NEPAL ELECTRICITY AUTHORITY
ENGINEERING SERVICE
PROJECT DEVELOPMENT DEPARTMENT
DURBARMARG, KATHMANDU

Geotechnical Investigation Report

For

Foundation Design of NEA Buildings

(Karnali Tower, Koshi Tower & Gandaki Tower)

At

Tudikhel, Kathmandu

Test Conducted by :
East Management Engineering Services Pvt. Ltd., Satdobato, Lalitpur

Submitted by:

BDA*nepal* (P.) Ltd. JV Innovative CREATEERS Pvt. Ltd. JV MRB & Associates
467-Ichhunadi Marg, Baluwatar, Kathmandu

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1. INTRODUCTION

This geotechnical investigation report is prepared based on the site exploration and laboratory test results carried out by EMES Pvt Ltd for proposed site of NEA Building (Towers) at Tudikhel, Katmandu. The scope of work was provided by the consultant M/S BDA*nepa*l Pvt Ltd. This is the final report which discusses briefly the field investigation works, analysis and interpretation of the obtained data and their recommendations for application in the foundation design of the buildings. A site plan showing borehole locations, borehole logs showing soil stratification along with the results of in-situ and laboratory tests are included in this report.

1.1 DESCRIPTION OF SITE

The site lies on the north east corner of Tundikhel within the premises Nepal Electricity Authority properties. The area is of commercial importance and high rise buildings with basement are gradually being built up. The site is at present scattered within the NEA office compound at different locations and elevations, and in open spaces among the existing buildings.

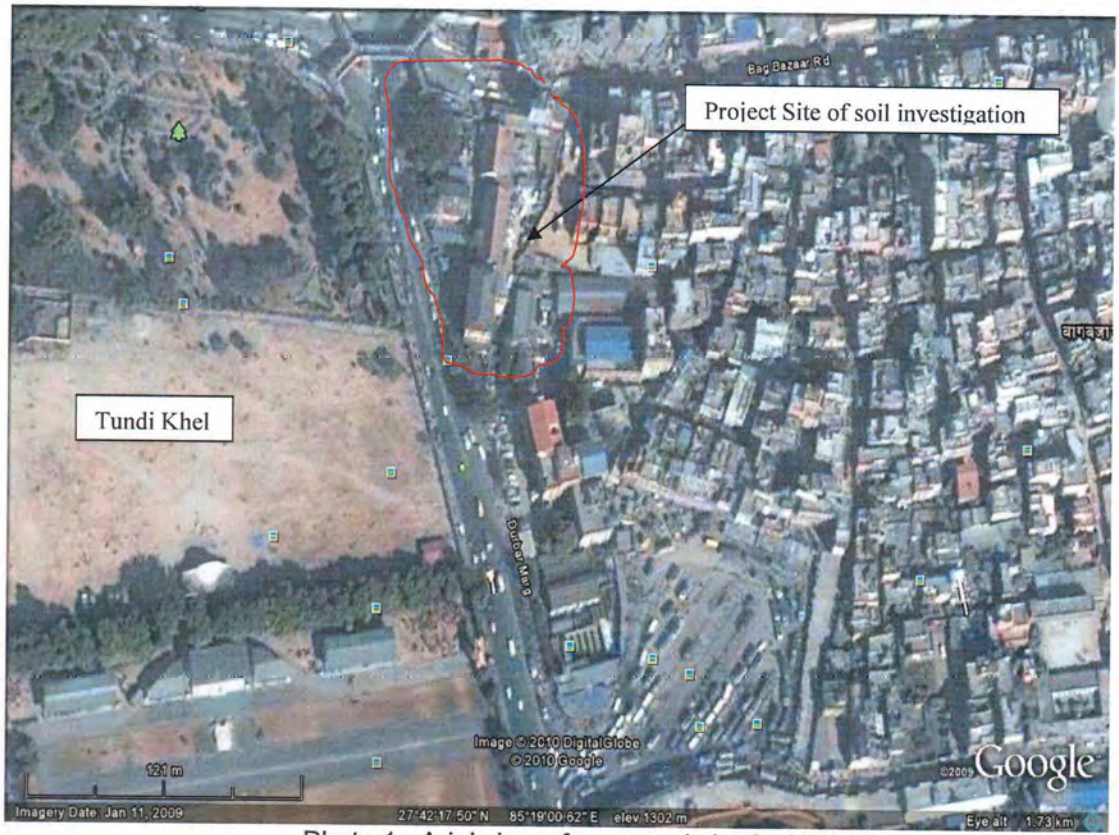

Photo 1: Arial view of proposed site for NEA Tower

1.2 GENERAL GEOLOGY AND GEOMORPHOLOGY

From the exploration record of boreholes 1 to 6 on the proposed site the soil profile of the terrain is as follows:

Except in location of borehole 3, a band of fill of about 50 cm to 2.0 meter is observed in all boreholes. It is underlain by heterogeneously layered sandy and silty bands of soil up to 3.0 in borehole 3 to 10 meter in other boreholes. Below sand band is observed a thick layer of cohesive soil consisting of lean clay, fat clay and elastic silt to the full depth of exploration (30 meter) in all boreholes.

The project site lies in the Gokarna formation. The Gokarna formation consists of slightly consolidated light to brownish gray, fine laminated and poorly graded silty sand with intercalation of clay of variable thickness. The thickness of the formation is as high as 300 m at places.

In general Geology, typical lithology of formation of the Kathmandu valley is one of the large intramontane basin developed in the lesser Himalayas, central Nepal. It consists of a thick lucastrine and fluvial deposits of fine and coarse sand, sandy loam, peat, sandy silty clay, carbonaceous clay, sand and gravel, all of which are more or less consolidated. The maximum thickness of these sediments is over 600 meter in some places. Recent drilling in these sediments has shown that the subsoil of central part of Kathmandu Valley is very soft up to a depth of about 20 meter.

Photo 2a: Soil type recovered in SPT Sample

Photo 2b: Soil type recovered in borehole 4

Geological map of the project area is shown in Fig. 1. The map is an extract from The Engineering and Environmental map of the Kathmandu valley published by the Department of Geology and Mines of the Government of Nepal.

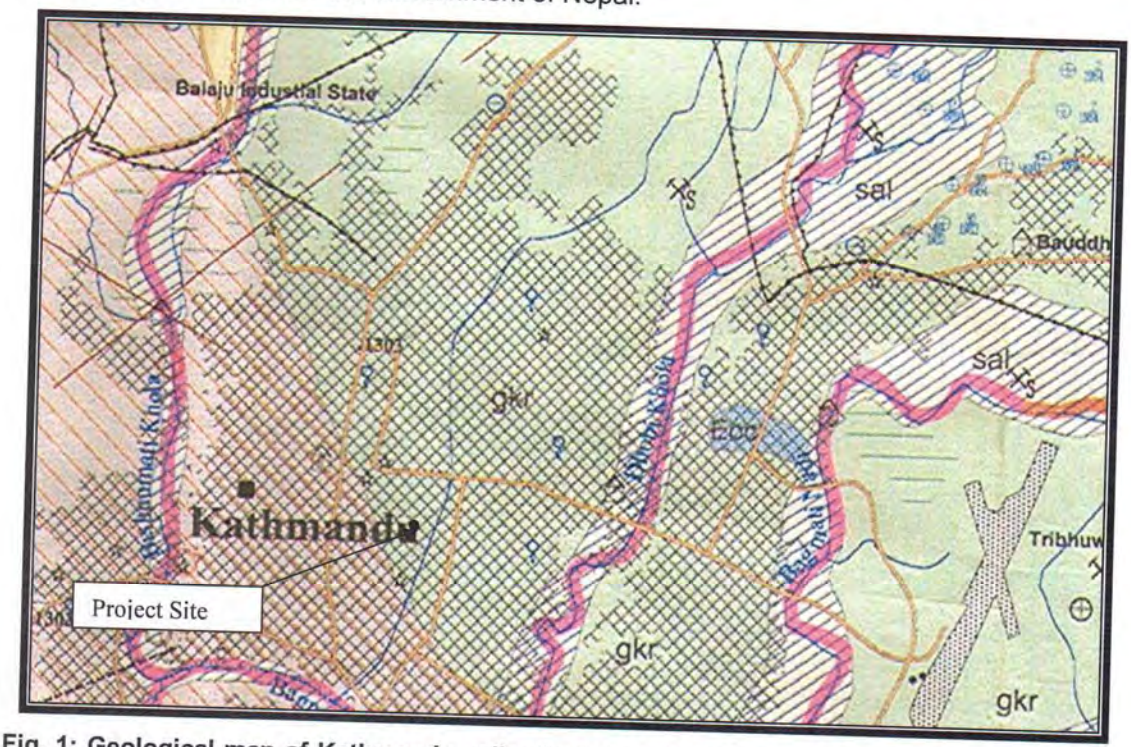

Fig. 1: Geological map of Kathmandu valley including project area (Source; Engineering and Environmental map of the Kathmandu valley

1.3 SEISMICITY

Many earth scientists believe that longitudinally the entire 2,400 km long Himalayan arc can be segmented into different individual parts (200-300 km) which periodically break and move separately and produce mega earthquake (catastrophic earthquake) in the Himalayan region. From east to west, the great earthquake of Assam, India (1950), Shilong, India (1897), Nepal-Bihar, India (1934) and Kangra, India (1905) are the mega-earthquakes of the last century produced by the movements in different parts of the Himalayan arc, all with magnitude around 8.0 - 8.7. When a sector of the Himalaya moves and produces earthquakes, it will take some time (from decades to century) to repeat the event at the same place. Nepal is prone to an earthquake of minor or major magnitude. Records of earthquakes since 1253 indicate that Nepal was hit by 16 major earthquakes - the 1833 (magnitude 7.9) and 1934(magnitude 8.3) are two of these which have occurred at an interval of 100 years. Statically, the earthquake occurrence data of the last century shows that in average Nepal was hit by a big earthquake in every 12 years (Nakarmi, 1997).

Statistics shows that 1934 earthquake was the severest for Kathmandu valley where significant damages to the lives and properties were observed. Buildings and other structures built on thick soft soils are very vulnerable to the force of earthquake as compared to the structures built on top of hard rocks. Due to the thick soil cover, during an earthquake, the structures in the Kathmandu Valley are shaken very strongly than the structures in the surrounding hills with rocky base.

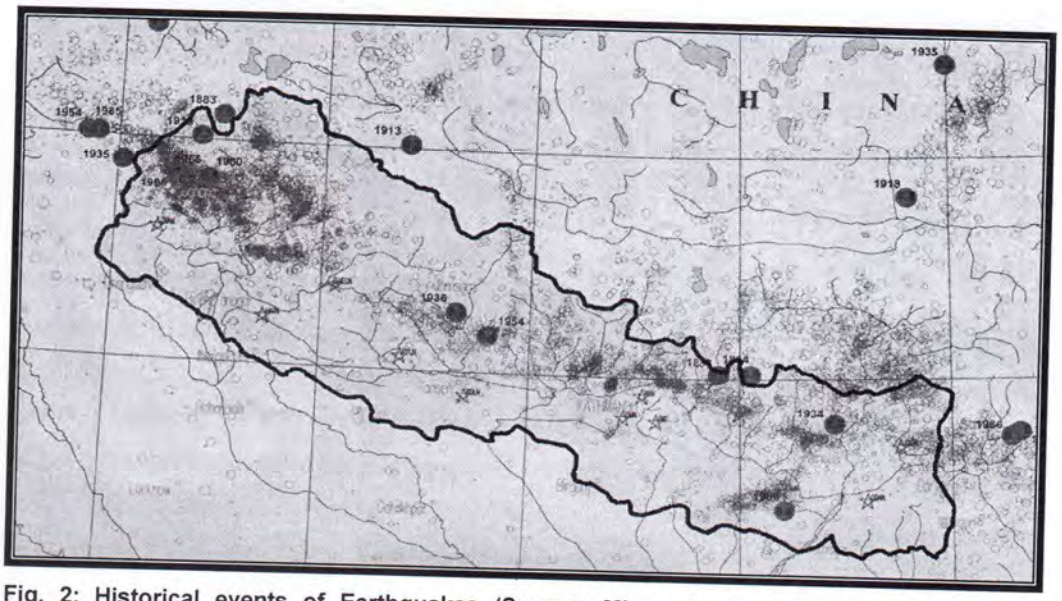

Fig. 2: Historical events of Earthquakes (Source: Microseismic epicentre map of Nepal Himalaya and adjoining region, 1997 published by DoMG, GON).

Now-a-days, earth scientists are most concerned about the lack of occurrence of any **great earthquake** between Kathmandu in the east and Dehra Dun, India in the west during the past many centuries, and have named it the **CENTRAL GAP**. It is most likely that this segment of the Himalaya is due for a major break to trigger a mega-earthquake in the Himalaya. It is even suspected that it may be the greatest earthquake that we have so far experienced in the Himalaya in the past few centuries. The area closer to the epicenter will suffer the maximum damage.

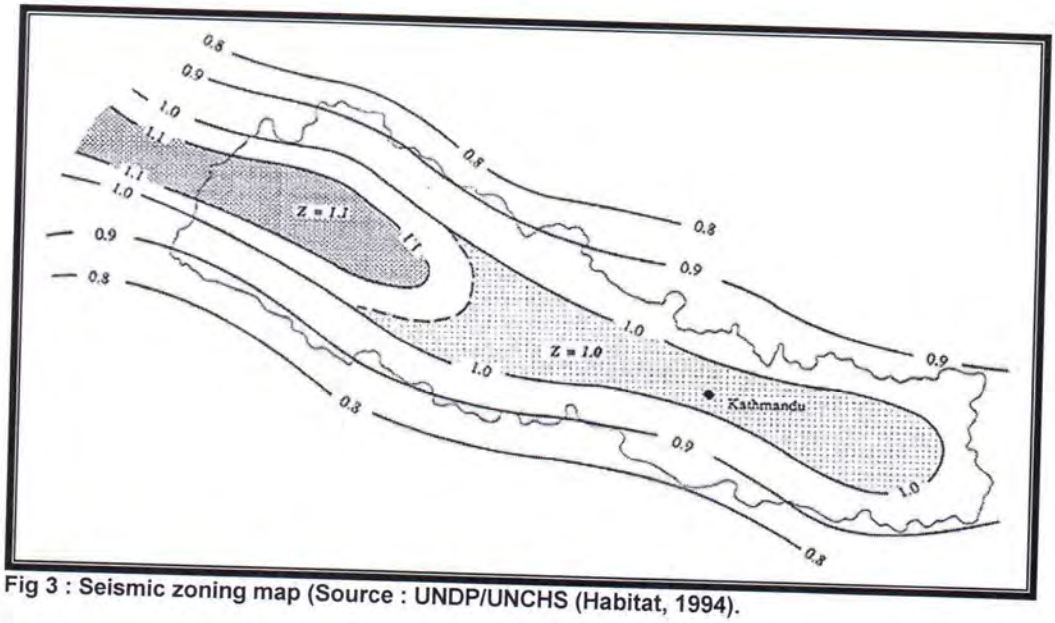

Fig 3 : Seismic zoning map (Source : UNDP/UNCHS (Habitat, 1994).

To counteract earthquake effect due consideration has to be taken in the structural design of buildings. The project area is located in the area having Seismic Zoning Factor, Z, equal to 1 according to the Nepal National Building Code (NBC 105: 1994).

2. OBJECTIVE AND SCOPE OF WORK

The objective behind this geotechnical investigation work is to provide information to the Engineer about the geo- profile of the project site, the engineering properties and load carrying capacity of the in-situ soil by carrying out different field works and various laboratories testing works. With aforesaid objectives, field investigation works was started on 01/06/2010 and was completed on 26/06/2010.

The scope of works consist of field work as well as laboratory works.

2.1 Field Work

Field works included advancement of borehole by percussion drilling, conducting Standard Penetration Test (SPT); collection of undisturbed and disturbed samples and measurements of ground water table.

2.2 Laboratory Work

The following laboratory tests have been carried out in order to assess the physical properties of the soil.

2.2.1 General Properties
- Sieve analysis
- Natural Moisture Content
- Specific Gravity
- Atterberg Limit

2.2.2 Shear Tests
- Direct Shear Test

2.2.3 Consolidation Test
- 1-D Consolidation Test

3. METHODOLOGY

The methodologies adopted for whole operation are described briefly in the following subheadings.

3.1 Percussion Drilling

The location of the borehole is shown in Fig 4. Six boreholes at selected locations were advanced by percussion drilling machine. Borehole1& 2 were drilled at the location of tower 1, 3 & 4 at tower 2 location and 5 & 6 in location of tower 3. 1 to 4 drill holes were drilled up to a depth of 30 meter and Boreholes 5 and 6 were drilled up to 33 meter each from original ground level. The method of percussion drilling has been selected based on the site observation.

The diameter of the hole was kept 150 mm so that undisturbed sample could be extracted for tests like Direct shear Test, and Consolidation Test. The soil extracted during drilling of each hole was observed carefully by the supervisor so as to make site borehole logs.

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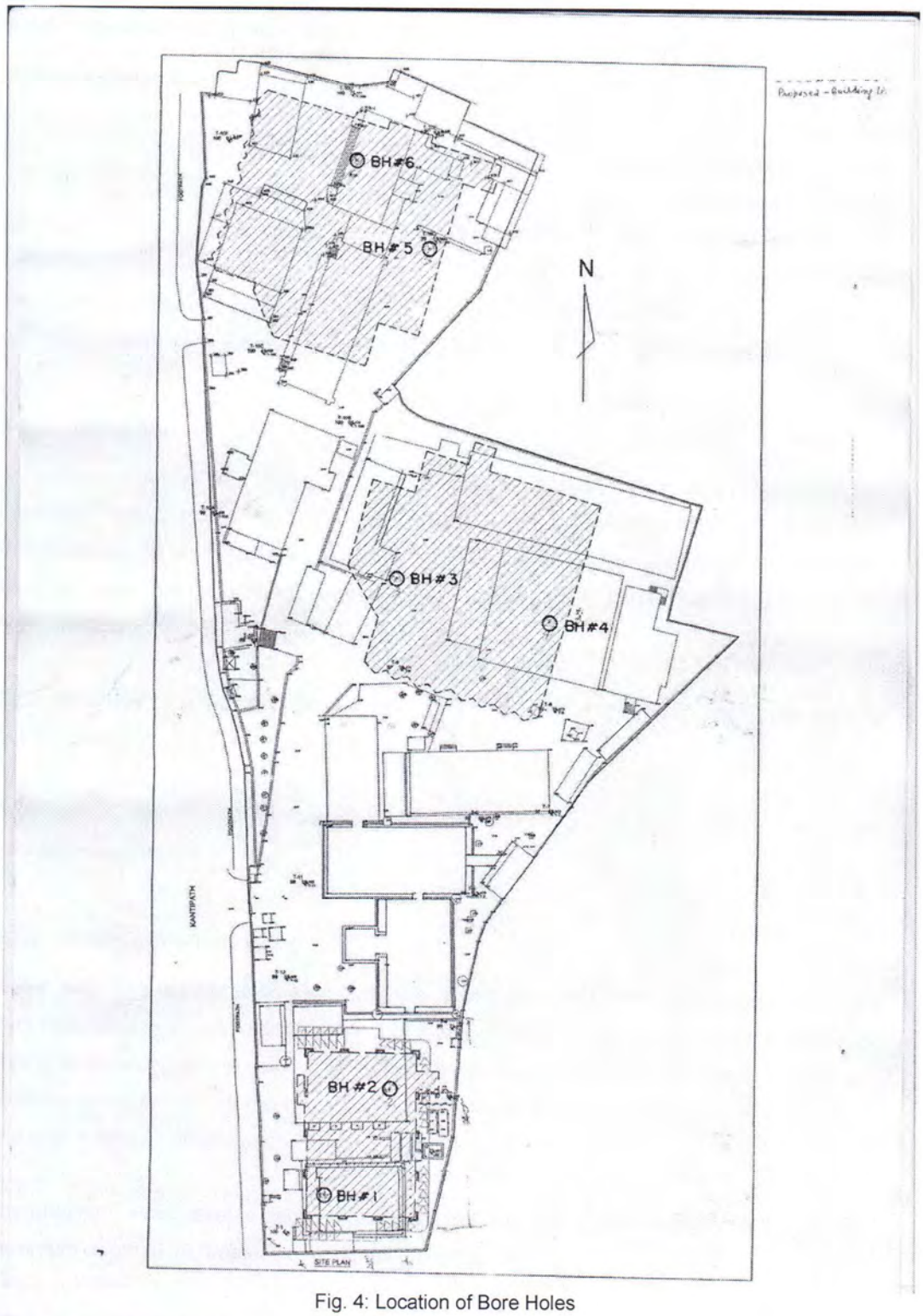

Fig. 4: Location of Bore Holes

3.1.1 Standard Penetration Tests (SPT)

Standard Penetration Test (SPT) was conducted in all drill holes. The tests were conducted at every 1.50 m interval, as far as possible, starting first at 1.50 m depth. The total number of blow count of a 65 kg hammer, falling freely through 75 cm height, required for 2nd and 3rd 150 mm penetration of split spoon sampler were recorded as field N-value and are presented in the borehole logs The purpose of the test is to obtain information on relative density of cohesionless soil and consistency of cohesive soils. The samples obtained in the split tube are disturbed but representative samples. They are preserved for determination of the index properties of the soil. A total of 124 tests were conducted in 6 boreholes.

3.1.2 Sampling

Before any sample was taken, the borehole was cleaned up of loose disturbed soil deposited during boring operation. The samples obtained in the split SPT tube were preserved as representative disturbed samples for carrying out classification tests. The samples thus obtained were placed in air tight plastic bags, labeled properly for identification.

22 Undisturbed samples were extracted from the boreholes at different depths so as to carry out consolidation and direct shear test.

As shown in Table 2, 11 numbers SPT samples were collected from different depths for various test purposes.

3.1.3 Water Table Monitoring

Water level was measured in each borehole during the period of investigation. The water level measured in a particular borehole at the end of 24hour's period after the completion of drilling, is recorded as the water level for that borehole. Fluctuation in the water level in any borehole observed during the investigation period was recorded every day before the start and end of every shift of work.

The observed water level in each borehole ranged from a minimum depth of 4.0 meter to a maximum depth of 19.0meter from original ground level.

3.2 Laboratory Testing

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Depending upon the type of soil and the scope of works, type and number of the laboratory test were determined in consultation with the Engineer. The tests were carried out utilizing standard procedures as specified by IS, BS, AASHTO or ASTM.

The type and number of tests programmed to carry out for the project is specified in Table 1.

Table 1: Type and Number of Laboratory tests

Tests	Sieve	NMC	Hydro meter	γ_{bulk}	Atterberg Limits	Sp. Gr.	D. Shear	Consolidation
No.	33	9	5	9	23	5	9	5

4. FIELD INVESTIGATION RESULTS

4.1. Percussion Drilling

The rough sketch of the percussion drilling logs was prepared at the site, which after laboratory testes, was finalized. They are shown in detail in Appendix A, BOREHOLE LOGS. The correction of the Standard Penetration field tests results from these boreholes is presented in Table 6 included in appendix.

Photo 3: Percussion drilling in borehole 4

Measured Standard Penetration Test (SPT) N-value varied from a minimum value of 2 to a maximum value of 26 with an average value of 9. The test result shows that the granular soil to be of loose to medium dense and elastic silt to lean clay is soft to stiff. Measured SPT N-value is shown in borehole logs. The interpretation of correction of field N-value is described in section 4.1.1 and corrected N-value (N1)60 is given in Table 6 in appendix.

4.1.1 Standard Penetration Test (SPT)

The SPT values have been corrected in accordance with the proposal of Skempton, (1986) and Liao and Whitman (1987) as outlined below with consideration of field procedure, hammer efficiency, borehole diameter, sample and rod length.

Photo 4: Standard Penetration Test in borehole 3

Correction of SPT N-value using the relation after Skempton, 1986

$N_{60} = E_m C_B C_S C_R N/0.60$

Where:

N_{60} = SPT N value corrected for field procedure

E_m = Hammer Efficiency

C_B = borehole diameter correction

C_S = Sample Correction

C_R = rod length correction

$_N$ = SPT N value recorded in the field

The correction factors taken are :

E_m =	0.55	for hand drop hammer (Table 3.3)
C_B =	1.0	for 100 mm dia. borehole (Table 3.4)
Cs =	1.0	for standard sampler (Table 3.4)
C_R =	0.75	for rod length 3.0 - 4.0 m (Table 3.4)
	0.85	for rod length 4.0 - 6.0 m (Table 3.4)
	0.95	for rod length 6.0 - 10 m (Table 3.4)
	1.00	for rod length >10 m (Table 3.4)

Correction of corrected N_{60} field value for overburden pressure using the relation after Liao and Whitman, 1987

$(N1)_{60} = N_{60} \sqrt{(100kPa/\sigma'_z)}$

Where:

N_{60} = SPT N value corrected for field procedure

$(N1)_{60}$ = SPT N-value corrected for field procedures and overburden stress

σ_z' = Vertical effective stress at the test location (kPa)

Table 3.3 and 3.4 mentioned above have been given in Appendix D.

4.2 Laboratory Investigation Results

4.2.1 General Properties

The results of physical and index properties of soil samples collected from various depths are presented in Table 2 given below.

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Table 2: Index Properties of soil samples

BH No	Level		Passing No 200	D60	D30	D10	Cu	Cc	Atterberg Limit (%)			USCS* Soil Classification		Consolidation Parameters	
	From	To							LL	PL	PI	Group	Description of soil	Cc*	e_o**
1	3.50 - 4.50		34.262									SM	Silty Sand		
	6.50 - 7.00		92.038						44	41	3	ML	Silt		
	10.50 - 10.95		64.300									SM	Silty Sand		
	12.50 - 13.00		77.601						36	24	12	CL	Lean Clay with Sand		
	15.50 - 16.00		98.416						59	35	24	MH	Elastic Silt		
	18.50 - 19.00		99.16						56	36	20	MH	Elastic Silt	0.17	1.315
2	4.50 - 4.95		96.792									CL-ML	Silty Clay		
	8.50 - 9.00		92.020						45	31	14	CL	Lean Clay	0.18	0.918
	14.50 - 15.00		99.545						61	40	21	MH	Elastic Silt		
	22.00 - 22.50		99.802						68	45	23	MH	Elastic Silt		
	27.50 - 28.00		99.825						64	43	21	MH	Elastic Silt		
3	4.50 - 4.95		22.337									SM	Silty Sand		
	7.50 - 7.95		35.433									SM	Silty Sand		
	12.50 - 13.00		99.676						51	33	18	MH	Elastic Silt		
	17.00 - 17.50		95.962						76	52	24	MH	Elastic Silt		
	24.50 - 25.00		87.842						63	40	23	MH	Elastic Silt	0.18	1.167
	29.50 - 30.00		99.100						89	53	36	MH	Elastic Silt		
4	6.00 - 6.45		39.143									SM	Silty Sand		
	9.00 - 9.45		1.94	2.9	0.9	0.32	9.1	0.8				SW	Well graded Sand		
	11.00 - 11.50		90.352						44	35	9	CL	Lean Clay		
	17.00 - 17.50		68.304						55	40	15	MH	Elastic Silt with Sand		
	22.00 - 22.50		99.771						65	46	19	MH	Elastic Silt		
	27.50 - 28.00		99.472						59	36	23	MH	Elastic Silt		
5	4.50 - 4.95		54.721									SM	Silty Sand		
	8.00 - 8.50		98.025						58	47	11	MH	Elastic Silt		
	12.50 - 13.00		98.433						52	30	22	MH	Elastic Silt	0.10	1.069
	18.50 - 19.00		97.894						47	30	17	CL	Lean Clay		
	26.50 - 27.00		99.818						67	48	19	MH	Elastic Silt		
6	3.00 - 3.45		20.075									SM	Silty Sand		
	6.00 - 6.45		2.40	0.7	0.4	0.23	3.0	0.9				SM	Poorly graded Sand		
	9.50 - 10.00		70.622						33	24	9	CH	Fat clay with Sand	0.16	1.248
	17.50 - 18.00		95.410						44	31	13	CL	Lean Clay		
	27.00 - 27.45		97.732						65	35	30	MH	Elastic Silt		

Notation

USCS= Unified Soil Classification System.

LL = Liquid Limit

PL = Plastic Limit

PI = Plasticity Index

* Cc = 0.009(LL-10) ---------- Terzaghi & Peck (1967)

** e_o = (Cc+0.156-0.00058wL)/0.411 ---------- Al-Khafaji and Andersland

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The grain size distribution curves of samples are provided in Appendix. Soil classification as per Unified Soil Classification System is provided in Table 2 above. Except in borehole 2, it is observed that the soil formation at the project area is mostly moist, grey silty fine sand at upper belt, under lain by Silt or elastic silt to the full depth of drilling. As per USCS Soil Classification System the soil below 3.5 meter to 12.0 meter the soil falls in SM, ML, SM. Soil below 10.5 meter is lean clay or silt falling in ML, MH group.

4.2.2 Strength Parameters

Direct Shear test was carried out on 9 undisturbed samples. The cohesion (c) and angle of internal friction (ϕ) of the soil below 6.5 meter to 33 meter from the existing ground level is found in the range of 6.0 to 25.0 kN/m^2 and 15.50° to 30.0° respectively. The tests results are provided in Table 3. Failure envelop plots of the tests are attached in Appendix C. Tests were performed on saturated sample under Consolidated Undrained (CUD) conditions.

Table 3: Shear strength parameters

BH# No.	Depth(m)	Type of sample	NMC %	γdry kN/m^3	γbulk kN/m^3	Sp.Gr.	Direct Shear		1-D Consolidation	
							C kN/m^2	ϕ °	Cc at 100kN/m^2	eo
1	6.50 - 7.00	UD-1	38.85	12.13	16.84		16.0	23.0		
	15.5- 16.00	UD-3	56.61	9.68	15.16		17.0	17.0		
	18.5- 19.00	UD-4	56.46	9.80	15.33	2.538	13.0	21.5	0.170	1.315
2	8.50 - 9.00	UD-1	34.92	12.76	17.22	2.668	9.0	28.0	0.180	0.918
3	24.5 - 25.0	UD-3	64.34	9.14	15.02	2.482	13.0	15.5	0.180	1.167
4	11.0 - 11.5	UD-1	39.76	11.93	16.67	2.560	11.0	20.5		
	27.5- 28.00	UD-3	67.75	8.75	14.68		6.0	20.0		
5	12.5 - 13.0	UD-2	54.49	10.15	15.68	2.511	11.0	20.0	0.100	1.069
6	9.50 - 10.0	UD-1	40.68	11.11	15.63	2.591	11.0	24.0	0.160	1.248

Note:
UD = Undisturbed sample
DS = Disturbed sample
NMC = Natural Moisture Content
γ_{dry} = Dry Density
Sp. Gr = Specific Gravity
Cc = Coefficient of Compression
eo = Initial void ratio.

Natural moisture content of the compressible soil varies from a minimum value of 34% to a maximum value of 68% with an average value of 52%. Bulk unit weight determination on

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selected samples of soil shows the values are in the range of 13.8kN/m^3 to17.2kN/m^3 with an average of about 15.5kN/m^3. The specific gravity of soil ranges from 2.482 to 2.668.

4.2.2.1 Allowable Bearing Capacity by SPT method

Since the foundation is proposed to be single or double basement, it should be taken to at 3.0 meter for single and 7.0 meter for double basement. Thus the foundations mostly rest on sand layer underlain by thick soft to stiff lean clay/silty soil. So the recommendation of semi empirical strain influence factor proposed by Schmertmann and Hartmann (1978) was used to find out the allowable bearing capacity (ABC) in granular material and consolidation settlement was assessed by using New Mart's chart to calculate safe bearing capacity within a settlement of 100mm for RAFT/MAT foundation of the size of 15m x 15m. The Schmertmann's expression for calculation is as follows:

$S_e = C1.C2\ \Delta q\ \Sigma_0^{z1}(I_z/E_s)\Delta_z$

Where

Se = net allowable settlement

C1 = a correction factor for the depth of foundation embedment

= 1-0.5 ($q/\Delta q$)

q = effective overburden pressure on foundation

C2 = a correction factor to account into creep in soil

= 1+0.2 log (time in year/0.1)

Δq = difference between stress at level of foundation and overburden pressure.

Δz = Thickness of soil layer

Es = Modulus of elasticity of sand

Iz = Strain influence at depth z

Approximate relationship between Cone penetration resistance (q_c) and SPT value $(N1)_{60}$ with Stress- Strain Modulus E_s (Bowles, 1982) are given below:

qc/N	Es (kN/m2)	Soil type
300-450	2 - 4qc	Fine to medium sand, slightly silty fine to medium sands

Taking an allowable settlement of Sandy soil and clayey/silty soil to be 125 mm in 5 years, the allowable pressure on foundation is calculated as shown in Sample Calculation.

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Also the method proposed by Meyerhof (1965), modified by Bowels (1977) was used to calculate the allowable bearing capacity of soil within a settlement of 25mm as proposed by the authors. The expression in this method is as follows

$q_{net(all)} = 11.98\ (N1)60\ ((3.28B+1)/3.28B)^2\ Fd.\ (Se/25)$

Where

$q_{net(all)}$ = net safe bearing capacity of soil within allowable settlement

Fd = depth factor = 1+0.33 (Df/B) ≤ 1.33

Se = Allowable settlement = 25mm

N = N-value over the depth of footing

B = Width of the foundation > 1.2 meter

Taking an allowable settlement of elastic silt or lean clay with or without sand and silty Sand to be 125mm as secondary settlement in 5 years, the allowable pressure on foundation is calculated as shown in appendix, Sample calculation.

4.2.2.2 Allowable Bearing Capacity by Laboratory Method

Shear parameters in plain strain measured in the laboratory by Direct shear test are used for calculations. The following modified equation for general shear failure as suggested by Brinch Hansen's Analysis (1961) is used for computation. A factor of safety of 3 is applied to calculate the safe bearing capacity (SBC) at this stage. If necessary, factor of safety could be lowered to 2.5 as suggested by National Building Code of India, 1983, Part II, Section 2. A sample calculation of safe bearing capacity of silty/clayey soil against general and local shear failure due to pressure from Mat foundation (15m x 15m) is presented in Appendix B. Calculation needs to be refined when more details about the type of foundation, loading intensity etc. are available.

$q_u = c.N_c.S_c.d_c.i_c + \sigma o.N_q.S_q.d_q.i_q R_{w1} + 0.5\ \gamma\ B.N\gamma.s\gamma.d\gamma.R_{w2}$

Where σo = overburden pressure at the foundation level

s = shape factor

d = depth factor

i = load inclination factor

Nc, Nq, Ng = bearing capacity factors proposed by Hansen

R_{w1}, R_{w2} = reduction factors for the water table

$SBC = q_u / 3$

4.2.3 Consolidation Parameters

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Consolidation parameters for clayey/silty soils are measured in laboratory by 1-D consolidation test. One dimensional consolidation settlement is found out by utilizing the calculated void ratios corresponding to any two successive incremental loads. The equation is:

$\rho_f = (e-e_o)/(1+e) \times H$ Where ρ_f = Settlement between initial and final loads

e_o = void ratio corresponding to the initial load

e = void ratio corresponding to the final load

H = thickness of the compressible clay layer

The settlement calculation was performed using the above formula for the clayey/silty soil, elastic silt or lean clay wherever present in the boreholes within the explored depth. The soil layer was divided into several bands as per the consolidation characteristics of the soil. Further, the soil band was subdivided into several layers of thickness of 50 cm to find out both immediate and elastic settlement of the soil under transmitted pressure from sandy band. For an incremental pressure of 17, 51 and 36kN/m^2 the band of clayey/silty soil under goes a settlement of 125mm for foundation at depths 3meter for tower 1, tower 2 and tower 3 respectively. The calculation is shown in Sample Calculation.

Calculated values of safe bearing capacity (SBC) by Schmertmann and Hartmann method for sandy soil, Meyerhoff and Bowels SPT(25mm) Method and Brinch Hansen method for c-ϕ soil are tabulated in Table 4.

Table 4: Allowable Bearing Capacity (ABC) by SPT and Shear failure methods

B H No.	Foundation Level	Mat Size L x B	Mat Foundation					
			General/Local Shear failure	SPT Value Method δ =25mm	1-D Consolidation Method, δ = 125mm			Min^m kN/m^2
					Incremental	Compensated	Total	
1 & 2	3.00	15.0 x 15.0	148	265	17.0	44.4	61	61
	5.00	15.0 x 15.0	203	84	17.0	74.0	91	84
	7.00	15.0 x 15.0	259	95	16.6	103.6	120	95
3 & 4	3.00	15.0 x 15.0	124	230	51.0	46.5	98	98
	5.00	15.0 x 15.0	175	223	46.0	62.0	108	108
	7.00	15.0 x 15.0	227	214	41.0	77.5	119	119
5 & 6	3.00	15.0 x 15.0	156	210	36.0	46.8	83	83
	5.00	15.0 x 15.0	218	344	33.5	78.0	112	112
	7.00	15.0 x 15.0	283	211	33.3	109.2	143	143

S B C = Safe Bearing Capacity

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The allowable bearing capacity is governed by settlement characteristic of soil demonstrated by SPT method or 1-D consolidation.
The soil was checked against general and local shear failure and it was found that the soil is safe against these failures.

5. Liquefaction

When a fine, or medium-fine, saturated, loose sand deposit is subjected to a sudden shock (generated by an earthquake) the mass will temporarily liquefy. This phenomenon is termed Liquefaction. When liquefaction takes place in a particular soil, part or whole of the bearing capacity of the soil disappears and the structure built on it tilts or even sinks.

The Environmental map of Kathmandu valley shows that the project area lies in a high liquefaction susceptible area.

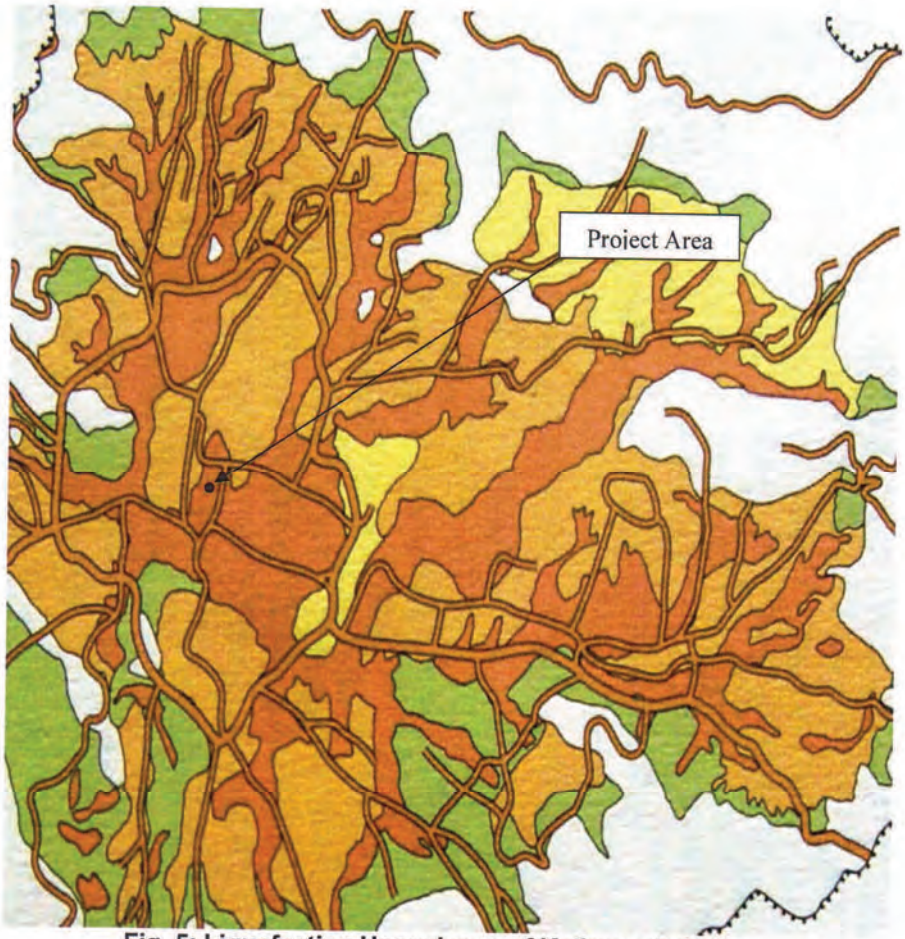

Fig. 5: Liquefaction Hazard map of Kathmandu Valley.

The past big earthquakes that in Niigata (1964), Mino-Owari (1891), Tonankai (1944), Fukui(1948), Jaltipan (1959), and Alaska (1964), have shown that saturated sandy soils in a loose to medium dense condition were liquefied during earthquakes varying in magnitude from 5.5 to 8.5 (Richter scale) and epicentral distance from several miles to hundred of miles.

From the case studies on soils of these areas, it has come to the knowledge that liquefaction potential characteristics of the soils are:

1. the soil contains less than 10 percent fines (silt and clay sizes)
2. D_{60} is between 0.2 mm and 1.0 mm
3. C_u (D_{60}/D_{10}) is between 2 and 5; and
4. the blow count per 30 cm standard penetration tests is less than 15.

Where:

D_{60} = 60 percent of the soil grains smaller than corresponding abscissa value in the grain size distribution curve;

D_{10} = 10 percent of the soil grains smaller than corresponding abscissa value in the grain size distribution curve;

Cu = Coefficient of uniformity = D_{60}/D_{10}

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Table 5: Characteristic Parameter for Liquefaction Assessment

BH #	Depth		% passing 0.075mm	D_{60} (mm)	Cu (D_{60}/D_{10})	Av (N1)60
1	3.5	4.0	34.262			14
	6.5	7.0	92.038			7
	10.5	11.0	64.300			18
	12.5	13.0	77.601			10
	15.5	16.0	98.416			8
	18.5	19.0	99.16			10
2	4.5	5.0	96.792			6
	8.5	9.0	92.020			7
	14.5	15.0	99.545			6
	22.0	22.5	99.802			9
	27.5	28.0	99.825			9
3	4.5	5.0	22.337			19
	7.5	8.0	35.433			7
	12.5	13.0	99.676			6
	17.0	17.5	95.962			6
	24.5	25.0	87.842			11
	29.5	30.0	99.100			11
4	6.0	6.5	39.143			17
	9.0	9.5	1.94	2.900	9.063	27
	11.0	11.5	90.352			7
	17.0	17.5	68.304			7
	22.0	22.5	99.771			8
	27.5	28.0	99.472			7
5	4.5	5.0	54.721			9
	8.0	8.5	98.025			8
	12.5	13.0	98.433			10
	18.5	19.0	97.894			8
	26.5	27.0	99.818			8
6	3.0	3.5	20.075			22
	6.0	6.5	2.40	0.700	3.043	40
	9.5	10.0	70.622			5
	17.5	18.0	95.410			6
	27.0	27.5	97.732			6

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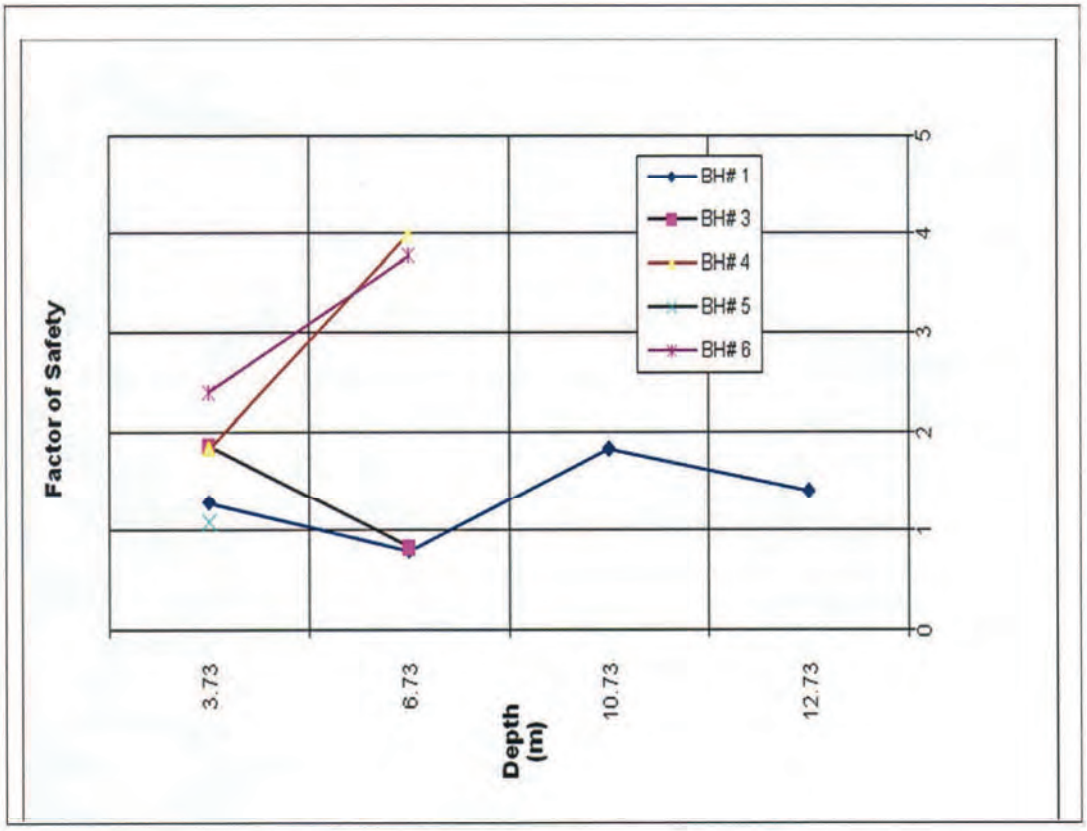

Fig. 6: Liquefaction potential at proposed site

The characteristics parameters for potential liquefaction of the soil derived from the laboratory test results are presented in Table 5. While comparing the prescribed soil properties with the liquefaction potential characteristic values for granular soil, shown above, the major soil properties indicate that liquefaction probable at certain area. A calculation of liquefaction potential of granular soil up to 12.0m by the method proposed by H.B. Seed and I.M. Idriss was carried out. From the calculation it was found that with a factor of safety of 1.0, liquefaction of soil is not probable in area of boreholes 2, 4, 5 and 6 whereas it is probable in borehole 1 and 3 locations up to about 8.0 meter both for a value of maximum ground acceleration of 0.08g. The soil below granular soil in every borehole is lean clay or elastic silt having fines more than 90%, there is no probability of liquefaction. The calculation is shown in Sample Calculation.

6. Modulus of Subgrade Reaction

The coefficient of subgrade modulus is defined as:

$$k = q/\Delta \text{ kN/m}^3$$

Where,

q = load per unit area

Δ = settlement due to unit pressure, q

The value of the coefficient of subgrade reaction is not a constant for a given soil, but rather depends on several factors, such as the length L, and the width B of the foundation and also the depth of embedment of the foundation. The detailed study by Terzaghi (1965) of the parameters affecting the coefficient of subgrade reaction indicated that the coefficient decreases with width of the foundation.

The appropriate method for calculating modulus of subgrade reaction is the plate load test which is carried out at site at the proposed foundation level. In absence of such test, it has to be correlated with other parameters and/or accept standard code provision.

Bowles has suggested an expression for approximate calculation of modulus of subgrade reaction of soil as:

$$ks = 40 \text{ (SF) } qa \text{ kN/m}^3$$

Where

qa = allowable bearing capacity of the soil,

SF = Factor of Safety = 3

According to the expression described above, the modulus of subgrade reactions for the soil worked out at a depth of 3.0meter are 7320, 11760, 9960kN/m^2/m respectively for tower 1, tower 2 and tower 3.

For the foundation in other depths, it is recommended to refer to Table 4.

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7. RESULTS AND DISCUSSION

The following result and discussions are derived from the geotechnical investigation works carried out within the proposed project site:

- From geo-technical point of view, the proposed building complex could be constructed with proper design. The recommend allowable bearing capacity of soils **for Raft or Mat foundation** at or near particular boreholes at a depth of 3.0meter, 5.0meter and 7.0meter is given below in the table:

B H No.	Foundation Level	Mat Size L x B	Recommended ABC
			kN/m^2
1 & 2	3.00	15.0 x 15.0	65
	5.00	15.0 x 15.0	85
	7.00	15.0 x 15.0	95
3 & 4	3.00	15.0 x 15.0	95
	5.00	15.0 x 15.0	105
	7.00	15.0 x 15.0	115
5 & 6	3.00	15.0 x 15.0	85
	5.00	15.0 x 15.0	110
	7.00	15.0 x 15.0	140

The value in between the depths can be interpolated.

The recommended allowable bearing capacity of soil is the sum of the incremental load within allowable settlement of foundation (125mm) and the pre-consolidation pressure due to removal of mass of excavated soil. It should be noted that shear failure criteria as well as settlement criteria both are responsible for the allowable bearing capacity of soil; smaller value calculated from different tests is considered to take care of the overall stability of the foundation.

- Because of presence of non-cohesive granular soil and probable rise in water table in summer, side fall (collapse) is probable. So, at the time of construction of foundation, it is strongly recommended to design the appropriate site protection measures based on the soil properties submitted in this report.

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- As described in the chapter SEISMICITY in this report, Nepal is very sensitive to experience very strong earthquake sooner or later. Therefore the Foundation design Engineer must pay due attention on seismic forces; it is recommended to follow the seismic design code NBC: 105-1994 for analysis and design of the building.

- As per the engineering and Environmental Map of Kathmandu valley, the project area lies in an area which is high hazardous from liquefaction potential point of view. Evaluation of the site utilizing N-Value method shows that part of the project sites for 3 towers is potential for liquefaction up to a depth of 8.0 mete for a value of 0.08g as the maximum ground acceleration at the surface. Below 12.0meter the soil is composed of fat clay, elastic silt or lean clay having fines more than 90%. So there is no probability of liquefaction.

  So, as engineering and Environmental Map of Kathmandu valley and soil investigation report, there is probability of liquefaction for maximum ground acceleration greater than 0.08g, it is recommended to take precautionary measures.

  Again, since damage in case of strong earthquake is possible, only steel or concrete construction with necessary protection is recommended.

- Allowable bearing capacity depends on many variables such as adopted allowable settlement, type of foundation, size and depth of foundation, importance of structure, cost of the project etc. Hence based on parameters obtained from this investigation provided in this report, calculations need to be refined during design phase.

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BORE HOLE LOG

PROJECT : Apartment Building Complex
LOCATION : Tudikhel,Kathmandu

BORE HOLE # : 1
DATE : 01/06/2010 - 03/06/2010

Depth (m)	Symbol	Description of Soil Strata	N-Value	Sample Depth (m)	Type of Sample	Water Table From Original Ground Surface
0.00 OGL						
0.20 – 2.00		Moist grey clayey sandy SILT with brick bats	11,15,6 / 21	1.50 - 1.95	SPT-1	
2.20 – 3.40		Moist grey silty SAND	9,4,4 / 8	3.00 - 3.45	SPT-2	
3.60 – 4.40		Moist grey sandy clayey SILT	1,1,2 / 3	4.50 - 4.95	SPT-3	4.0m
4.60 – 7.60		Moist grey SILT	1,2,2 / 4	6.00 - 6.45	SPT-4	
				6.50 - 7.00	UD-1	
7.60 – 12.00		Moist grey fine silty Sand	1,2,4 / 6	7.50 - 7.95	SPT-5	
			3,5,7 / 12	9.00 - 9.45	SPT-6	
			4,6,8 / 14	10.50 - 10.95	SPT-7	
12.00 – 15.00		Moist grey Lean Clay with Sand	3,4,6 / 10	12.00 - 12.45	SPT-8	
				12.50 - 13.00	UD-2	
			2,3,5 / 8	13.50 - 13.95	SPT-9	
			3,4,4 / 8	15.00 - 15.45	SPT-10	

Sampler (a) Thin Wall Tube of 85 mm Internal Dia.
(b) Split Spoon

Drilling Method : Percussion drilling method (Vertical)

SPT N-Value (In-situ)

UD Undisturbed soil sample for lab analysis

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BORE HOLE LOG

PROJECT : Apartment Building Complex
LOCATION : Tudikhel,Kathmandu

BORE HOLE # : 1 (Cont.)
DATE : 01/06/2010 - 03/06/2010

Depth (m)	Symbol	Description of Soil Strata	N-Value	Sample Depth (m)	Type of Sample	Water Table From Original Ground Surface
15.00						
15.20						
15.40						
15.60				15.50 - 16.00	UD-3	
15.80						
16.00						16.0
16.20						
16.40						
16.60			2,3,4 / 7	16.50 - 16.95	SPT-11	
16.80						
17.00						17.0
17.20						
17.40						
17.60						
17.80						
18.00						18.0
18.20			3,4,5 / 9	18.00 - 18.45	SPT-12	
18.40						
18.60				18.50 - 19.00	UD-4	
18.80						
19.00						19.0
19.20						
19.40						
19.60			3,5,6 / 11	19.50 - 19.95	SPT-13	
19.80						
20.00						20.0
20.20						
20.40						
20.60						
20.80						
21.00						21.0
21.20			4,4,5 / 9	21.00 - 21.45	SPT-14	
21.40						
21.60						
21.80						
22.00						22.0
22.20						
22.40		Moist grey Elastic SILT				
22.60			3,5,6 / 11	22.50 - 22.95	SPT-15	
22.80						
23.00						23.0
23.20						
23.40						
23.60						
23.80						
24.00						24.0
24.20			2,3,5 / 8	24.00 - 24.45	SPT-16	
24.40						
24.60						
24.80						
25.00						25.0
25.20						
25.40						
25.60						
25.80			4,6,5 / 11	25.50 - 25.95	SPT-17	
26.00						26.0
26.20						
26.40						
26.60						
26.80						
27.00						27.0
27.20			3,6,6 / 12	27.00 - 27.45	SPT-18	
27.40						
27.60						
27.80						
28.00						28.0
28.20						
28.40						
28.60						
28.80			4,5,7 / 12	28.50 - 28.95	SPT-19	
29.00						29.0
29.20						
29.40						
29.60						
29.80			5,6,6 / 12	30.00 - 30.45	SPT-20	
30.00		End of bore hole at 30.00 m depth				30.0

Sampler (a) Thin Wall Tube of 85 mm Internal Dia.
(b) Split Spoon

Drilling Method : Percussion drilling method (Vertical)

SPT N-Value (In-situ)

UD Undisturbed soil sample for lab analysi

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BORE HOLE LOG

PROJECT : Apartment Building Complex
LOCATION : Tudikhel, Kathmandu

BORE HOLE # 2
DATE : 05/06/2010 - 07/06/2010

Depth (m)	Symbol	Description of Soil Strata	N-Value	Sample Depth (m)	Type of Sample	Water Table From Original Ground Surface
0.00 OGL						
0.20 – 2.00		Moist grey silty fine SAND with brick bats	4,1,1 / 2	1.50 - 1.95	SPT-1	1.0
2.20 – 3.00		Moist grey clayey fine sandy SILT				2.0 – 3.0
3.20 – 8.60		Moist grey Silty clay	6,6,8 / 14	3.00 - 3.45	SPT-2	4.0
			1,2,2 / 4	4.50 - 4.95	SPT-3	5.0
			1,2,3 / 5	6.00 - 6.45	SPT-4	6.0
			1,2,3 / 5	7.50 - 7.95	SPT-5	7.0 – 8.0
8.60 – 12.00		Moist grey lean clay		8.50 - 9.00	UD-1	
			1,2,3 / 5	9.00 - 9.45	SPT-6	9.0 – 10.0
			4,5,7 / 12	10.50 - 10.95	SPT-7	10.50m, 11.0
12.20 – 15.00		Moist grey Elastic Silt	3,5,6 / 11	12.00 - 12.45	SPT-8	12.0 – 13.0
			3,2,3 / 5	13.50 - 13.95	SPT-9	14.0
				14.50 - 15.00	UD-2	
			3,3,4 / 7	15.00 - 15.45	SPT-10	15.0

Sampler (a) Thin Wall Tube of 85 mm Internal Dia.
(b) Split Spoon

Drilling Method Percussion drilling method (Vertical)

SPT N-Value (In-situ)

UD Undisturbed soil sample for lab analysis

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BORE HOLE LOG

PROJECT : Apartment Building Complex
LOCATION : Tudikhel,Kathmandu

BORE HOLE # 2 (Cont.)
DATE : 05/06/2010 - 07/06/2010

Depth (m)	Symbol	Description of Soil Strata	N-Value	Sample Depth (m)	Type of Sample	Water Table From Original Ground Surface
15.00						
15.20						
15.40						
15.60						
15.80						
16.00						16.0
16.20						
16.40						
16.60			2,2,3 / 5	16.50 - 16.95	SPT-11	
16.80						
17.00						17.0
17.20						
17.40						
17.60						
17.80						
18.00						18.0
18.20			2,4,5 / 9	18.00 - 18.45	SPT-12	
18.40						
18.60						
18.80						
19.00						19.0
19.20						
19.40						
19.60			4,5,5 / 10	19.50 - 19.95	SPT-13	
19.80						
20.00						20.0
20.20						
20.40						
20.60						
20.80						
21.00						21.0
21.20			5,5,6 / 11	21.00 - 21.45	SPT-14	
21.40						
21.60						
21.80						
22.00						22.0
22.20				22.00 - 22.50	UD-3	
22.40						
22.60		Moist grey Elastic Silt	4,5,6 / 11	22.50 - 22.95	SPT-15	
22.80						
23.00						23.0
23.20						
23.40						
23.60						
23.80						
24.00						24.0
24.20			4,6,5 / 11	24.00 - 24.45	SPT-16	
24.40						
24.60						
24.80						
25.00						25.0
25.20						
25.40						
25.60						
25.80			3,4,5 / 9	25.50 - 25.95	SPT-17	
26.00						26.0
26.20						
26.40						
26.60						
26.80						
27.00						27.0
27.20			3,5,6 / 11	27.00 - 27.45	SPT-18	
27.40						
27.60				17.50 - 28.00	UD-3	
27.80						
28.00						28.0
28.20						
28.40						
28.60						
28.80			4,6,7 / 13	28.50 - 28.95	SPT-19	
29.00						29.0
29.20						
29.40						
29.60						
29.80			3,4,6 / 10	30.00 - 30.45	SPT-20	
30.00		End of bore hole at 30.00 m depth)				30.0

Sampler (a) Thin Wall Tube of 85 mm Internal Dia
(b) Split Spoon

Drilling Method : Percussion drilling method (Vertical)

SPT N-Value (In-situ)

UD Undisturbed soil sample for lab analy

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BORE HOLE LOG

PROJECT : Apartment Building Complex
LOCATION : Tudikhel,Kathmandu

BORE HOLE # : 3
DATE : 08/06/2010 - 11/06/2010

Depth (m)	Symbol	Description of Soil Strata	N-Value	Sample Depth (m)	Type of Sample	Water Table From Original Ground Surface
0.00 OGL						
0.20 – 0.40 – 0.60		Moist grey gravelly SAND				
0.80 – 1.00 – 1.20 – 1.40		Moist grey gravelly clayey SILT				1.0
1.60 – 1.80 – 2.00		Moist grey clayey silty SAND	1,2,3 / 5	1.50 - 1.95	SPT-1	2.0
2.20 – 2.40 – 2.60 – 2.80 – 3.00		Moist grey silty SAND				3.0
3.20 – 3.40 – 3.60		Moist grey clayey SILT	2,3,2 / 5	3.00 - 3.45	SPT-2	
3.80 – 4.00 – 4.20 – 4.40 – 4.60 – 4.80 – 5.00 – 5.20 – 5.40 – 5.60 – 5.80 – 6.00		Moist grey silty fine SAND	3,5,7 / 12	4.50 - 4.95	SPT-3	4.0
6.20 – 6.40 – 6.60		Moist grey silty fine to coarse SAND	3,6,7 / 13	6.00 - 6.45	SPT-4	5.0
6.80 – 7.00 – 7.20 – 7.40 – 7.60 – 7.80 – 8.00 – 8.20 – 8.40 – 8.60 – 8.80 – 9.00 – 9.20 – 9.40 – 9.60 – 9.80 – 10.00		Moist grey clayey silty fine SAND	2,3,2 / 5	7.50 - 7.95	SPT-5	6.0 – 7.0 – 7.50m – 8.0
			4,4,6 / 10	9.00 - 9.45	SPT-6	9.0
10.20 – 10.40 – 10.60 – 10.80 – 11.00 – 11.20 – 11.40 – 11.60 – 11.80 – 12.00 – 12.20 – 12.40 – 12.60 – 12.80 – 13.00 – 13.20 – 13.40 – 13.60 – 13.80 – 14.00 – 14.20 – 14.40 – 14.60 – 14.80 – 15.00		Moist grey Elastic Silt	4,5,7 / 12	10.50 - 10.95	SPT-7	10.0 – 11.0
			2,2,2 / 4	12.00 - 12.45	SPT-8	12.0
				12.50 - 13.00	UD-1	
			2,3,3 / 6	13.50 - 13.95	SPT-9	13.0 – 14.0
			2,3,4 / 7	15.00 - 15.45	SPT-10	15.0

Sampler (a) Thin Wall Tube of 85 mm Internal Dia.
(b) Split Spoon

SPT N-Value (In-situ)

Drilling Method : Percussion drilling method (Vertical)

UD Undisturbed soil sample for lab anal

BORE HOLE LOG

PROJECT : Apartment Building Complex
LOCATION : Tudikhel,Kathmandu

BORE HOLE # 3 (Cont.)
DATE 08/06/2010 - 11/06/2010

Depth (m)	Symbol	Description of Soil Strata	N-Value	Sample Depth (m)	Type of Sample	Water Table From Original Ground Surface
15.00						
15.20						
15.40						
15.60						
15.80						
16.00						16.0
16.20						
16.40						
16.60			2,2,3	16.50 - 16.95	SPT-11	
16.80			5			
17.00						17.0
17.20				17.00 - 17.50	UD-2	
17.40						
17.60						
17.80						
18.00						18.0
18.20			2,3,3	18.00 - 18.45	SPT-12	
18.40			6			
18.60						
18.80						
19.00						19.0
19.20						
19.40						
19.60			2,3,2	19.50 - 19.95	SPT-13	
19.80			5			
20.00						20.0
20.20		Moist grey Elastic SILT				
20.40						
20.60						
20.80						
21.00						21.0
21.20			2,2,3	21.00 - 21.45	SPT-14	
21.40			5			
21.60						
21.80						
22.00						22.0
22.20						
22.40						
22.60			2,5,5	22.50 - 22.95	SPT-15	
22.80			10			
23.00						23.0
23.20						
23.40						
23.60						
23.80						
24.00						24.0
24.20			7,7,6	24.00 - 24.45	SPT-16	
24.40			13			
24.60				24.50 - 25.00	UD-3	
24.80						
25.00						25.0
25.20						
25.40						
25.60						
25.80			10,7,7	25.50 - 25.95	SPT-17	
26.00			14			26.0
26.20						
26.40						
26.60						
26.80						
27.00						27.0
27.20			7,6,7	27.00 - 27.45	SPT-18	
27.40		Moist grey Elastic Silt	13			
27.60						
27.80						
28.00						28.0
28.20						
28.40						
28.60						
28.80			6,7,8	28.50 - 28.95	SPT-19	
29.00			15			29.0
29.20						
29.40						
29.60				29.50 - 30.00	UD-4	
29.80			5,7,6	30.00 - 30.45	SPT-20	
30.00		End of bore hole at 30.00 m depth	13			30.0

Sampler (a) Thin Wall Tube of 85 mm Internal Dia.
(b) Split Spoon

Drilling Method : Percussion drilling method (Vertical)

SPT N-Value (In-situ)

UD Undisturbed soil sample for lab analy

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BORE HOLE LOG

PROJECT : Apartment Building Complex
LOCATION : Tudikhel,Kathmandu

BORE HOLE # : 4
DATE : 12/06/2010 - 15/06/2010

Depth (m)	Symbol	Description of Soil Strata	N-Value	Sample Depth (m)	Type of Sample	Water Table From Original Ground Surface
0.00 OGL						
0.20 – 0.60		Moist grey clayey fine sandy SILT with brick bats				
0.80 – 2.00		Moist grey clayey silty SAND	1,2,4 / 6	1.50 - 1.95	SPT-1	1.0
2.20 – 3.20		Moist grey silty SAND	10,6,2 / 8	3.00 - 3.45	SPT-2	2.0 – 3.0
3.40 – 4.60		Moist grey silty SAND	2,5,3 / 8	4.50 - 4.95	SPT-3	4.0
4.80 – 6.20		Moist grey silty SAND	4,5,6 / 11	6.00 - 6.45	SPT-4	5.0 – 6.0
6.40 – 7.60		Moist grey silty SAND	3,5,6 / 11	7.50 - 7.95	SPT-5	7.0
7.80 – 9.20		Moist grey silty coarse SAND	7,9,12 / 21	9.00 - 9.45	SPT-6	8.0 – 9.0
9.40 – 10.60		Moist gray Lean Clay	3,3,4 / 7	10.50 - 10.95	SPT-7	10.0
10.80 – 11.20		Moist gray Lean Clay		11.50 - 11.50	UD-1	11.0
11.40 – 12.20		Moist grey Elastic Silt	2,2,3 / 5	12.00 - 12.45	SPT-8	12.0
12.40 – 13.60		Moist grey Elastic Silt	2,3,4 / 7	13.50 - 13.95	SPT-9	13.0 – 14.0
13.80 – 14.80		Moist grey Elastic Silt	3,5,6 / 11	15.00 - 15.45	SPT-10	15.0
15.00						

Sampler (a) Thin Wall Tube of 85 mm Internal Dia.
(b) Split Spoon

Drilling Method : Percussion drilling method (Vertical)

SPT N-Value (In-situ)

UD Undisturbed soil sample for lab analys

BORE HOLE LOG

PROJECT : Apartment Building Complex
LOCATION : Tudikhel,Kathmandu

BORE HOLE # : 4 (Cont.)
DATE : 12/06/2010 - 15/06/2010

Depth (m)	Symbol	Description of Soil Strata	N-Value	Sample Depth (m)	Type of Sample	Water Table From Original Ground Surface
15.00						
15.20 – 16.60		Moist grey Elastic Silt with Sand	2,3,4 / 7	16.50 - 16.95	SPT-11	16.0
16.80 – 17.20				17.00 - 17.50	UD-2	17.0
17.40 – 18.20			3,3,4 / 7	18.00 - 18.45	SPT-12	18.0
18.40 – 19.40						19.0 / 19.0m
19.60			3,4,5 / 9	19.50 - 19.95	SPT-13	
19.80 – 21.20						20.0 / 21.0
21.20			5,4,5 / 9	21.00 - 21.45	SPT-14	
21.40 – 22.20				22.00 - 22.50	UD-3	22.0
22.60			4,5,5 / 10	22.50 - 22.95	SPT-15	
22.80 – 24.20		Moist grey Elastic Silt				23.0 / 24.0
24.20			3,4,4 / 8	24.00 - 24.45	SPT-16	
24.40 – 25.80						25.0
25.80			3,4,3 / 7	25.50 - 25.95	SPT-17	
26.00 – 27.20						26.0 / 27.0
27.20			4,5,5 / 10	27.00 - 27.45	SPT-18	
27.40 – 27.60				27.50 - 28.00	UD-4	
27.80 – 28.80						28.0
28.80			3,4,5 / 9	28.50 - 28.95	SPT-19	
29.00 – 29.80						29.0
29.80			3,4,4 / 8	30.00 - 30.45	SPT-20	
30.00		End of bore hole at 30.00 m depth				30.0

Sampler : (a) Thin Wall Tube of 85 mm Internal Dia
(b) Split Spoon

Drilling Method : Percussion drilling method (Vertical)

SPT : N-Value (In-situ)

UD : Undisturbed soil sample for lab analy

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BORE HOLE LOG

PROJECT : Apartment Building Complex
LOCATION : Tudikhel,Kathmandu

BORE HOLE # 5
DATE 17/06/2010 - 20/06/2010

Depth (m)	Symbol	Description of Soil Strata	N-Value	Sample Depth (m)	Type of Sample	Water Table From Original Ground Surface
0.00 OGL						
0.20 – 1.60		Moist grey sandy SILT with brick bats	1,1,1 / 2	1.50 - 1.95	SPT-1	1.0
1.80 – 3.00		Moist grey silty medium SAND				2.0 – 3.0
3.20		Moist grey silty fine SAND	1,2,4 / 6	3.00 - 3.45	SPT-2	
3.40 – 4.60						4.0
4.60			1,3,3 / 6	4.50 - 4.95	SPT-3	
4.80 – 5.00						5.0
5.20 – 6.00		Moist grey clayey fine sandy SILT				6.0
6.20		Moist grey Elastic Silt	2,2,3 / 5	6.00 - 6.45	SPT-4	
6.40 – 7.00						7.0
7.20 – 7.60			1,2,3 / 5	7.50 - 7.95	SPT-5	
7.80 – 8.20				8.00 - 8.50	UD-1	8.0
8.40 – 9.00						9.0
9.20		Moist grey Elastic Silt	3,3,4 / 7	9.00 - 9.45	SPT-6	
9.40 – 10.00						10.0
10.20						10.00m
10.40 – 10.60			2,2,3 / 5	10.50 - 10.95	SPT-7	
10.80 – 11.00						11.0
11.20 – 11.40						
11.60 – 11.80						
12.00						12.0
12.20			2,3,4 / 7	12.00 - 12.45	SPT-8	
12.40						
12.60				12.50 - 13.00	UD-2	
12.80 – 13.00						13.0
13.20 – 13.40						
13.60			4,5,6 / 11	13.50 - 13.95	SPT-9	
13.80 – 14.00						14.0
14.20 – 14.40						
14.60						
14.80			3,3,3 / 6	15.00 - 15.45	SPT-10	
15.00						15.0

Sampler (a) Thin Wall Tube of 85 mm Internal Dia.
(b) Split Spoon

Drilling Method : Percussion drilling method (Vertical)

SPT N-Value (In-situ)

UD Undisturbed soil sample for lab analys

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BORE HOLE LOG

PROJECT : Apartment Building Complex
LOCATION : Tudikhel,Kathmandu

BORE HOLE # : 5 (Cont.)
DATE : 17/06/2010 - 20/06/2010

Depth (m)	Symbol	Description of Soil Strata	N-Value	Sample Depth (m)	Type of Sample	Water Table From Original Ground Surface
15.00						
15.20 – 16.40		Moist grey Elastic Silt				16.0
16.60 – 18.40		Moist grey Lean Clay	4,3,4 / 7	16.50 - 16.95	SPT-11	17.0
			4,4,4 / 8	18.00 - 18.45	SPT-12	18.0
18.60 – 30.00		Moist grey Elastic Silt		18.50 - 19.00	UD-3	19.0
			3,4,5 / 9	19.50 - 19.95	SPT-13	20.0
			3,3,4 / 7	21.0 - 21.45	SPT-14	21.0
			3,3,3 / 6	22.50 - 22.95	SPT-15	22.0
			4,5,5 / 10	24.0 - 24.45	SPT-16	23.0
			4,5,4 / 9	25.50 - 25.95	SPT-17	24.0
				26.50 - 27.00	UD-4	25.0
			5,6,7 / 13	27.00 - 27.45	SPT-18	26.0
			3,4,4 / 8	28.50 - 28.95	SPT-19	27.0
			7,9,9 / 18	30.00 - 30.45	SPT-20	28.0
						29.0
						30.0

Sampler : (a) Thin Wall Tube of 85 mm Internal Dia.
(b) Split Spoon

SPT : N-Value (In-situ)

Drilling Method : Percussion drilling method (Vertical)

UD : Undisturbed soil sample for lab analy

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BORE HOLE LOG

PROJECT : Apartment Building Complex
LOCATION : Tudikhel,Kathmandu

BORE HOLE # : 5 (Cont.)
DATE : 17/06/2010 - 20/06/2010

Depth (m)	Symbol	Description of Soil Strata	N-Value	Sample Depth (m)	Type of Sample	Water Table From Original Ground Surface
30.00						
30.20 – 33.00		Moist grey Elastic Silt	10,11,11 / 22	31.50 - 31.95	SPT-21	31.0, 32.0, 33.0
33.20 – 33.40		End of bore hole at 33.45 m depth	11,12,11 / 23	33.00 - 33.45	SPT-22	34.0, 35.0, 36.0, 37.0, 38.0, 39.0, 40.0, 41.0, 42.0, 43.0, 44.0, 45.0

Sampler (a) Thin Wall Tube of 85 mm Internal Dia
(b) Split Spoon

Drilling Method : Percussion drilling method (Vertical)

SPT N-Value (In-situ)

UD Undisturbed soil sample for lab anal

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BORE HOLE LOG

PROJECT : Apartment Building Complex
LOCATION : Tudikhel,Kathmandu

BORE HOLE # : 6
DATE : 21/06/2010 - 23/06/2010

Depth (m)	Symbol	Description of Soil Strata	N-Value	Sample Depth (m)	Type of Sample	Water Table From Original Ground Surface
0.00 OGL						
0.20 – 0.60		Moist grey silty SAND with gravel and brick bats				
0.80 – 2.00		Moist grey silty fine to medium SAND	5,5,7 / 12	1.50 - 1.95	SPT-1	1.0
2.20 – 4.40		Moist grey silty fine SAND	5,6,7 / 13	3.00 - 3.45	SPT-2	3.0
						4.0
4.60 – 7.40		Moist grey silty fine to medium SAND	10,12,14 / 26	4.50 - 4.95	SPT-3	4.50m
						5.0
			12,12,14 / 26	6.00 - 6.45	SPT-4	6.0
						7.0
7.60 – 9.40		Moist grey find sandy SILT	3,4,5 / 9	7.50 - 7.95	SPT-5	8.0
			2,2,2 / 4	9.00 - 9.45	SPT-6	9.0
9.60 – 11.00		Moist grey Fat Clay		9.50 - 10.00	UD-1	10.0
			2,2,3 / 5	10.50 - 10.95	SPT-7	11.0
11.20 – 15.00		Moist grey Lean Clay	2,3,2 / 5	12.00 - 12.45	SPT-8	12.0
			2,3,4 / 7	13.50 - 13.95	SPT-9	13.0
			3,5,6 / 11	15.00 - 15.45	SPT-10	14.0
						15.0

Sampler (a) Thin Wall Tube of 85 mm Internal Dia.
(b) Split Spoon

Drilling Method : Percussion drilling method (Vertical)

SPT N-Value (In-situ)

UD Undisturbed soil sample for lab analy

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BORE HOLE LOG

PROJECT : Apartment Building Complex
LOCATION : Tudikhel,Kathmandu

BORE HOLE # : 6 (Cont)
DATE : 21/06/2010 - 23/06/2010

Depth (m)	Symbol	Description of Soil Strata	N-Value	Sample Depth (m)	Type of Sample	Water Table From Original Ground Surface
15.00						
15.20 – 16.60		Lean Clay	2,3,4 / 7	16.50 - 16.95	SPT-11	16.0
16.80 – 17.60				17.50 - 18.00	UD-2	17.0
17.80 – 18.20			2,2,2 / 4	18.00 - 18.45	SPT-12	18.0
18.40 – 18.60						
18.80 – 19.60		Moist grey Elastic Silt	3,4,3 / 7	19.50 - 19.95	SPT-13	19.0
19.80 – 21.20			3,3,4 / 7	21.0 - 21.45	SPT-14	20.0
21.40 – 22.60			2,2,3 / 5	22.50 - 22.95	SPT-15	21.0
22.80 – 24.20			5,5,6 / 11	24.0 - 24.45	SPT-16	22.0
24.40 – 25.80			4,5,6 / 11	25.50 - 25.95	SPT-17	23.0
26.00 – 27.20			5,4,4 / 8	27.00 - 27.45	SPT-18	24.0
27.40 – 28.80			3,4,5 / 9	28.50 - 28.95	SPT-19	25.0
29.00 – 29.80			5,6,5 / 11	30.00 - 30.45	SPT-20	26.0
30.00						27.0
						28.0
						29.0
						30.0

Sampler (a) Thin Wall Tube of 85 mm Internal Dia.
(b) Split Spoon

SPT N-Value (In-situ)

Drilling Method : Percussion drilling method (Vertical)

UD Undisturbed soil sample for lab analy

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BORE HOLE LOG

PROJECT : Apartment Building Complex
LOCATION : Tudikhel,Kathmandu

BORE HOLE # : 6 (Cont.)
DATE 21/06/2010 - 23/06/2010

Depth (m)	Symbol	Description of Soil Strata	N-Value	Sample Depth (m)	Type of Sample	Water Table From Original Ground Surface
30.00						
30.20		Moist grey Elastic Silt	6,6,7 / 13	31.50 - 31.95	SPT-21	
30.40						
30.60						
30.80						
31.00						31.0
31.20						
31.40						
31.60						
31.80						
32.00						32.0
32.20						
32.40						
32.60						
32.80						
33.00						33.0
33.20		End of bore hole at 33.45 m depth	6,7,8 / 15	33.00 - 33.45	SPT-22	
33.40						
33.60						
33.80						
34.00						34.0
34.20						
34.40						
34.60						
34.80						
35.00						35.0
35.20						
35.40						
35.60						
35.80						
36.00						36.0
36.20						
36.40						
36.60						
36.80						
37.00						37.0
37.20						
37.40						
37.60						
37.80						
38.00						38.0
38.20						
38.40						
38.60						
38.80						
39.00						39.0
39.20						
39.40						
39.60						
39.80						
40.00						40.0
40.20						
40.40						
40.60						
40.80						
41.00						41.0
41.20						
41.40						
41.60						
41.80						
42.00						42.0
42.20						
42.40						
42.60						
42.80						
43.00						43.0
43.20						
43.40						
43.60						
43.80						
44.00						44.0
44.20						
44.40						
44.60						
44.80						
45.00						45.0

Sampler (a) Thin Wall Tube of 85 mm Internal Dia
(b) Split Spoon

SPT N-Value (In-situ)

Drilling Method : Percussion drilling method (Vertical)

UD Undisturbed soil sample for lab anal

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