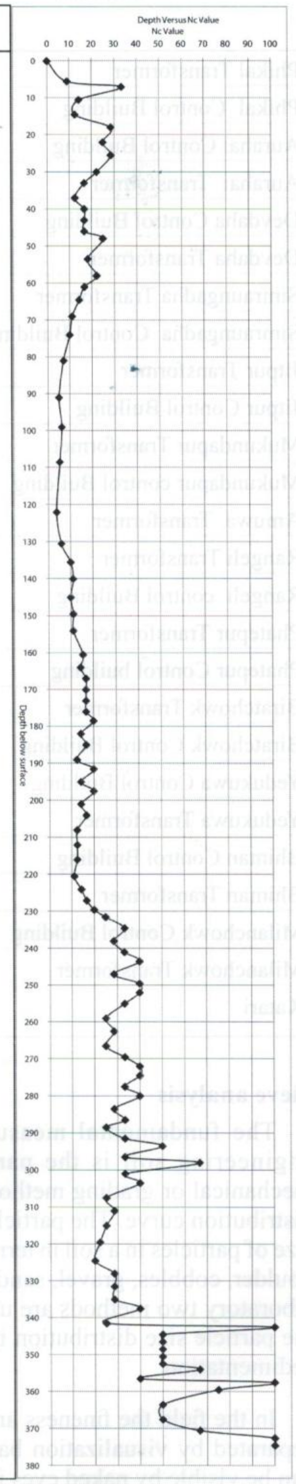


Table 2: Results of the sieve analysis

Location	Composition %			USC	Description
	Gravel	Sand	Silt and Clay		
Phikal Transformer	0	0	100	ML	Silt of low compressibility
Phikal Control Building	0	0	100	ML	Silt of low compressibility
Aurahai Control Building	0	0	100	MI	Silt of medium compressibility
Aurahai Transformer	0	0	100	MI	Silt of medium compressibility
Devdaha Control Building	0	0	100	CL	Clay of low compressibilty
Devdaha Transformer	0	0	100	ML	Silt of low compressibility
Simraungadha Transformer	0	0	100	CI	Clay of medium compressibility
Simraungadha Control Building	0	0	100	CI	Clay of medium compressibility
Jitpur Transformer	0	0	100	CI/ML	Clay/silt of low compressibilty
Jitpur Control Building	0	0	100	CI	Clay of low compressibilty
Mukundapur Transformer	0	0	100	CL	Clay of low compressibilty
Mukundapur control Building	0	0	100	CL	Clay of low compressibilty
Amuwa Transformer	0	0	100	ML	Silt of low compressibility
Rangeli Transformer	0	0	100	MI	Silt of medium compressibility
Rangeli control Building	0	0	100	MI	Silt of medium compressibility
Phatepur Transformer	0	0	100	ML	Silt of low compressibility
Phatepur Control building	0	0	100	ML	Silt of low compressibility
Biratchowk Transformer	0	0	100	ML	Silt of low compressibility
Biratchowk Control Building	0	0	100	ML	Silt of low compressibility
Yedukuwa Control Building	0	0	100	CL	Clay of low compressibilty
Yedukuwa Transformer	0	0	100	CI	Clay of medium compressibility
Bhiman Control Building	62	36	2	GW	Well graded gravel and sand
Bhiman Transformer	61	37	2	GW	Well graded gravel and sand
Milanchowk Control Building	48	50	2	GW	Well graded gravel and sand
Milanchowk Transformer	48	50	2	GW	Well graded gravel and sand
Katari	48	50	2	GW	Well graded gravel and sand

Sieve analysis

The fundamental measure for the classification of engineering soil is the particle size analysis. This is mechanical or grading method that results the particle size distribution curve. The particle size distribution express the size of particles in a soil in terms of percentages by weight of boulder, cobbles, gravel, sand, silt, and clay (Bell 1992). In laboratory two methods are usually employed to determine the particle size distribution in a soil. They are sieving and sedimentation.

In the field the fineness and coarseness of the soil were separated by visualization basis. The size of particles that can be visible by naked eyes is categorized as coarser (sand and gravel) otherwise as finer (Silt and clays). Among the coarser particles the grain that cannot be held in a single paw is considered as boulder. The grains can be easily grasped within a hand are cobbles and those that can be held between a finger and thumbs are pebbles. The grains can be picked up from the mass of sediment having size smaller the pebble is considered as granules. The smaller grains than that of granules are considered as sands. The finer particles of silt and clays are determined by chewing a small fraction of soil. During chewing if it feels smooth the soil is considered as clay and if feels gritty, the soil is considered as silt.

According to the distribution of particle size, the soil can be classified as following:

Uniformly graded: the proportion of particle size concentrating within a narrow range is described as uniformly or poorly graded.

Well graded: Coarse-grained soil without excess of particles in any size range and without any lack of their intermediate size-range is regarded as well-graded soil. A well graded soil posses a wide range of particle size ranging

Table 3: Results of the Atterberg limit test

Location	Liquid Limit	Plastic Limit (PL)	Plasticity Index (PI)	A-line (IP)	Flow (FI)	Index Index (TI)	Toughness Phikal
Transformer	28.5	23.61	4.89	6.21	8.38	0.58	
Phikal Control Building	34.4	28.97	5.43	10.51	3.63	1.50	
Aurahai Control Building	35	26.46	8.54	10.95	1.86	4.59	
Aurahai Transformer	37	27.3	9.70	12.41	1.61	6.02	
Devdaha Control Building	22.2	12.22	9.98	1.6	1.79	5.59	
Devdaha Transformer	22	18.32	3.68	1.46	3.36	1.09	
Simraungadha Transformer	44	21.94	22.06	17.52	1.94	11.39	
Simraungadha Control Building	44.4	21.94	22.46	17.81	1.8	12.47	
Jitpur Transformer	21.6	5.72	15.88	1.17	3.86	4.12	
Jitpur Control Building	20	4.46	15.34	0	1.12	13.68	
Mukundapur Transformer	30	13.86	16.14	7.3	1.47	10.96	
Mukundapur control Building	29.6	12.22	17.38	7.01	1.3	13.38	
Amuwa Transformer	18	NA	NA	-1.46	-0.18	NA	
Rangeli Transformer	46	42.42	3.58	18.98	2.94	1.22	
Rangeli control Building	48	46.67	1.33	20.44	2.07	0.64	
Phatepur Transformer	34	24.1	9.9	10.22	-2.51	-3.95	
Phatepur Control building	31.8	26.67	5.13	8.61	1.38	3.71	
Biratchowk Transformer	30	28.52	1.48	7.3	3.03	0.49	
Biratchowk Control Building	30.00	28.54	1.46	7.30	2.12	0.69	
Yedukuwa Control Building	24	13.33	-10.67	2.92	2.66	4.02	
Yedukuwa Transformer	23	18.89	4.11	2.19	3.04	1.35	

from gravel to clay.

Gap or skip graded: A gap-graded soil lacks some or at least one intermediate size particles.

Sieve analyses of all the samples collected during the field work are presented in Table 2. The results of the sieve analysis show that the soil types found in the different sites are of medium to low compressibility i.e. excellent for the foundations.

Liquid limit and plastic limit test

The amount of water content in a cohesive soil controls the deformation behavior of that soil. This response of soil to the stress is regarded as the soil consistency. In other words soil consistency indicates the degree of firmness of a cohesive soil. A cohesive soil changes from non-plastic to plastic and plastic to viscous when the water content increases (Johnson and DeGraff 1988). The consistency for a particular soil is defined by the water content present in it when it changes its response to stress. These changes are called the Atterberg limits. The Atterberg limits are defined in terms of liquid limit (LL), plastic limit (PL), and shrinkage limit (SL).

Liquid limit (LL)

The water content at which a cohesive soil changes from viscous to plastic state and vice versa is regarded as the liquid limit. At this stage all soils possess certain small shear strength.

Plastic limit (PL)

The water content at the transition of a plastic soil into a semisolid soil is regarded as the plastic limit. At this limit the soil rolled into threads of about 3mm diameter just crumbles. Between the plastic limit and the liquid limit, the soil behaves as plastic material. This range of water content is termed as the Plasticity Index (PI) and is calculated by:

$$PI = LL - PL$$

Shrinkage limit (SL)

When the water content decreases from the plastic limit, the soil approaches a point where no volume of the soil change on further drying up. Beyond this point discoloration of soil may occur. This limit is called as shrinkage limit. Between the shrinkage limit and plastic limit the soil is considered as semisolid.

The results of the liquid limit and plastic limit are presented in Table 3. The results are used to find out Plasticity Index (PI), A-Line Ip, Flow Index and Toughness Index. They can be used also for the liquefaction potential for the soil (Lambe, 1951). Most of the sites are safe from liquefaction from the vertical loading except Biratchowk. Due to very shallow ground water table at Biratchowk sand boiling may occur and should be considered during detail design stage. The liquid limit and plastic limit data are used for the classification of the soil. These data are also used to cross check the strength parameters such as c (cohesion), ø (friction angle) and for determining the compressibility of the soil.

Moisture content

The results of moisture content are presented in Table 4. Moisture content is determined taking some portion of the undisturbed sample collected for the direct shear at the time of sample preparation for direct shear test and also from the disturbed sample. Both of these samples were waxed and sealed to prevent moisture loss. Generally the granular soil has less moisture content than the fine soil. The dry unit weight of the soil is considered as its unit weight of the soil for the calculation of the much reliable safe bearing capacity.

Specific gravity determination

Specific gravity is the ratio of the mass/ weight in the air of a given volume of dry soil material to the mass / weight of equal volume of distilled water at 4°C. But as the value of the specific gravity depends on the temperature, hence its value is reported at standard temperature of 27°C. Specific gravity of the soil passing through 4.75 mm sieve is considered here. Thus the specific gravity of the soil classified as GW is not considered here. The specific gravity of the soil is presented in Table 5.

Direct shear test

Direct shear test is carried to determine the shear strength parameters for a given soil. The strength of a soil depends of its resistance to shearing stresses. It is made up of basically the components; (1) Frictional – due to friction between individual particles and (2) Cohesive - due to adhesion between the soil particles. The test is carried out on either undisturbed samples or remolded samples. To facilitate the remolding purpose, a soil sample may be compacted at optimum moisture content in a compaction mould. Then

Table 4: Results of the moisture contents

Location	Moisture Content %
Phikal Transformer	32.34
Phikal Control Building	31.97
Aurahai Control Building	28.85
Aurahai Transformer	28.98
Devdaha Control Building	18.43
Devdaha Transformer	17.15
Simraungadha Transformer	30.43
Simraungadha Control Building	31.05
Jitpur Transformer	12.11
Jitpur Control Building	10.78
Mukundapur Transformer	21.19
Mukundapur control Building	22.12
Amuwa Transformer	6.52
Rangeli Transformer	33.18
Rangeli control Building	34.32
Phatepur Transformer	36.44
Phatepur Control building	34.02
Biratchowk Transformer	31.62
Biratchowk Control Building	30.44
Yedukuwa Control Building	22.17
Yedukuwa Transformer	22.86
Bhiman Control Building	4.13
Bhiman Transformer	3.98
Milanchowk Control Building	1.32
Milanchowk Transformer	1.41
Katari	9.4

Table 5: Results of the specific gravity test

Location	Specific Gravity
Phikal Transformer Site	2.64
Phikal Control Building Site	2.63
Aurahai Control Building	2.68
Aurahai Transformer	2.72
Devdaha Control Building	2.62
Devdaha Transformer	2.66
Simraungadha Transformer	2.74
Simraungadha Control Building	2.73
Jitpur Transformer	2.71
Jitpur Control Building	2.73
Mukundapur Transformer	2.70
Mukundapur control Building	2.78
Amuwa Transformer Site	2.64
Rangeli Transformer	2.71
Rangeli control Building	2.72
Phatepur Transformer	2.78
Phatepur Control building	2.76
Biratchowk Transformer	2.68
Biratchowk Control Building	2.72
Yedukuwa Control Building	2.67
Yedukuwa Transformer	2.72

specimen for the direct shear test could be obtained using the correct cutter provided.

A normal load is applied to the specimen and the specimen is sheared across the pre-determined horizontal plane between the two halves of the shear box. Measurements of shear load, shear displacement and normal displacement are recorded. The test is repeated for two or more identical specimens under different normal loads. From the results, the shear strength parameters can be determined. Here we use direct shear test to calculate the cohesion (C), friction angle (ø) and unit weight (γ) of the soil. The entire tests are carried out in undisturbed soil samples. These values are tabulated in Table 6.

Bearing capacity of the soil

The direct shear test data are used to calculate the bearing capacity of the soil. The maximum allowable net loading intensity on the soil allowing for both shear and settlement effects is the allowable bearing capacity of the soil (Meyerhof, 1951). Shear parameters in the plain strain measured in the laboratory by the direct shear test are used for the calculations. Ultimate bearing capacity for strip foundation is calculated by using the "Terzaghi Equation" (Terzaghi and Peck, 1967) as given;

$$q = c\,N_c + \gamma\, z\, N_q + 0.5\, \gamma\, B\, N_\gamma$$

Where q = ultimate bearing capacity in kN/m2, c = cohesion in kN/m2, Nc, Nq and Nγ are the Terzaghi's bearing capacity coefficients, B = width of the foundation, Z = depth below the surface.

Bearing capacity of the soil is also calculated by using the "Hasen Equation" (Hansen 1970).

Table 6: Results of the direct shear test

Sub Stations	Site	Dry Unit Weight (γ)	Angle of Internal Friction (ø)	Cohesion (C)
Phikal	Transformer	13.06	28.5	5
	Control Building	14.10	30	6
Aurahai	Transformer	16.00	27	7
	Control Building	14.14	26	4
DevDaha	Transformer	15.30	28	1
	Control Building	14.95	27	1
Simraungadha	Transformer	15.84	22	6
	Control Building	16.20	28	11
Jitpur	Transformer	14.08	28	0
	Control Building	14.00	27	5
Mukundapur	Transformer	15.04	25	5
	Control Building	15.01	25.8	8
Amuwa	Transformer	15.21	25	2
	Control Building			
Rangeli	Transformer	13.51	21	14
	Control Building	14.45	26.9	8
Phatepur	Transformer	13.97	29.5	2
	Control Building	14.20	28.7	10
Biratchowk	Transformer	15.08	29	6
	Control Building	15.02	30	4
Yedukuwa	Transformer	16.20	31.2	9
	Control Building	15.92	30.5	7
Bhiman	Transformer	19.7	34.5	0
	Control Building	20.10	36	0
MilanChowk	Transformer	19.23	33.2	0
	Control Building	20.12	34.9	0
Katari	Transformer	18.89	35.8	0
	Control Building			

"Hansen Equation" is given as

$$q = c\, Nc\, Sc\, Zc + \gamma z\, Nq\, Sq\, Zq + 0.5\gamma B\, N\gamma\, S\gamma\, Z\gamma$$

Where $Nc = (Nq - 1)\,Cot\varnothing$
$Nq = Tan\,2\,(450 + \varnothing/2)e\pi tan\varnothing$
$N\gamma = 1.5\,(Nq - 1)\,tan\varnothing$ are the bearing capacity coefficients.
Sc, Sq and Sγ are the shape factors as follows;
$Sc = 1 + (NqB/ NcL)$
$Sq = 1 + \{(B/ L)\,Tan\varnothing\}$
$S\gamma = 1 - (0.4B/ L)$
Zc, Zq and Zγ are the depth factors as follows;
$Zc = 1 + (0.42/ B)$, $Zq = 1 + \{2\,Tan\varnothing(1-Sin\varnothing)2Z/B\}$, $Z\gamma = 1$
Z = depth of the foundation.
W = width of the foundation.
L = Length of the foundation.

Safe bearing capacity is calculated as
Safe bearing capacity = $\{(q - \gamma Z)/F.S.\} + \gamma Z$
Where q = bearing capacity, F.S. = Factor of safety, γ = Unit weight of soil., Z = depth of foundation.

The safe bearing capacity in general for the strip 1.2m wide, isolated 2m x 2m, Raft 5m x 5m for all the sites are calculated. The results of the bearing capacity using Terzaghi method are presented in Table 7. The results of the bearing capacity by Hasen method are presented in Table 8.

The inclination factor and the pore water pressure are not considered while calculating the bearing capacity of the soil. Similarly the bearing capacity by Terzaghi and Hansen methods depends on the friction angle and cohesion only

Table 7: Results of the bearing capacity by Terzagi Method, (a) Results of the bearing capacity for isolated footings (depth 2 m), (b) Results of the bearing capacity for the strip footings (depth 2 m), (c) Results of the bearing capacity for mat foundation (depth 2 m)

a. Calculation of the Bearing Capacity by Terzagi Method (Isolated Footings)

Location	Ultimate Bearing Capacity (kN/m²)	Safe Bearing Capacity (kN/m²)	Net Safe Bearing Capacity (kN/m²)
Phikal Transformer Site	937.48	338.61	286.37
Phikal Control Building Site	1135.47	406.69	350.29
Aurahai Control Building	673.60	252.81	196.25
Aurahai Transformer	907.00	334.33	270.33
Devdaha Control Building	656.90	248.87	189.07
Devdaha Transformer	797.00	296.27	235.07
Simraungadha Transformer	516.00	203.68	140.32
Simraungadha Control Building	1606.40	567.87	503.07
Jitpur Transformer	704.00	262.83	206.51
Jitpur Control Building	954.00	346.00	290.00
Mukundapur Transformer	653.40	247.88	187.72
Mukundapur control Building	1006.50	365.52	305.48
Amuwa Transformer Site	583.87	225.04	164.20
Rangeli Transformer	563.22	214.76	160.72
Rangeli control Building	1081.20	389.30	331.50
Phatepur Transformer	936.14	339.99	284.11
Phatepur Control building	1408.20	497.80	441.00
Biratchowk Transformer	1048.48	379.65	319.33
Biratchowk Control Building	2478.96	856.36	343.49
Yedukuwa Control Building	1570.76	555.43	491.75
Yedukuwa Transformer	2120.40	739.20	674.40
Bhiman Control Building	3778.80	1299.80	1219.40
Bhiman Transformer	3092.90	1070.37	991.57
Milanchowk Control Building	2857.04	992.59	912.11
Milanchowk Transformer	2596.05	903.81	826.89
Katari	3154.63	1089.32	1013.76

b. Calculation of the Bearing Capacity by Terzagi Method (Strip Foundations)

Location	Ultimate Bearing Capacity (kN/m²)	Safe Bearing Capacity (kN/m²)	Net Safe Bearing Capacity (kN/m²)
Phikal Transformer Site	843.45	298.56	255.03
Phikal Control Building Site	1024.36	360.25	313.25
Aurahai Control Building	605.73	220.76	173.63
Aurahai Transformer	830.20	298.07	244.73
Devdaha Control Building	585.14	214.98	165.15
Devdaha Transformer	711.32	257.51	206.51
Simraungadha Transformer	471.65	178.34	125.54
Simraungadha Control Building	1463.84	509.55	455.55
Jitpur Transformer	625.15	227.16	180.22
Jitpur Control Building	864.40	306.80	260.13
Mukundapur Transformer	595.05	218.40	168.27
Mukundapur control Building	922.44	327.49	277.46
Amuwa Transformer Site	524.86	195.23	144.53
Rangeli Transformer	530.80	194.95	149.91
Rangeli control Building	988.72	348.84	300.67
Phatepur Transformer	835.56	297.15	250.58
Phatepur Control building	1288.92	448.57	401.24
Biratchowk Transformer	951.97	337.43	287.16
Biratchowk Control Building	2166.54	742.21	304.04
Yedukuwa Control Building	1417.93	493.87	440.80
Yedukuwa Transformer	1900.08	654.96	600.96
Bhiman Control Building	3232.08	1104.16	1037.16
Bhiman Transformer	2706.78	928.53	862.86
Milanchowk Control Building	2454.64	845.04	777.97
Milanchowk Transformer	2234.53	770.48	706.38
Katari	2708.83	928.13	865.16

c. Calculation of the Bearing Capacity by Terzagi Method (Mat Foundations)

Location	Ultimate Bearing Capacity (kN/m^2)	Safe Bearing Capacity (kN/m^2)	Net Safe Bearing Capacity (kN/m^2)
Phikal Transformer Site	1290.10	456.15	403.91
Phikal Control Building Site	1552.13	545.58	489.18
Aurahai Control Building	928.12	337.65	281.09
Aurahai Transformer	1195.00	430.33	366.33
Devdaha Control Building	926.00	338.57	278.77
Devdaha Transformer	1118.30	403.37	342.17
Simraungadha Transformer	682.32	259.12	195.76
Simraungadha Control Building	2141.00	746.07	681.27
Jitpur Transformer	999.68	361.39	305.07
Jitpur Control Building	1290.00	458.00	402.00
Mukundapur Transformer	872.24	320.83	260.67
Mukundapur control Building	1321.71	470.59	410.55
Amuwa Transformer Site	805.18	298.81	237.97
Rangeli Transformer	684.81	255.29	201.25
Rangeli control Building	1428.00	504.90	447.10
Phatepur Transformer	1313.33	465.72	409.84
Phatepur Control building	1855.50	646.90	590.10
Biratchowk Transformer	1410.40	500.29	439.97
Biratchowk Control Building	3650.52	1246.88	491.44
Yedukuwa Control Building	2143.88	746.47	682.79
Yedukuwa Transformer	2946.60	1014.60	949.80
Bhiman Control Building	5829.00	1983.20	1902.80
Bhiman Transformer	4540.85	1553.02	1474.22
Milanchowk Control Building	4366.04	1495.59	1415.11
Milanchowk Transformer	3951.77	1355.72	1278.80
Katari	4826.40	1646.58	1571.02

Table 8: Results of the bearing capacity by Hasen Method, (a) Results of the bearing capacity for isolated footings (depth 2 m), (b) Results of the bearing capacity for the strip footings (depth 2 m), (c) Results of the bearing capacity for mat foundation (depth 2 m)

a. Calculation of the bearing capacity by Hasen method (Isolated Footings)

Location	Ultimate Bearing Capacity (kN/m²)	Safe Bearing Capacity (kN/m²)	Net Safe Bearing Capacity (kN/m²)
Phikal Transformer Site	1202.37	418.20	374.67
Phikal Control Building Site	1590.02	548.81	501.81
Aurahai Control Building	910.58	322.38	275.25
Aurahai Transformer	1284.78	449.59	396.26
Devdaha Control Building	912.36	324.05	274.22
Devdaha Transformer	1053.61	371.60	320.60
Simraungadha Transformer	704.63	256.00	203.20
Simraungadha Control Building	2365.34	810.05	527.46
Jitpur Transformer	917.39	324.57	277.64
Jitpur Control Building	1344.18	466.73	327.23
Mukundapur Transformer	897.15	319.10	268.97
Mukundapur control Building	1431.84	497.29	343.66
Amuwa Transformer Site	773.00	277.95	227.25
Rangeli Transformer	824.85	292.96	247.93
Rangeli control Building	1563.50	540.43	382.37
Phatepur Transformer	1229.00	428.29	381.73
Phatepur Control building	2100.04	718.95	509.50
Biratchowk Transformer	1485.98	515.43	465.17
Biratchowk Control Building	3297.16	1119.08	480.38
Yedukuwa Control Building	2450.02	837.90	608.64
Yedukuwa Transformer	3003.66	1022.82	724.09
Bhiman Control Building	4990.24	1690.21	1209.90
Bhiman Transformer	3943.62	1340.81	956.48
Milanchowk Control Building	3754.04	1278.17	1034.09
Milanchowk Transformer	3346.39	1141.10	777.31
Katari	4059.90	1378.49	1104.67

b. Calculation of the bearing capacity by Hasen method (Strip Footings)

Location	Ultimate Bearing Capacity (kN/m2)	Safe Bearing Capacity (kN/m2)	Net Safe Bearing Capacity (kN/m2)
Phikal Transformer Site	1345.75	466.00	422.46
Phikal Control Building Site	1774.21	610.20	563.20
Aurahai Control Building	1022.32	359.63	312.49
Aurahai Transformer	1447.44	503.81	450.48
Devdaha Control Building	1009.47	356.42	306.59
Devdaha Transformer	1161.90	407.70	356.70
Simraungadha Transformer	801.73	288.36	235.56
Simraungadha Control Building	2654.52	906.44	852.44
Jitpur Transformer	1007.10	354.47	307.54
Jitpur Control Building	1500.49	518.83	472.16
Mukundapur Transformer	1012.07	357.41	307.28
Mukundapur control Building	1613.93	557.99	507.96
Amuwa Transformer Site	863.64	308.16	257.46
Rangeli Transformer	954.66	336.23	291.20
Rangeli control Building	1758.37	605.39	557.22
Phatepur Transformer	1354.95	470.28	423.71
Phatepur Control building	2358.61	805.14	757.80
Biratchowk Transformer	1661.60	573.97	523.71
Biratchowk Control Building	3569.31	1209.80	535.46
Yedukuwa Control Building	2711.94	925.21	872.14
Yedukuwa Transformer	3328.24	1131.01	1077.01
Bhiman Control Building	5258.44	1779.61	1712.61
Bhiman Transformer	4184.51	1421.10	1355.44
Milanchowk Control Building	3992.37	1357.62	1290.55
Milanchowk Transformer	3566.81	1214.58	1150.48
Katari	4298.05	1457.87	1394.90

c. Calculation of the bearing capacity by Hasen method (Mat Foundations)

Location	Ultimate Bearing Capacity (kN/m^2)	Safe Bearing Capacity (kN/m^2)	Net Safe Bearing Capacity (kN/m^2)
Phikal Transformer Site	1179.21	410.48	366.95
Phikal Control Building Site	1569.59	542.00	495.00
Aurahai Control Building	886.82	314.46	267.33
Aurahai Transformer	1240.42	434.81	381.47
Devdaha Control Building	920.30	326.70	276.87
Devdaha Transformer	1070.66	377.29	326.29
Simraungadha Transformer	662.02	241.79	188.99
Simraungadha Control Building	2301.12	788.64	734.64
Jitpur Transformer	942.03	332.78	285.85
Jitpur Control Building	1326.47	460.82	414.16
Mukundapur Transformer	863.24	307.80	257.67
Mukundapur control Building	1380.31	480.12	430.08
Amuwa Transformer Site	761.73	274.19	223.49
Rangeli Transformer	740.32	264.79	219.75
Rangeli control Building	1515.02	524.27	476.11
Phatepur Transformer	1248.57	434.82	388.25
Phatepur Control building	2039.17	698.66	651.32
Biratchowk Transformer	1460.36	506.89	456.63
Biratchowk Control Building	3463.72	1174.60	482.41
Yedukuwa Control Building	2459.70	841.13	788.06
Yedukuwa Transformer	3005.37	1023.39	969.39
Bhiman Control Building	5521.17	1867.19	1800.19
Bhiman Transformer	4313.70	1464.17	1398.50
Milanchowk Control Building	4090.75	1390.41	1323.34
Milanchowk Transformer	3632.73	1236.55	1172.45
Katari	4457.80	1511.12	1448.15

Table 9: Results of the resistivity measurements

Location	Resistivity ρ in Ω - m	Resistance R in Ω
Phikal Transformer Site	20.00	0.40
Phikal Control Building Site	19.60	0.39
Aurahai Control Building	1.10	0.02
Aurahai Transformer	1.15	0.02
Devdaha Control Building	1.33	0.03
Devdaha Transformer	1.33	0.03
Simraungadha Transformer	1.50	0.03
Simraungadha Control Building	1.12	0.02
Jitpur Transformer	77.00	1.53
Jitpur Control Building	2.00	0.04
Mukundapur Transformer	2.00	0.04
Mukundapur control Building	2.30	0.05
Amuwa Control Building	3.90	0.08
Amuwa Transformer Site	3.70	0.07
Rangeli Transformer	2.10	0.04
Rangeli control Building	2.41	0.05
Phatepur Transformer	1.61	0.03
Phatepur Control building	1.29	0.03
Biratchowk Transformer	1.46	0.03
Biratchowk Control Building	1.61	0.03
Yedukuwa Control Building	1.24	0.02
Yedukuwa Transformer	1.19	0.02
Bhiman Control Building	32.00	0.64
Bhiman Transformer	19.10	0.38
Milanchowk Control Building	24.40	0.49
Milanchowk Transformer	29.70	0.59
Katari	40	0.8

and slight variation in the friction angle has greater effect on bearing capacity of the soil. Therefore, the factor of safety in the calculation of the bearing capacity is taken between 3 and 5. In a case; the excavated depth is left for a long time without filing the safe bearing capacity of the soil is determined by the formula

Safe bearing capacity of the soil = q/F.S.
Net safe bearing capacity of the soil = q/F.S. - γZ
(Presented in Tables 7 and 8).

Resistivity measurements

Resistivity measurements were carried out only to explore the suitability of the sites for the purposed construction of substations in terms of earthing. As the substations will be equipped with transformer and switchyard it is necessary to have good conductive soil for the earthing purpose. Resistivity measurement showed that the sites are suitable for the construction of purposed substations. The resistance R of the site is calculated by using the resistivity (ρ) of the site measured by Earth Tester, MEGGER® DET 3/2.

The measured resistivity of the site is calculated by using the formula $\rho = 2\pi \times a \times R$.

Where; ρ = resistivity, a = distance between two electrodes, R = resistance. The resistivity data are for the depth up to 8m. The results of the resistance are presented in Table 9.

DISCUSSIONS

Site maps were prepared during the detail survey and in each map control building and switchyard location is fixed according to the orientation of the high voltage line. Boreholes were drilled using hand auger so if boulder were encountered, the boreholes were stopped at that depth. During the SPA test if the tip of the SPA was stopped by the boulder than SPA test was also stopped at that depth. The SPA test was once carried out in the nearby area to conform the presence of boulder and if the SPA is stopped once again than it was carried out up to that depth only. The bearing capacity obtained by the Hasen methods are recommended for the design as it is calculated by considering both cohesion and the friction angle of the soil. The length and breadth of the footings also control the bearing capacity of the soil so it is recommended that if the design is not similar as given above it is recommended that bearing capacity should be recalculated after the detail design of the foundation. In the calculation of the bearing capacity, inclined loading and horizontal loading like earthquake shaking is not considered. The SPA test should be performed twice to prevent any biases from the sampling location. Once the standard value is obtained for large sample it can be used to determine the bearing capacity of the soil reducing the laboratory test.

CONCLUSIONS

The cohesion and friction angle are the most important and sensitive parameter in the calculation of the bearing capacity of the soil. Bearing capacity obtained by using 35 times Nc value and bearing capacity from laboratory data has a correlation coefficient of ~0.83. So if the litholog of the area are available, Nc value obtained from the SPA test can be converted to ultimate bearing capacity. The resistivity data obtained in the field are suitable for the earthing as these are below the normal value. Resistivity measurement showed that the sites are suitable for the construction of purposed substations in terms of earthing.

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