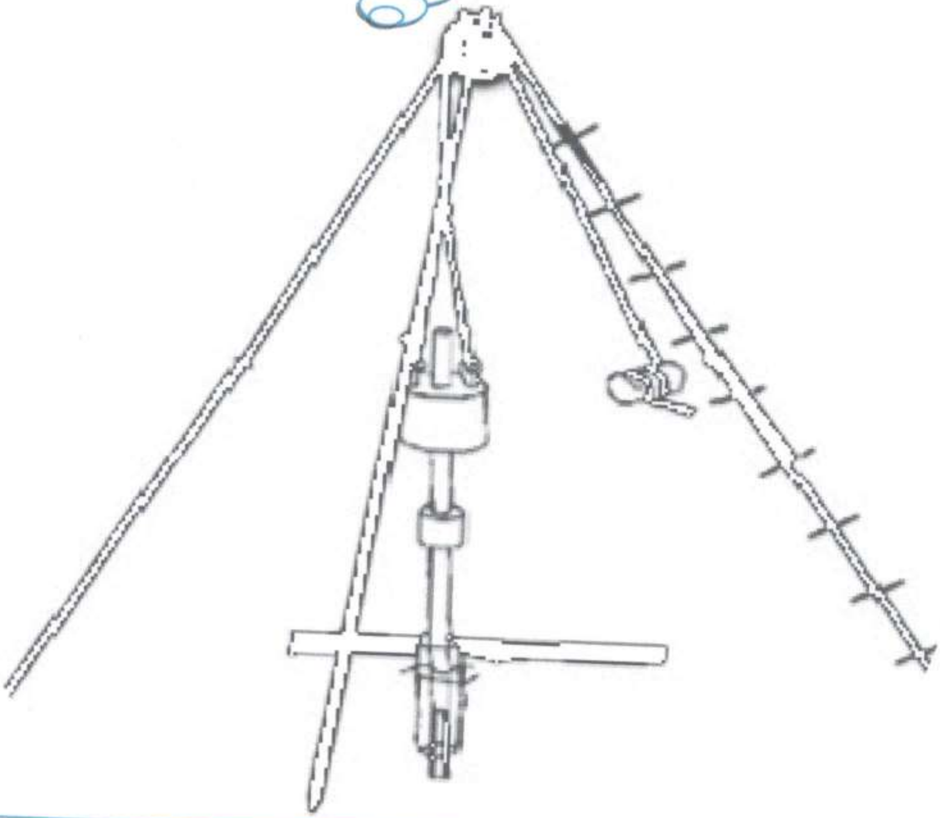
# REPORT ON



# AMLEKHGUNJ SUBSTATION CONSTRUCTION PROJECT, BARA

## SUBMITTED TO:

***CLIENT:***
***NEPAL ELECTRICITY AUTHORITY (NEA)***

## SUBMITTED BY:

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# SOIL INVESTIGATION REPORT

## OF

## Amlekhgunj Substation

## AT

## Amlekhgunj,
## Bara District
## Madhesh Province
## NEPAL

**Client: Amlekgunj Substation Construction Project; Project Management Directorate Nepal Electricity Authority**

**Prepared By: Expert Testing Laboratory Pvt. Ltd.**

**Date: 2022-06-07**

# ACKNOWLEDGEMENT

We would like to express our deepest gratitude towards**Nepal Electricity Authority (NEA)** for entrusting and providing us with the opportunity for detailed soil investigation of the **Amlekhgunj Substation Construction Project, Bara.**

Finally, we are thankful towards all the individuals involved directly and indirectly towards all the test performed, preparation of the reports and have been helpful throughout the journey of this soil test.

Expert Testing Laboratory Pvt. Ltd.

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## 1. GENERAL INTRODUCTION

This geotechnical investigation report is prepared based on the site exploration and laboratory test results carried out by Expert Testing PVT. LTD, Bafal lalitpur for proposed substation construction project in Amlekhgunj, Bara Nepal. The investigation characterizes the subsurface conditions and develops the necessary requirement for the proposed safe bearing capacity of the foundation, characteristics of soil and identification soil type from field and laboratory experiments. Total number of four bore holes are drilled using rotatory drilling, locations of bore holes are decided through discussion with Expert Testing PVT. LTD. representative and representatives of client and contractor. Bore hole 1 (BH-01) is located 415 meters N-NE of Nepal Oil Cooperation oil depo, 190 meters East of East-West Highway and 320m West from the bank of Duhaura Khola. Locations of bore holes are shown in figure 1.1, 1.2 and 1.3.

The investigation characterizes the subsurface conditions and develops the necessary requirement for the proposed safe bearing capacity of the foundation and other properties of soil. The field soil investigation work was carried out from June 24th to June 28th and laboratory investigations were carried from June 29th to July 1st of 2022. The total quantity of soil investigation included one borehole of 20m depth as per agreement. Standard Penetration Tests (SPT) or Dynamic Cone Penetration Test (DCPT) was conducted at 1.5m depth interval starting from 1.5m to furnish the compactness of the soil strata at field. Disturbed and undisturbed samples were collected for further laboratory investigations. Field observation and classification of soil sample were done and ground water table (GWT) was measured for each bore hole inserting measuring string in each bore hole after letting the GWT stabilize for some hours after drilling.

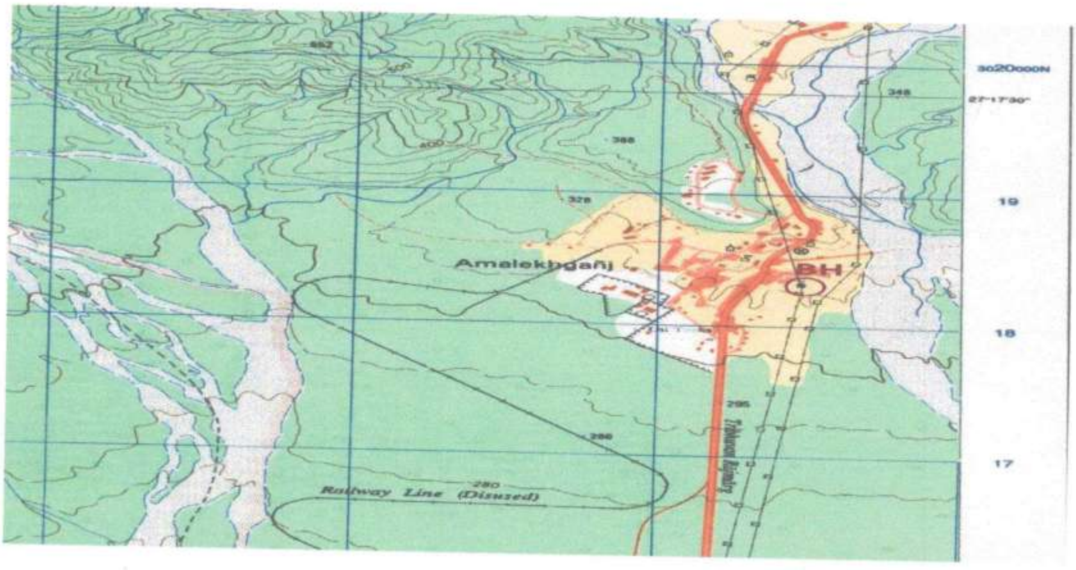


*Figure 1-1 Map of Investigation area*

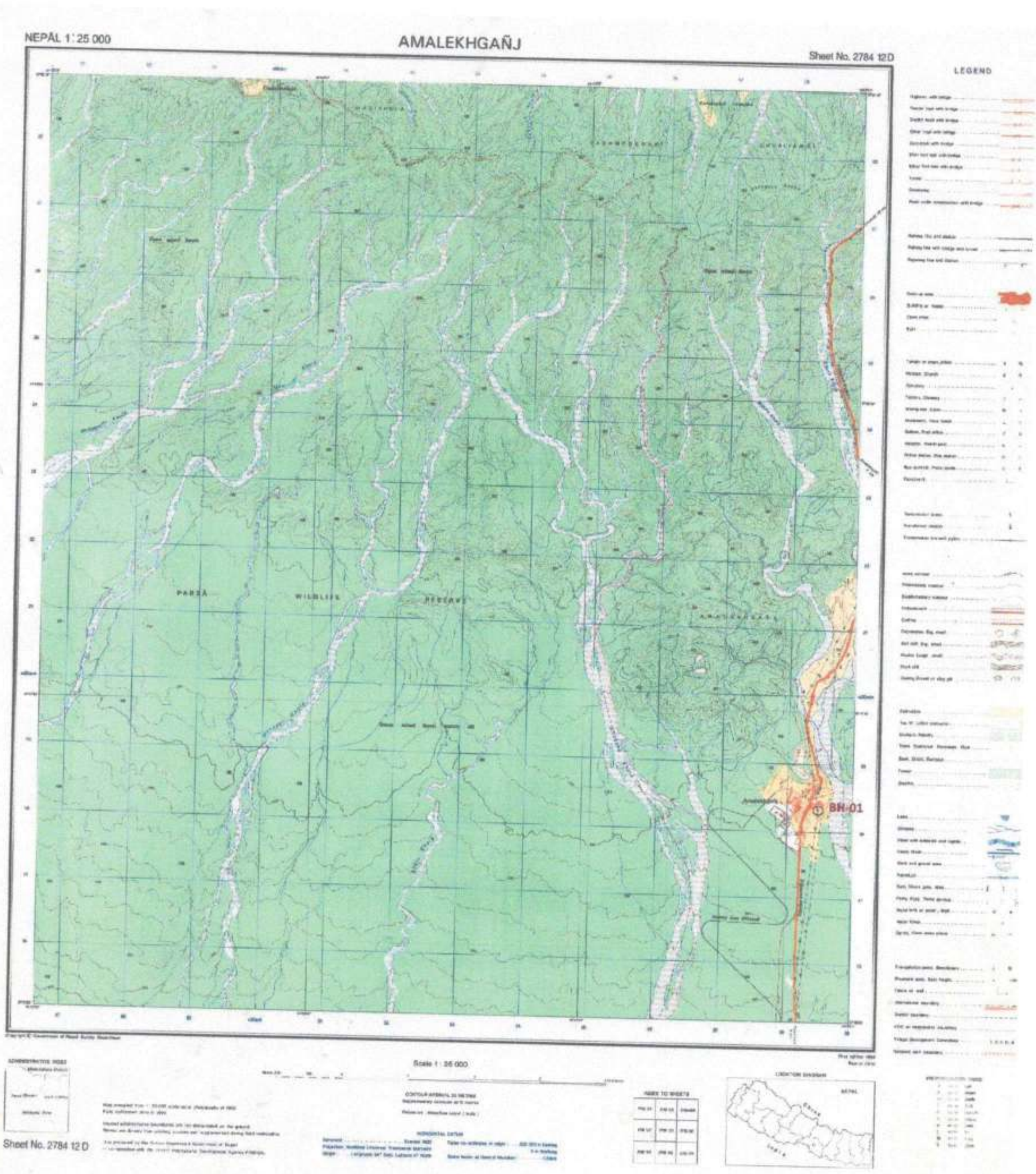


*Figure 1-2 Topographic map of the of the project area*

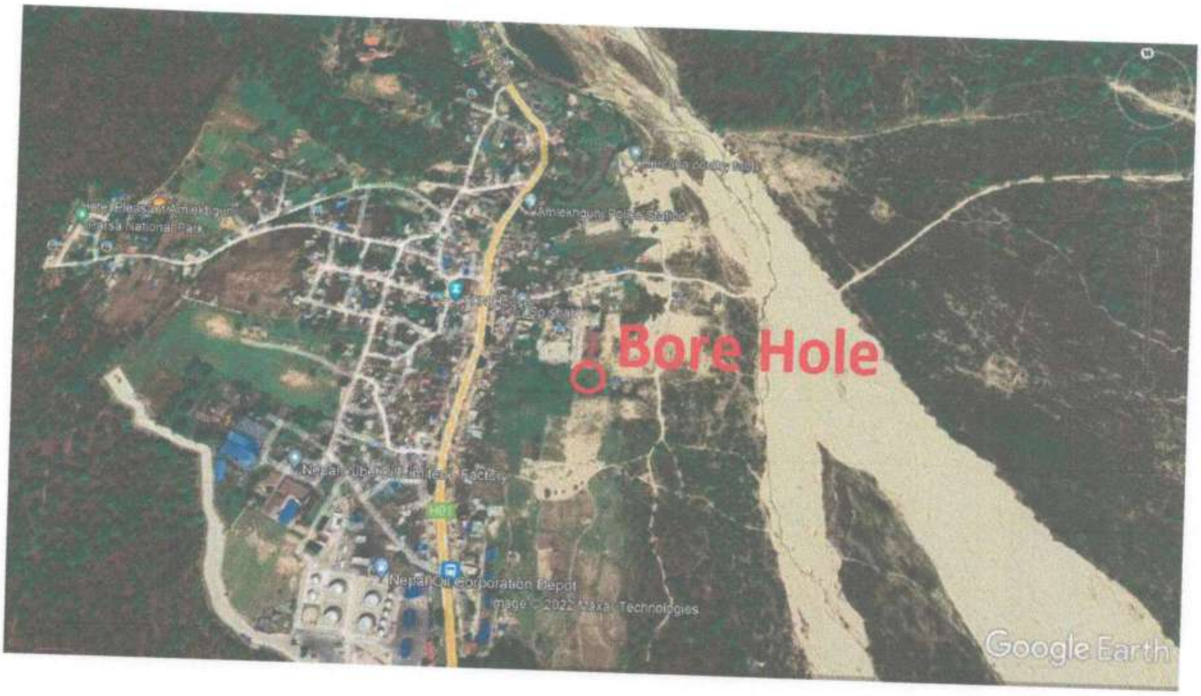


*Figure 1-3 Satellite image map of project area*

## 2. SCOPE OF INVESTIGATION

The scope of work includes the following:

- Making 75 mm nominal diameter bore holes each of 20.0 m depth at one specified locations using suitable approved method of boring.
- Conducting standard penetration tests in the bore holes at 1.50 m interval in depth & at everychange of strata, whichever is earlier.
- Collecting undisturbed soil samples from bore holes at 3.00 m interval in depth (if possible forUndisturbed sampling) or at every change of strata, whichever is earlier.
- Collecting disturbed soil samples from bore holes at regular interval and at every identifiablechange of strata to supplement the boring records.
- Recording the depth of ground water table in all the bore holes if observed up to the depth ofexploration during boring work as per specifications.
- Conducting the laboratory tests on selected disturbed / undisturbed soil samples collected fromvarious bore holes.
- Preparation and submission of reports which includes Drill logs, Results of in situ and laboratory test, Assessment of liquefaction Susceptibility, Assessment of bearing capacity, Analysis of ground improvement techniques and Recommendations of foundation type and depth.



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# 3. METHODOLOGY

## 3.1 Desk Study

Site conditions, topographical and geological characteristic of the project area were collected from previous geotechnical investigation conducted nearby this project, topographical map, and geological map. However, very limited information is available for desk study as no geotechnical investigations nearby area are found and comprehensive soil information system has not been established yet. The geology of the proposed site is comprised of different formations as shown in Figure 4.1 project site is located near boundary of Siwalik range Himalayan geology and Indo-gangetic deposits. Major geological features near site is Main Frontal Thrust. As project site is located at 320m from bank of non-perineal river having history of flash flooding, from past satellite images high flood has not reached near project site but special attention should be given to the impact of flooding on project.

A seismic hazard map of Nepal at 10% probability of exceedance in 50 years was used for seismic analysis of soil (Nepal National Building Code: 105:2020 (NBC-105 2020). A peak ground acceleration of 0.38 g is recommended for this site (Figure4.5). On the basis of these past data's, a general criterion was developed for rating the soil condition along proposed building area. However, those studies did not focus on the site-specific design of foundation considering major geotechnical parameters like liquefaction possibility, earthquake magnitude, ground amplification, and peak ground acceleration, which are very important aspect for foundation analysis. In general, as per previous nearby areas experiences, the proposed structure seems to lie on non-liquefiable zone followed by medium stiff silty layer.

## 3.2 Field investigation

The proposed geo-technical investigation was performed to characterize the subsurface conditions at the site, to evaluate the bearing capacity of foundation soil and to recommend safe bearing capacity for different type of foundation including the settlement analysis and the potential of liquefaction.

Field investigation work was carried out in June 24-29, 2022. Drilling works were carried out using one set of percussion and rotatory drilling machine. The sides of the boreholes were lined with 100mm casing pipes.

### 3.2.1 Standard Penetration Test (SPT)

It consists of driving a Split Spoon sampler with an outside dia. of 50 mm into the soil at the base of borehole. Driving is accomplished by a drop of hammer weighing 63.5 kg falling freely through a height of 750 mm onto the drive head. First of all the spoon is driven 150 mm into the soil at the bottom of the borehole. It is then driven further 300 mm and the number of blows (N values) required to drive this distance recorded Standard Penetration Tests (SPT) were conducted in the boreholes at 1.5 m intervals. The tests were conducted in accordance with IS: 2131-1981.

Summary of SPT test is given in Annex 1 of this report. Photo graph of SPT test is shown in figure 3.1.

*Figure 3-1 SPT test arrangement and rotatory bore hole drilling arrangement at BH-01*

From BH-01 samples from 1.0m to 20.0m were boulders/gravels mixed with gray sands as shown in figure 3.2 to 3.8, gravel and boulders were most of rock Sand stone to Feldspar having high hardness 5-7 in Mohs hardness scale. Size of gravels and boulders obtained were from 17mm to 34mm. Samples consisting boulder or gravel with very significant amount of fine, laboratory test for these samples were conducted mainly for infilling sand but bearing capacity is determine using IS 10042-1981, bearing capacity is also determined based on properties of infilling sand and SPT/DCPT values. Strength of rock forming boulder or gravel could have been obtained from unconfined compressive test but as sample obtained were of not sufficient size so this test was not possible. Core recovery was also very less along with small size of samples obtained laving mainly length less than 10cm which signifies the absence of large sized boulders or bed rock.


*Figure 3-2 Sample of BH-01 Depth 3m*

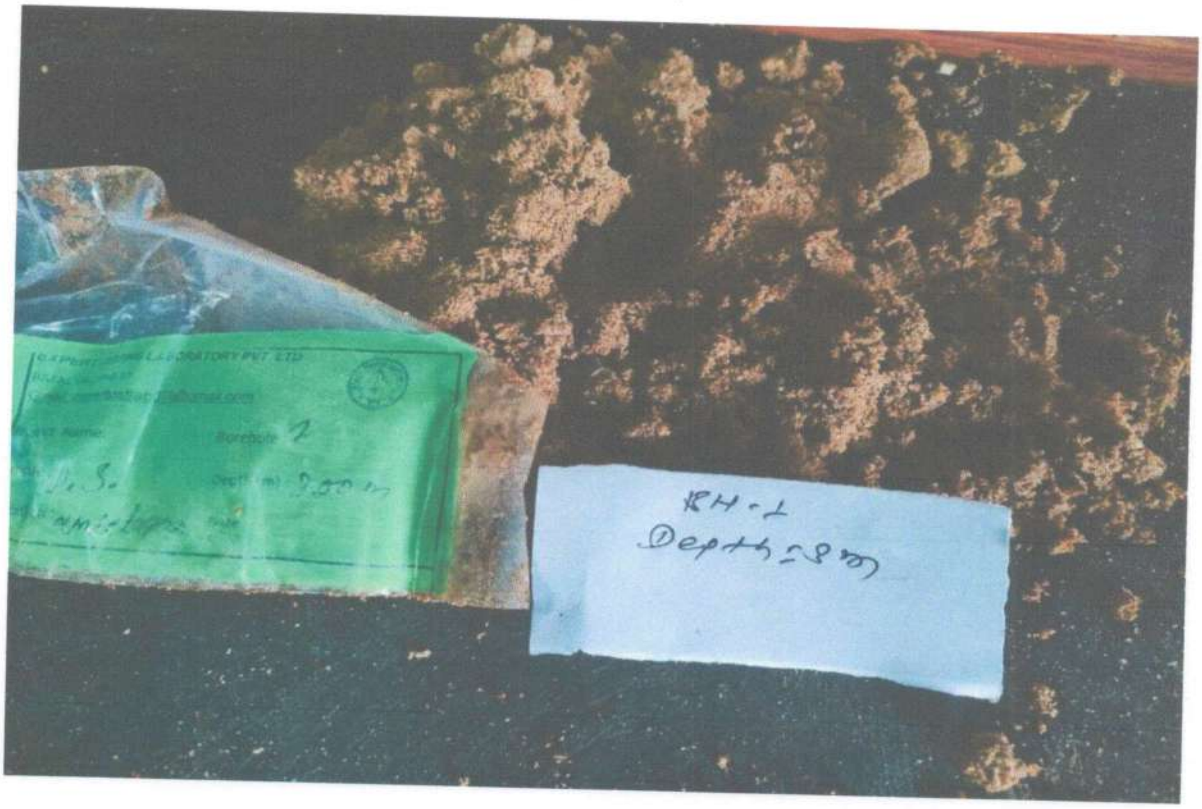


*Figure 3-3 Sample of BH-01 Depth 3m*


*Figure 3-4 Sample of BH-01 Depth 4.5m*


*Figure 3-5 Sample of BH-01 depth 12m*



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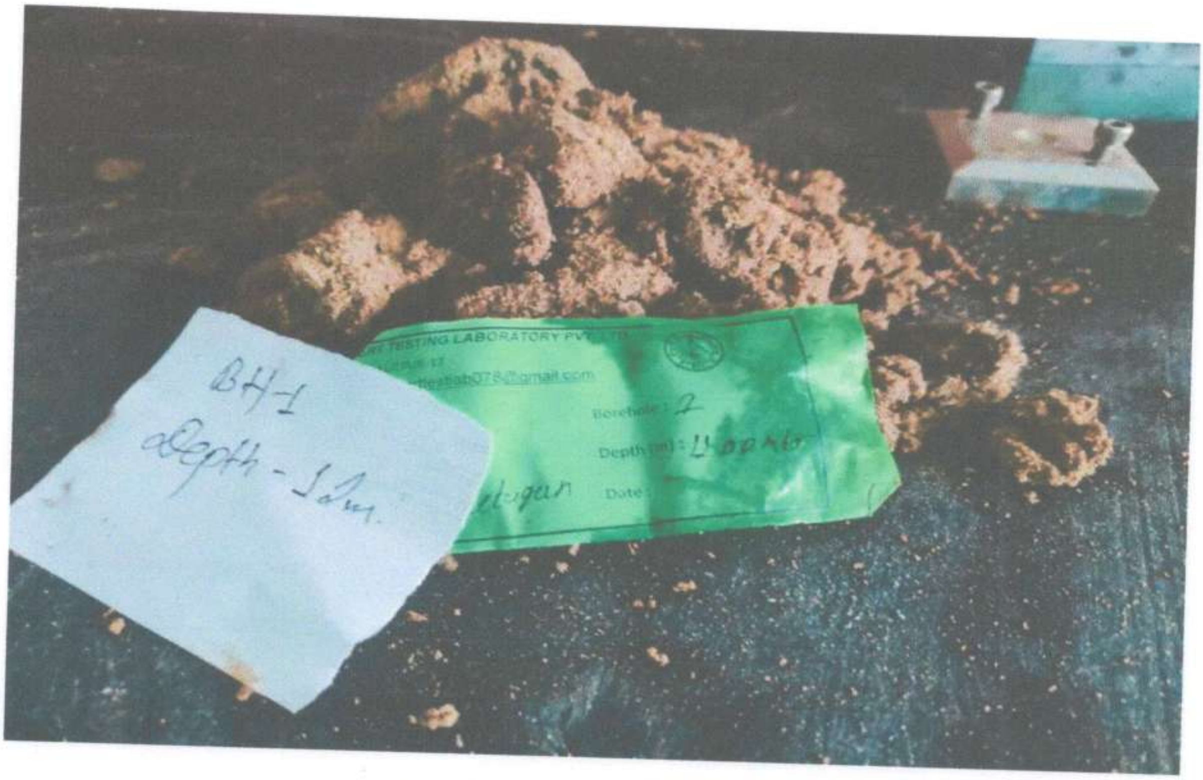


*Figure 3-6 Soil Sample of BH-01 depth 12m*


*Figure 3-7 Soil Sample of BH-01 depth 19.5m*

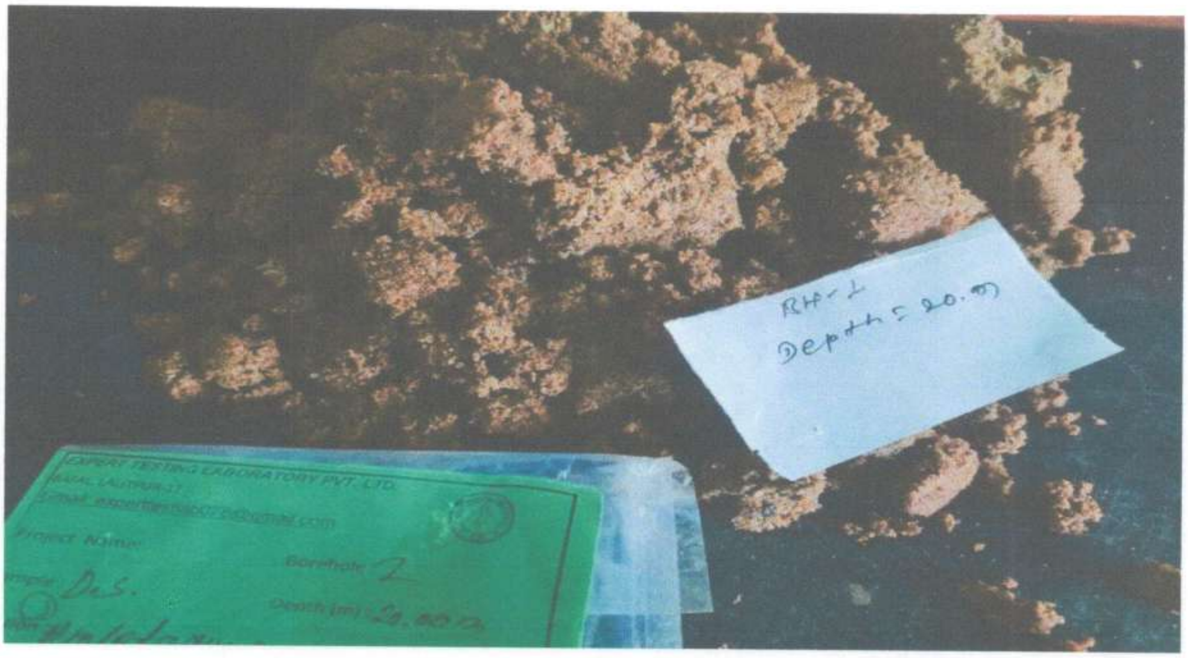


*Figure 3-8 Soil Sample from BH-01 depth 19.5m*

### 3.2.2 Dynamic Cone Penetration Test (DCPT)

It consists of driving a cone by blows of hammers. The number of blows for driving the cone through a specified distance is a measure of the dynamic cone resistance. Dynamic Cone Penetration test are performed by a 50 mm cone. The method for DCPT is similar to that of SPT. First of all, the cone is driven 100 mm into the soil at the bottom of the bore hole. It is then driven further 200 mm and the number of blows ($N_{cbr}$ values) required to drive this distance is recorded. The result i.e., $N_{cbr}$ values first corrected to the Standard Penetration Test (SPT) value (N) and that provides and estimation of degree of compaction of soil strata, values of angles of internal friction ($\phi$) and allowable bearing capacity. The dynamic cone resistance is correlated with the SPT (N) as given below.

$N_{cbr}$ = 1.5 N for depth up to 3 m
= 1.75 N for depth 3 to 6 m
= 2 N for depth greater than 6 m

### 3.2.3 Sample Collection

Before any disturbed samples were taken, the boreholes were washed clean to flush any loose disturbed soil particles deposited during the boring operation. The samples obtained in the split spoon barrel of SPT tube during SPT tests were preserved as representative disturbed samples. The disturbed samples recovered were placed in air-tight double 0.5 mm thick transparent plastic bags, labeled properly for identification and finally sealed to avoid any loss of moisture. Only then, the samples were transportation to the laboratory for further investigation.

Undisturbed Sample are extracted by means of thin wall tube (Shelby tube). The tubes are pushed into the ground and the samples are recovered mechanically. The tube are sealed with wax and wrapped with airtight polythene sheets and then bound by adhesive tapes and properly labelled. The tubes were properly packed in a wooden box so as to minimize the disturbances during transportation to the laboratory and avoided the changes of moisture content of sample. These sample are used for the determination of strength and consolidation parameters.

### 3.2.4 Ground Water Table

Prediction of depth of ground water table needs the installation of piezometers and regular monitoring of those for at least a year. Since, the time frame and the installation are beyond the scope of the work, visual examination was performed to find the depth. Ground Water Table (GWT) was monitored as per bore log sheets during the drilling. Ground water table was observed are shown in bore hole log as in Annex 1. Process of GWT measurement in field is shown in figure 3.9.

*Figure 3-9 Ground water table measurement in field at BH-01*

## 3.3 Laboratory investigation

All the requisite laboratory tests were carried out in accordance with IS standard specifications. Standard laboratory test was carried out to characterize the soil strata. The laboratory test includes the following tests: Moisture Content, Grain Size Analysis, Specific Gravity, Atterberg Limits, Direct Shear Tests, and bulk density test were conducted. Investigations were conducted for infilling materials.

### 3.3.1 Natural moisture content

The natural water content was determined from samples recovered from the split spoon sampler. Natural moisture content is determined referring IS: 2720 (Part-2)-1992. Summary of natural moisture content test is given in Annex 10 of this report.

### 3.3.2 Specific gravity

The specific gravity test is made on the soil sample which was grounded to pass 2.0 mm IS sieve. Specific gravity is defined as the ratio of the weight of a given volume of soil particles in air to the weight of an equal volume of distilled water at a temperature of 20 °C. It is important for computing most of the soil properties e.g., void ratio, unit weight, particle size determination by hydrometer, degree of saturation etc. This method covers determination of the specific gravity of soils by means of a pycnometer. Specific gravity is determined referring IS: 2720 (Part-3)-1992. Summary of specific gravity test is given in Annex 12 of this report.

### 3.3.3 Grain size analysis

Grain size distribution was determined by dry sieving process. Sieve analysis was carried out by sieving a soil sample through sieves of known aperture size (e.g., 4.75mm, 2mm, 1.18mm, 425, 300, 150 and 75 microns) by keeping one over the other, the largest size being kept at the top and the smallest size at the bottom. The soil is placed on the top sieve and shake for 10 minutes using a mechanical shaker. The soil retained on each sieve was weighed and expressed as a percentage of the weight of sample. Grain size analysis is determined referring IS: 2720 (Part-4)-1992. Summary of grain size analysis test is given in Annex 9 of this report.

### 3.3.4 Atterberg limits

The physical properties of fine-grained soils (clay and silt) get affected with water content. Depending upon the amount of water present in a fine-grained soil, it can be in liquid, plastic or solid consistency states. The Atterberg Test was used for determining the consistency of a cohesive (fine) soil. The Liquid Limit is the water content at which a soil has a small shear strength that it flows to close a groove of standard width when jarred in a specified manner. The Plastic Limit is the water content at which a soil begins to crumble when rolled into threads of specified size i.e., 3mm. The water content determined at a stage when the rolled thread of soil just starts crumbling. Three such tests and the average value of water content were taken as Plastic Limit. The Plasticity Index is the numerical difference between the Liquid

Limit and the Plastic Limit. The liquid limit of the fine-grained soils was determined using the Casagrande liquid limit device. A Plastic limit was determined using the standard 'rolling the soil into a thread of 3mm' method. Casagrande plasticity chart was employed to determine the classification of fine-grained soil according to the Unified Soil Classification System. However, in this study, the Atterberg limit tests are not applicable as the soil found in the site which were sand. Atterberg limits were determined referring IS: 2720 (Part-5)-1992. As Atterberg limit test is conducted for fine grained soils consisting clay and silts, but soil samples collected are coarse sand to gravel from all bore holes so Atterberg limit test is not required.

### 3.3.5 Direct shear test

The shear strength of a soil mass is its property against sliding along internal planes within itself and is determined in this case to compute the safe bearing capacity of the foundation soil. Direct shear tests were conducted on disturbed samples collected from the three boreholes. The samples were carefully extruded from the sampling tubes and molded using standard mould of 6.0 x 6.0 $cm^2$ cross-sectional areas and trimmed to 2.5 cm high. Solid metal plates were placed on both surfaces of the samples to prevent the dissipation of pore water during shearing. The direct shear equipment is mechanically operated, and shearing is applied at more or less constant strain rate. The samples were sheared at three different normal stresses (i.e., 5 kPa, 10 kPa, 15 kPa). The direct shear test results are presented in terms of the failure envelops to give the angle of internal frictions ($\phi$) and the cohesion intercepts (c). Direct shear tests were conducted referring IS: 2720 (Part-13)-1992. Summary of direct shear test is given in Annex 8 of this report.

*Figure 3-10 Direct Shear Test arrangement*

### 3.3.6 Bulk and Dry density

Bulk and dry density is determined for samples obtained from split spoon sampler and undisturbed samples referring IS 2720 (part-8)-1983. Summary of bulk density test is given in Annex 11 of this report.

## 4. Data Interpretation and Analysis

After conducting desk study (study of available geological map of area, pervious soil investigations in that area, and other maps, research papers), field investigation and laboratory investigations following analysis and interpretations were conducted.

### 4.1 Standardization of SPT value

The recorded SPT values are converted to standardized energy N60 as per Skempton (1986):

$N_{60} = (E_m\ C_B\ C_S\ C_R\ N_{rec})/60$

| | | | |
|---|---|---|---|
| $N_{60}$ | = | SPT N value corrected for field procedure | |
| $N_{rec}$ | = | measured penetration number | |
| $E_m$ | = | hammer efficiency (%) | = 0.55 for hand drop hammer |
| $C_B$ | = | correction for borehole diameter | = 1.0 for 65 mm to 115 mm dia. |
| $C_S$ | = | sampler correction | =1.0 for standard sampler |
| $C_R$ | = | correction for rod length | = 0.7 for rod length 0.0 – 3.0 m |
| | | | = 0.75 for rod length 3.0 – 4.0 m |
| | | | = 0.85 for rod length 4.0 – 6.0 m |
| | | | = 0.95 for rod length 6.0 – 10.0 m |
| | | | = 1.0 for rod length > 10.0 m |

**Correction for Overburden:**

In granular soils, the value of N is affected by the effective overburden pressure. For that reason, the value of N60 obtained from field exploration under different effective overburden pressures should be changed to correspond to a standard value.

$\sigma_v$ = Effective over burden pressure in kPa.

**Dilatancy Correction (for fine sand and silts below water table)**

Terzaghi and Peck (1976) gave correction for water pressure as,

If Nrec ≤ 15, then Ncorr =Nrec

Nrec ≥ 15 then Ncorr = ½(Nrec-15)

## 4.2 General geology of site

Geological map of the project area is shown in Fig. 4.1 and 4.2. The map is an extract from Geology of the Nepal Himalaya by Megh Raj Dhital and geological map of Chitwan Dun valley by Tamrakar et al 2008. Project area is located at the foothill of Siwalik (lower Siwalik) and just above main frontal thrust (MFT) of Great Himalayan. Main Frontal Thrust (MFT) is youngest fault system and southern most structure in Himalayan fold and thrust belt, it is very active and all mega quakes in Main Himalayan Thrust are transported to the surface along this fault, so during design of structure for project seismic considerations should be given higher priority. As per geological map sandy braided system mainly Sand stone. Mud Stone, pebble conglomerates are dominant in Siwalik portion. As project area is in the bank of Duhaura Khola so alluvial deposits consisting gravel to boulders with sand as infilling were observed.

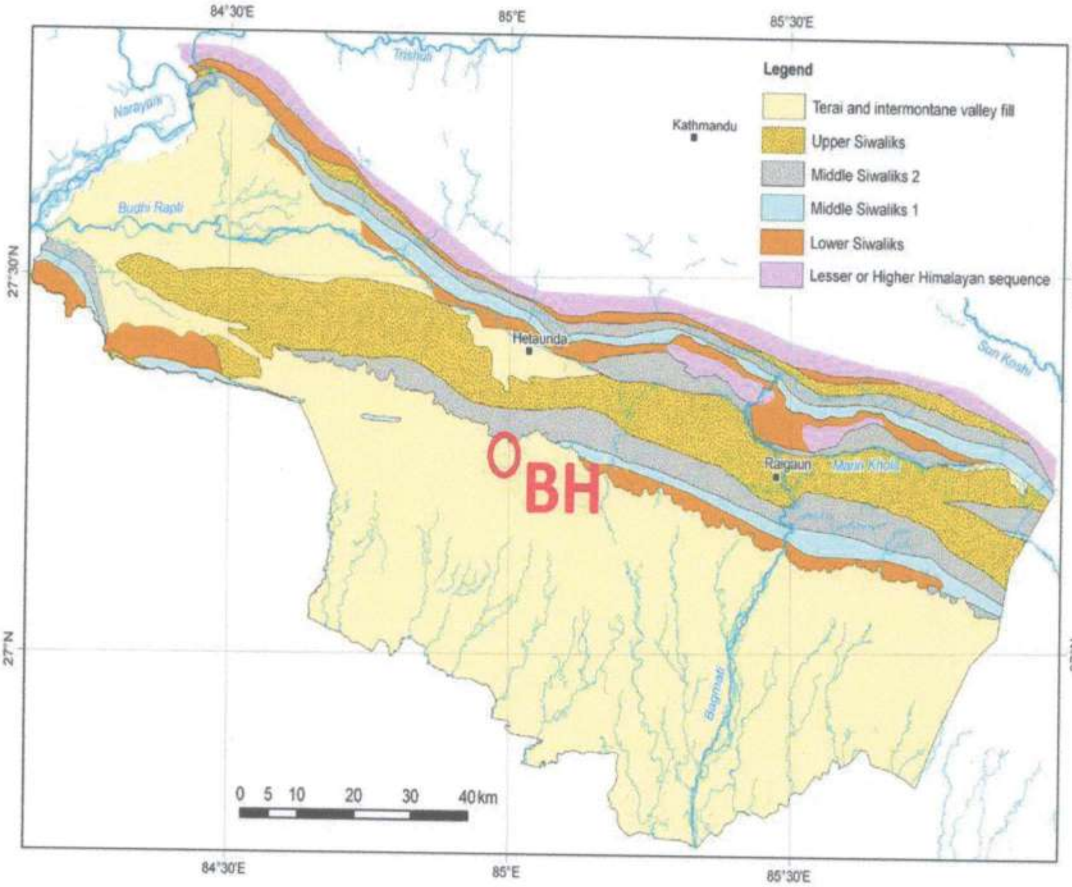


*Figure 4-1 River terraces distributed in seti khola between Khaireni and Pokhara (Yamanata et. al. 1982)*

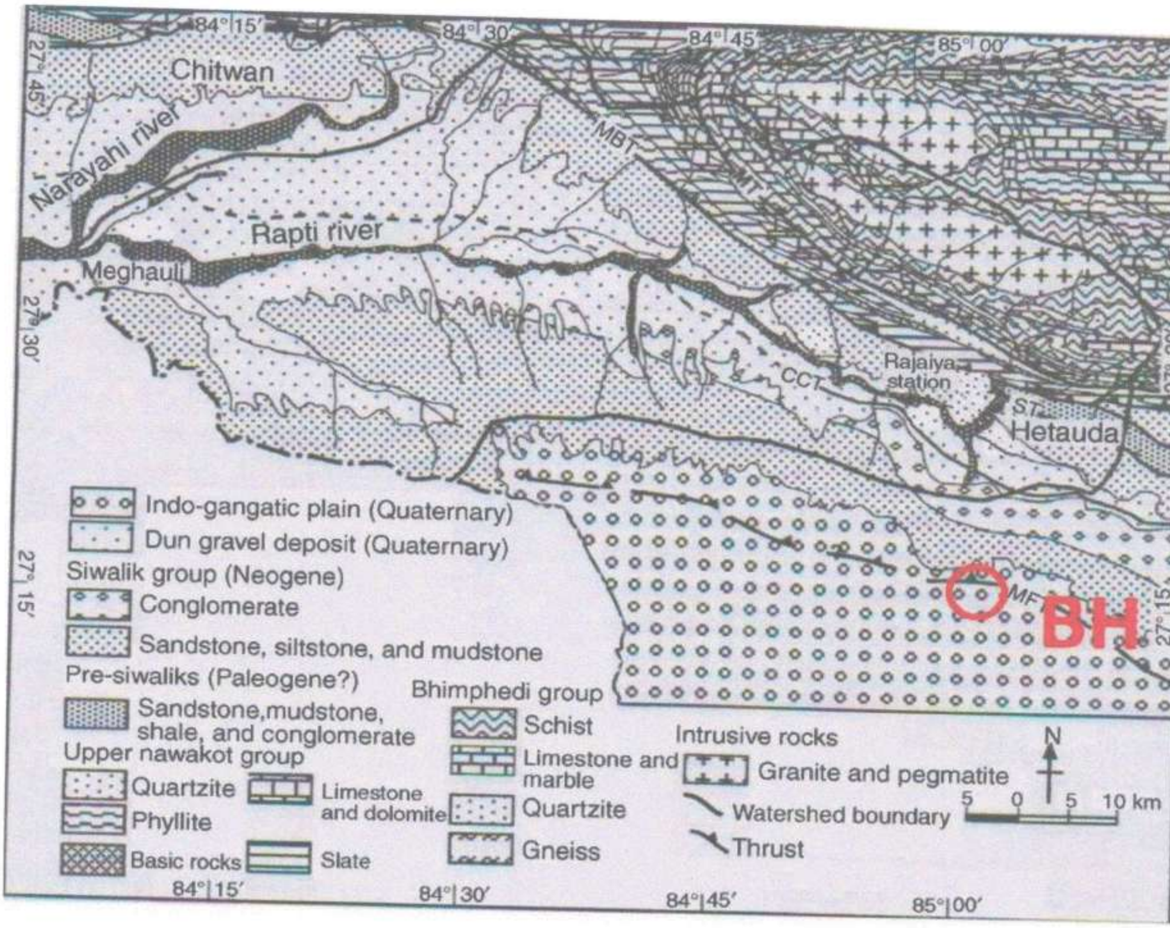


*Figure 4-2*

## 4.3 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 as shown in figure 4.3. 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.

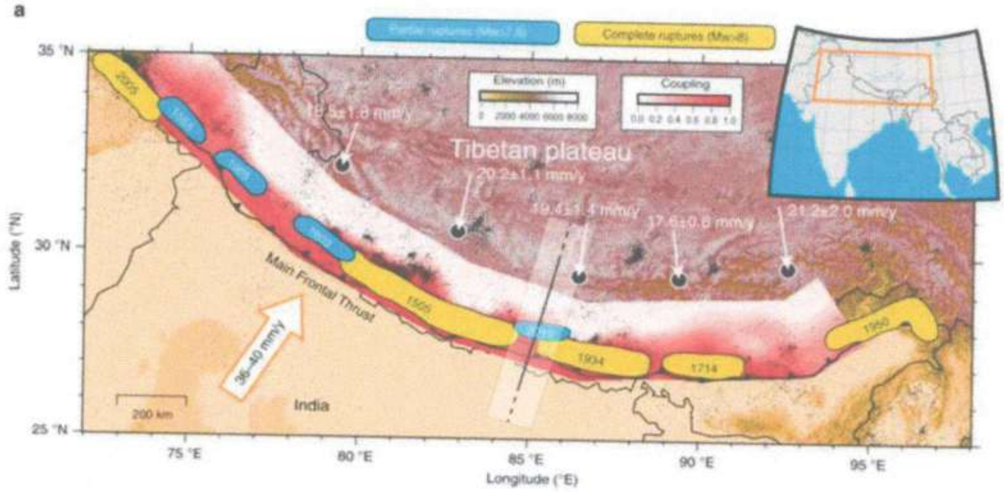


*Figure 4-3 Topographic relief coupling modes and historical seismicity: Stevens V. and Avouac J. (2015)*

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. Historical incidents of earth quakes in Nepal and surrounding is shown in figure 4.2. 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).

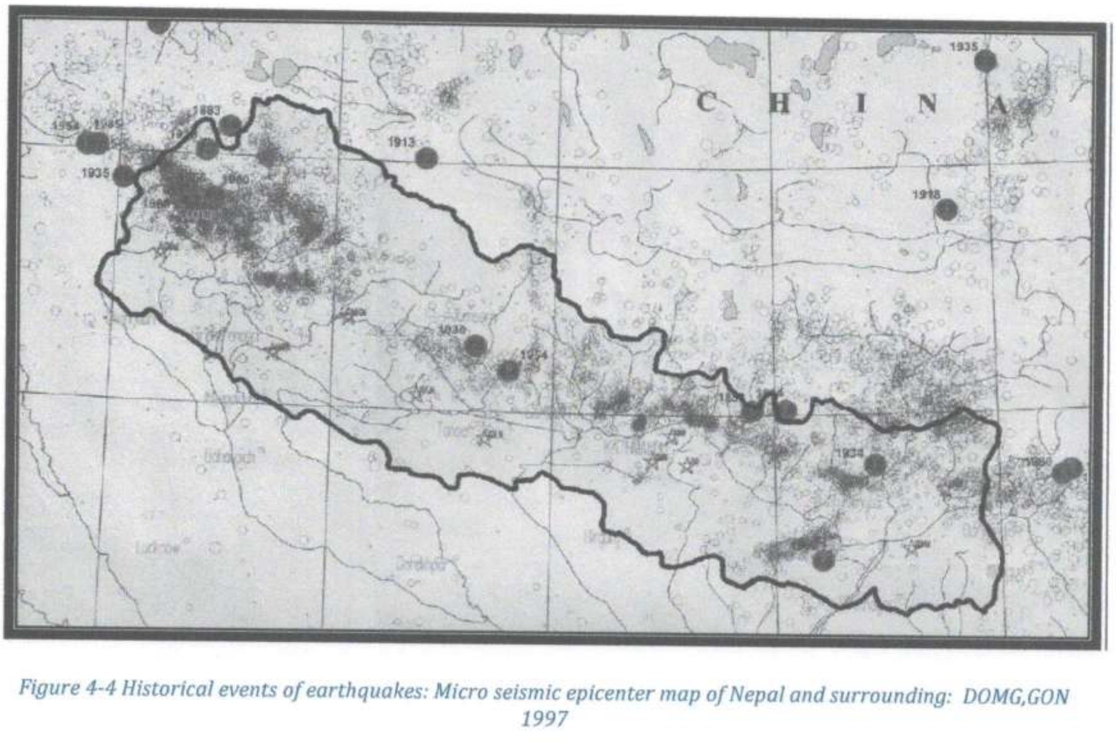


*Figure 4-4 Historical events of earthquakes: Micro seismic epicenter map of Nepal and surrounding: DOMG,GON 1997*

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.

Ground motion can be simply quantified by peak values of expectable acceleration, velocity and/or displacement. Empirical relationships, called attenuation equations, can be derived from the interpretation of available strong motion records and relate peak ground motion parameters to magnitude and distance from the source of energy release. Attenuation equations are sensitive to the estimates of distance and magnitude, especially in the near-field. Peak ground acceleration (PGA) often represents the main seismic evaluation parameter for simplified analysis purposes. The peak ground acceleration (usually as a fraction of the peak) is the earthquake ground motion parameter usually used in the seismic coefficient method of analysis. Attenuation model of Young's et al (1997) for subduction zones for bed rock was used in development of seismic hazard map of Nepal as shown in figure 4.3.

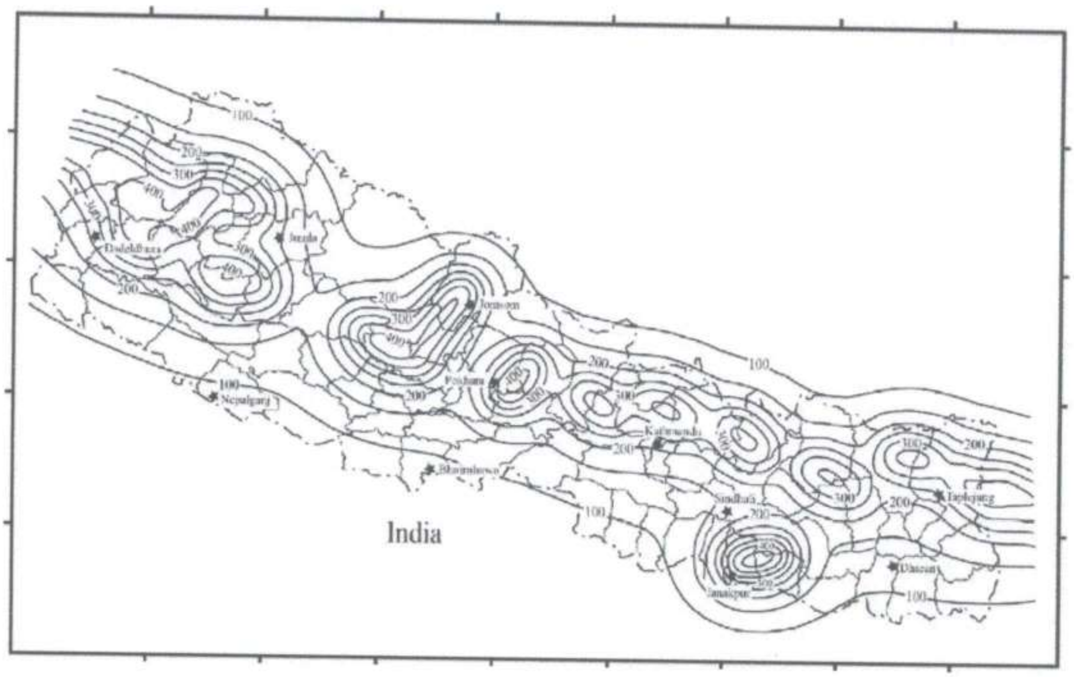


*Figure 4-5 Probabilistic seismic hazard assessment map of Nepal : DOMG,GON*

When fine or medium, saturated, loose sand deposit is subjected to a sudden shock (generated by an earthquake) the mass will densify and consolidate or temporarily liquefy. This phenomenon is termed 'Liquefaction'. Pore-water pressures within such layers increase as the soils are cyclically loaded, resulting in a decrease in vertical effective stress and shear strength. If the shear strength drops below the applied cyclic shear loadings, the layer is expected to transition to a semi fluid state until the excess pore-water pressure dissipates. When liquefaction takes place in a particular soil then the bearing capacity of the soil disappears and the structure built on it gets tilts or even sinks. The past big earthquakes, 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 epicenter distance from several miles to hundreds of miles.

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 Seismic Hazard Map of Nepal prepared by National Seismological center, Departments of mines and geology, Nepal, Kathmandu is highly liquefiable zone, which may experience maximum ground acceleration of 200 gal to 250 gal, whereas as per Building Department Memorandum for Multistory Building it must be 360 gal ≈ 0.36g.

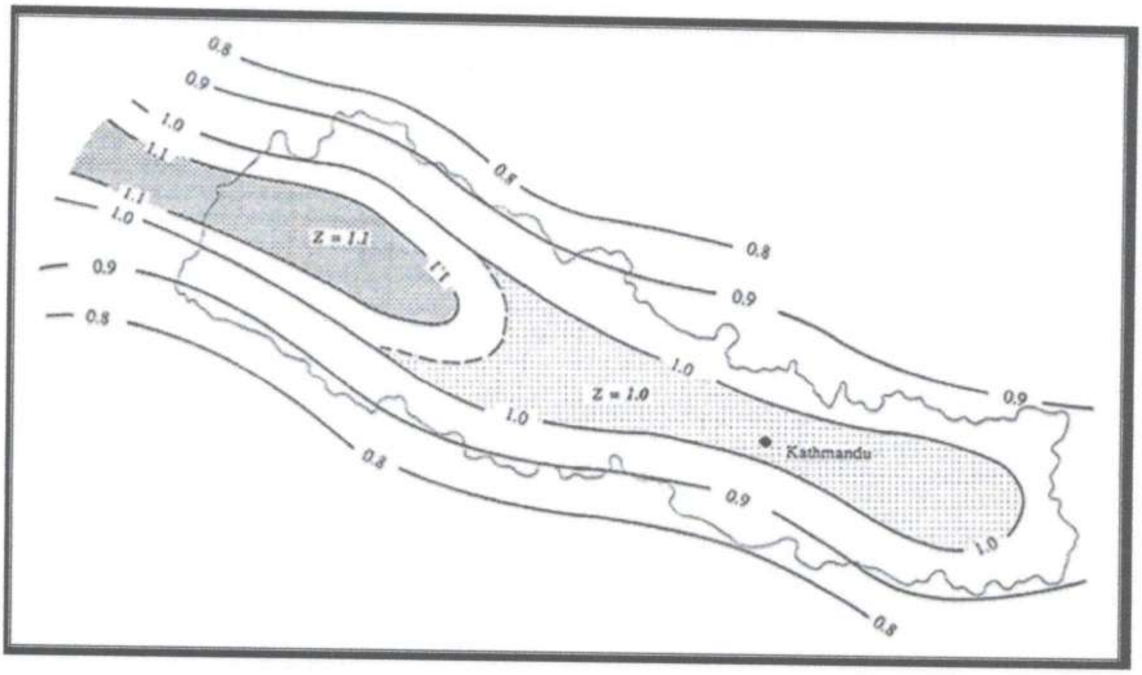


*Figure 4-6 Seismic zoning map : UNDP/UNCHS Habitat 1994*

## 4.4 Liquefaction analysis

Saturated loose to medium dense cohesion-less soils and low plastic silts tend to densify and consolidate when subjected to cyclic shear deformations inherent with large seismic ground motions. Pore-water pressures within such layers increase as the soils are cyclically loaded, resulting in a decrease in vertical effective stress and shear strength. If the shear strength drops below the applied cyclic shear loadings, the layer is expected to transition to a semi fluid state until the excess pore-water pressure dissipates.

## Analysis of Liquefaction

The stress-based approach for evaluating the potential for liquefaction triggering, initiated by Seed and Idriss (1967), compares the earthquake-induced cyclic stress ratios (CSR) with the cyclic resistance ratios (CRR) of the soil. The soil's CRR is usually correlated to an in-situ parameter SPT blow count. Factor of safety is evaluated as,

$$FOS = \frac{CRR_{7.5}}{CSR} * MSF \quad \text{--------------------------}$$

Where, $CRR_{7.5}$ = Cyclic Resistance Ratio for earthquake of magnitude 7.5

CSR = Normalized cyclic stress that results in liquefaction

MSF = Magnitude scaling factor that accounts for the effects of the number of cycles during earthquake duration

$= 6.9e^{-M/4} - 0.058 \leqslant 1.8$ for sand

$= 1.12e^{-M/4} + 0.828 \leqslant 1.13$ for clay

$CRR_{7.5} = \exp\left(\frac{(N_1)_{60cs}}{14.1} + \left(\frac{(N_1)_{60cs}}{14.1}\right)^2 - \left(\frac{(N_1)_{60cs}}{23.6}\right)^3 + \left(\frac{(N_1)_{60cs}}{25.4}\right)^4 - 2.8\right)$

$(N_1)_{60cs}$ = Clean sand SPT count according to Idriss et. al 2008

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

$\Delta(N_1)_{60cs} = \exp\left(1.63 + \frac{9.7}{FC+0.01} - \left(\frac{15.7}{FC+0.01}\right)^2\right)$

FC = Fine content % obtained from sieve analysis

$(N_1)_{60}$ = Corrected SPT value normalized for atm. pressure 100 kPa

$CSR = 0.65 \frac{\sigma_{vc}}{\sigma'_{vc}} \frac{\alpha_{max}}{g} r_d$

$\alpha_{max}$ = peak horizontal acceleration of ground = 0.36g

g = gravitational acceleration $m^2/sec$

$\sigma_{vc}$ and $\sigma'_{vc}$ = Total and effective vertical stress at depth of analysis in kPa

$r_d$ = stress reduction coefficient = $\exp(\alpha(z)+\beta(z)*M_w)$

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

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

z = depth of analysis in meters

$M_w$ = Magnitude of earthquake considered

**Liquefaction potential index (LPI)** is a single-valued parameter to evaluate regional liquefaction potential. Although, Factor of Safety (FS) shows the liquefaction potential of a soil layer at a particulardepth in the subsurface, it does not show the degree of liquefaction severity at a liquefaction-prone site. Iwasaki et al. (1978) proposed liquefaction potential index (LPI) to overcome this limitation of Factor of Safety (FS). Liquefaction potential index (LPI) provides an integration of liquefaction potential over the depth of a soil profile and predicts the performance of the whole soil column as opposed to a single soil layer at particular depth and depends on the magnitude of the peak horizontalground acceleration (Luna and Frost, 1998). LPI combines depth, thickness, and factor of safety against liquefaction (FS) of soil layers and predicts the potential of liquefaction to cause damage at the surfacelevel at the site of interest.

LPI at a site is computed by integrating the factors of safety (FS) along the soil column up to 20 m depth. A weighting function is added to give more weight to the layers closer to the ground surface. The liquefaction potential index (LPI) proposed by Iwasaki et al. (1978, 1982) is expressed as follows:

LPI= $\int_0^{20} f(z).w(z)\,dz$

Where, z is depth of the midpoint of the soil layer (0 to 20 m) and dz is differential increment of depth. The weighting factor, w(z), and the severity factor f(z) as below

$f(z) = 1 - FS$ for $FS < 1.0$

$f(z) = 0$ for $FS \geq 1.0$

$w(z)=10-0.5*z$ for $z< 20m$

$w(z) =0$ for $z>20m$

The level of liquefaction severity

| LPI | Iwasaki et al. (1982) | Luna and Frost (1998) | MERM (2003) |
|---|---|---|---|
| $LPI = 0$ | Very low | Little to none | None |
| $0 < LPI < 5$ | Low | Minor | Low |
| $5 < LPI < 15$ | High | Moderate | Medium |
| $15 < LPI$ | Very high | Major | High |

Detail calculation of liquefaction potential analysis is given in Annex 6 of this report and from which it is observed that project site has low level of liquefaction severity.

## 4.5 Allowable bearing capacity of shallow foundation using c and ϕ

The bearing capacity analysis has been carried out for foundation soil. The well-known Indian Standard (IS 6403:1981) has been used to compute ultimate bearing capacity ($q_{ult}$) of soil on the basis of shear failure criteria.

General shear failure,
$q_{ult} = c*Nc*Sc*dc*ic + \gamma*D*(N_q - 1)*Sq*d_q*i_q + 0.5*\gamma*B*N_\gamma*S_\gamma*d_\gamma*i_\gamma*W'$
Local Shear failure,
$q'_{ult} = c*N'c*Sc*dc*ic + \gamma*D*(N'_q - 1)*Sq*d_q*i_q + 0.5*\gamma*B*N'_\gamma*S_\gamma*d_\gamma*i_\gamma*W'$

Where $\gamma$ is the bulk unit weight of soil and bearing capacity factors $N_c$, $N_q$, $N_\gamma$ are determined using table 1 of IS 6403:1981 for internal frictional angle of soil $\phi$ whereas bearing capacity factors $N'_c$, $N'_q$, $N'_\gamma$ are determine using table 1 of IS 6403:1981 for reduced internal frictional angle $\phi' = \tan^{-1}(0.67*\tan(\phi))$. $S_c$, $S_q$, $S_\gamma$ are shape factor which depends up on plan dimension and shape of foundation and can be determined from table 2 of IS 6403:1981. $d_c$, $d_q$, $d_\gamma$ are depth factor according to IS 6403:1981 they can be determined as below

$d_c = 1+0.2*\frac{D_f}{B}\sqrt{N_\emptyset}$
$d_q = d_\gamma = 1$ for $\phi < 10^o$
$d_q = d_\gamma = 1+0.1*\frac{D_f}{B}\sqrt{N_\emptyset}$ for $\phi > 10^o$
$N_\emptyset = \tan^2(\pi/4+\phi/2)$
$D_f$ = Depth of foundation and B= width of foundation
$i_c$, $i_q$, $i_\gamma$ are inclination factor for inclination of loading to the vertical ($\alpha$) according to IS 6403:1981 they can be determined as below
$i_c = i_q = (1-\alpha/90)^2$ and $i_\gamma = (1-\alpha/\phi)^2$

W' is the factor considering effect of water table, if water table will permanently remain below a depth (Df+B) beneath ground level surrounding the footing then W'=1.0, if water table is likely to rise to the base of footing or above then W'=0.5 and for in between linear interpolation should be performed.

## 4.6 Allowable bearing capacity of shallow foundation using SPT value

Several empirical equations are available to estimate the allowable bearing pressure of the soil. Following are the some widely used equations to estimate the allowable bearing pressure of the soil assuming a factor of safety of 2.5.

.$q_{allow}$ = 8*N*((B+0.3)/B)^2*(1+0.33*D/B) kPa (Meyerhoff, 1956)
$q_{allow}$ = 47.8*N kPa (Terzaghi and Peck, 1967)
$q_{allow}$ = 34.0*N kPa (Strounf and Butler, 1975)

Where, N= Corrected average SPT N value
B = Width of footing (m)
D = Depth of footing (m)

### 4.7 Allowable bearing capacity of shallow foundation using allowable settlement

The maximum allowable settlement for isolated footings in sand is generally 25 mm and for a mat foundation in sand the allowable settlement is 75 mm (IS 1904: 1978). For isolated footings in cohesive soil, allowable settlement is generally 25 mm and for a mat foundation in cohesive soil the allowable settlement is 100 mm (IS 1904: 1978). According to Meyerhof's (1965) modified by Bowles (1977) safe allowable bearing capacity can be determined using equation

$Q_{safe}$= 11.98 *N60* 〖((3.28 B+1)/3.28B)〗 ^2*fd*(S/25)*Rw1

Where, N60= Corrected average SPT N value

B = Width of footing (m)

S = Allowable settlement (25mm)

fd = Depth factor= 1+0.33(Df/B) $\leqslant$1.33

Rw1= water correction factor, for water table at just below footing=0.5

### 4.8 Allowable bearing capacity of shallow footing over gravel and boulder

According to IS 10042-1981, allowable bearing capacity of boulder deposit can be determined using empirical equation as below

$$Q_{allowable} = \frac{1}{2.54}\left[\frac{N''*Sa}{D*Bf}\right]$$

Where, N'' = cumulative number of blows corresponding to depth D in meter

Sa = allowable settlement (25mm)

$B_f$ = width of strip footing

**Calculations for bearing capacity of different sized shallow footing (isolated and Mat footing ) by different methods mentioned above is given in Annex 4 of this report and summary of bearing capacity is given in Annex 7 of this report. Allowable gross bearing capacity varies with depth of footing and size of footing, bearing capacity of isolated footing (size < 5m) is recommended as 200 kPa and for Mat footing (size > 5m) is recommended as 150 kPa at depth 1.5m from ground surface.**

## 4.9 Modulus of elasticity and Subgrade modulus

Modulus of elasticity of granular soil can be estimated from SPT value using Mayne(1990), according to which

Modulus of Elasticity ($E_s$)= Pa $*\alpha*N_{60}$

Where, Pa = atmospheric pressure in kPa

$\alpha$ = 5 for Sand with fines

= 10 for clean normally consolidated sand

= 15 for over consolidated sand

$N_{60}$= Corrected SPT value

Subgrade reaction modulus can be estimated using

$K = E_s/(B*(1-\mu^2))$

Where, $E_s$ = modulus of elasticity of soil

B= width of footing

$\mu$ = poission's ratio for soil

## 4.10 Settlement analysis of shallow foundation

The settlement of shallow foundation can be divided into two major categories:

### a.) Elastic, or immediate settlement and

Immediate or elastic settlement of a foundation takes place during or immediately after the construction of the structure.

Elastic settlement in granular soils can also be evaluated by the use of a semi-empirical strain influence factor proposed by Schmertmann's et al. (1978). According to this method, the settlement:

$$S_e=C_1*C_2*q_n*\sum_0^z \frac{I_z}{E_s}\Delta z$$

Where,

$C_1$=correction factor for embedment of foundation=$1-0.5*(q_o/q_n)$

$C_2$=Correction factor to account for creep in soil = $1+0.2*\log(t/0.1)$; t is time in year

$q_o$= Over burden pressure at base of foundation = $\gamma*D_f$

$q_n=q_u-q_o$

$q_u$=Stress at level of foundation from foundation kPa
$D_f$= Depth of foundation (m)
$\gamma$ = unit weight of soil (kN/m$^3$)
$\Delta z$=Increment in depth (m)
z =Total depth up to which effect will be considered (m)
$I_z$ =Vertical influence factor obtained from figure 4.8
$E_s$ =Modulus of Elasticity of soil, for square footing Bowles (1982) gave empirical equation using cone penetration resistance ($q_c$)

$E_s = 2.5*q_c$ for square/circular footing
$E_s = 3.5*q_c$ for strip footing
$E_s = E_{s\ square}*(1+0.4*\log(L/B))$ ; L, B length and width of footing

$q_c$ (kg/cm2) can be correlated to corrected SPT value $N_{60}$ using figure4.9 depending on mean grain size ($d_{50}$) .

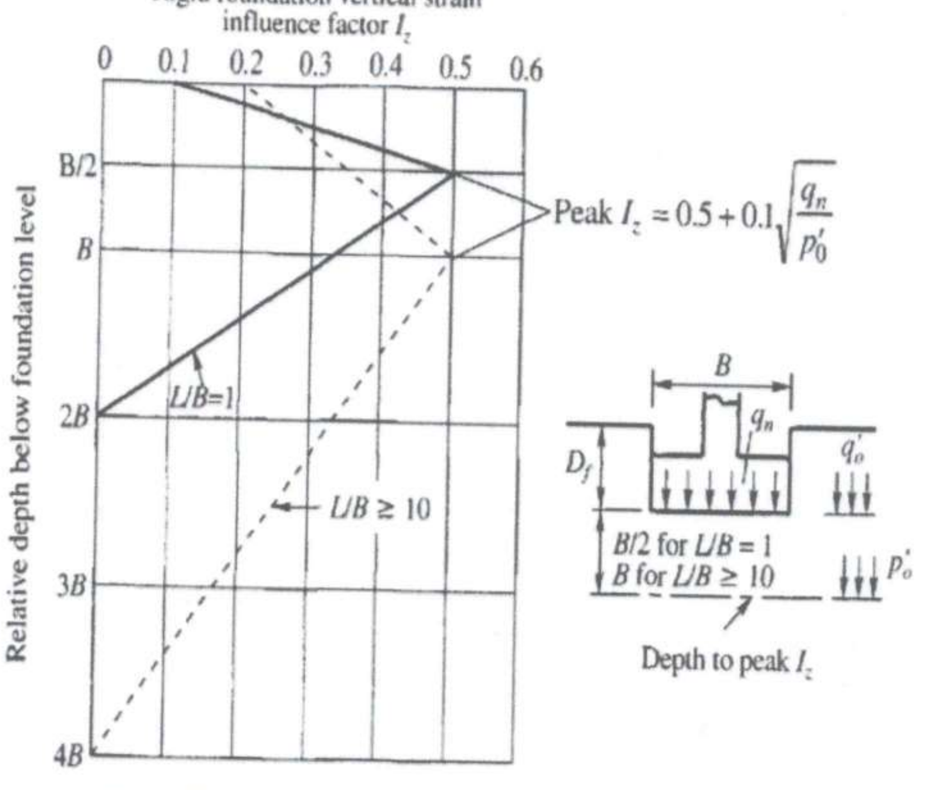


*Figure 4-7 Equation for strain influence factor: Schmertmann's et al. (1978)*

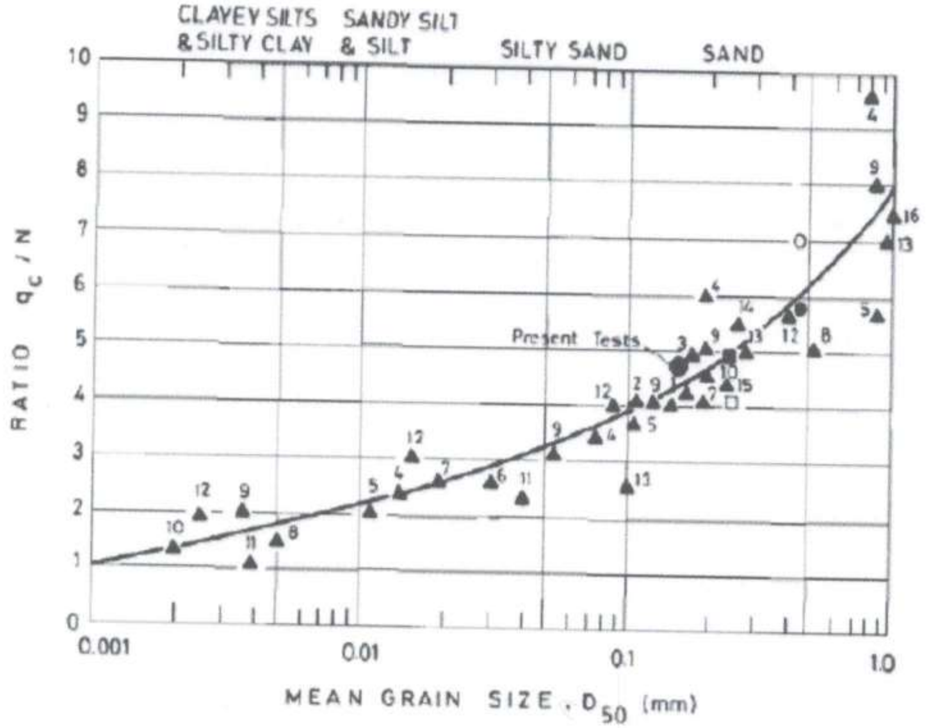


*Figure 4-8 Relation between $q_c$/N and $D_{50}$ : Ismael and Jeraagh 1986*

Elastic settlement in saturated clay for poison's ratio 0.5 can be determined from relation given Janbu et. al. (1956) average settlement of flexible foundation, which is as below

$$S_e = A_1 * A_2 * \frac{q_o * B}{E_s}$$

Where, '$A_1$' and '$A_2$' are function of H/B and L/B which is determined from figure4.10 given by Christian and Carrier (1978). 'H' is depth of clay layer below foundation in meter, 'B' is width of footing in meter in meter, '$q_o$' average vertical pressure from foundation kPa and '$E_s$' is modulus of elasticity of soil in kPa.

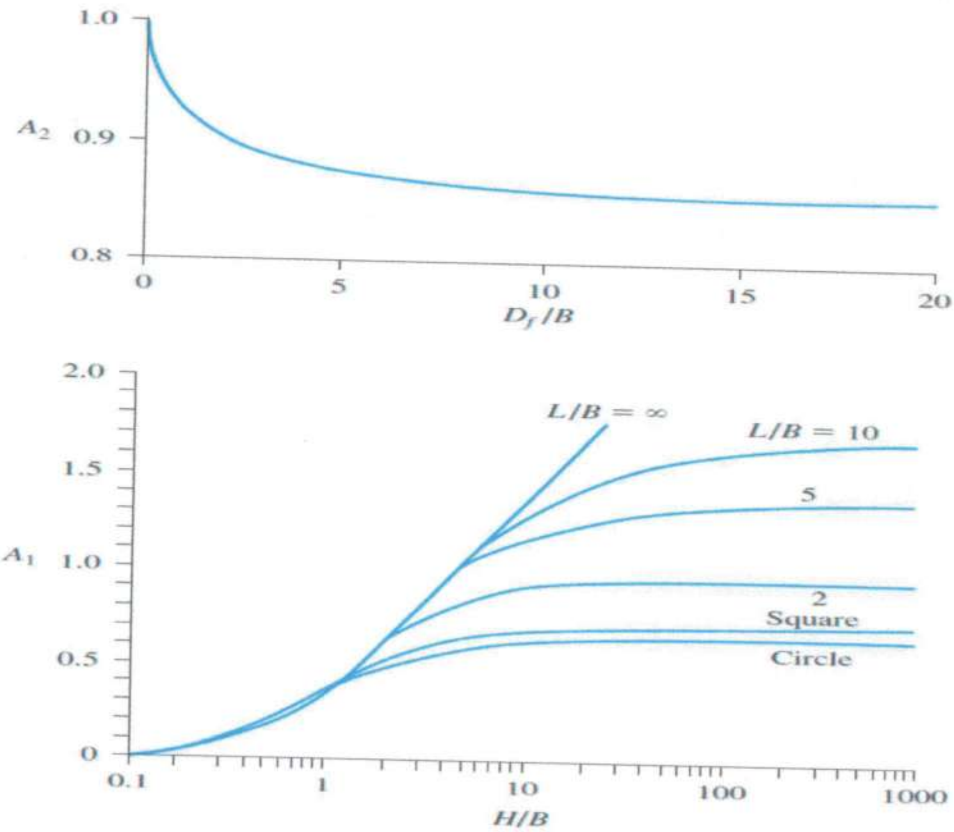


*Figure 4-9 Values of A1 and A2 for elastic settlement calculation: Christian, J. T. and and Carrier,W. D. (1978).*

Note: For rigid foundation settlement can be considered as 80% of flexible foundation.

## b.) Consolidation settlement

In clay layers total settlement can be expressed as sum of immediate settlement ($S_e$) and consolidation settlement ($S_c$). Consolidation settlement consolidation settlement occurs over time in saturated clayey soils subjected to an increased load caused by construction of the foundation. Consolidation settlement depends up on the extent of clay layer beneath foundation in that case according to IS 8009 part-I:1976 consolidation settlement can be computed as below,

$$S_c=\lambda*\frac{H_t}{1+e_o}C_c * log_{10}(\frac{P_o+\Delta P}{P_o})$$

Where,

$P_o$ =Effective pressure at mid height of clay layer before construction in kPa
$\Delta P$ =Average increment in pressure after construction in kPa
$e_o$ = Initial void ratio at clay
$C_c$ = Compression index obtained from consolidation test results,
For preliminary analysis according to IS 8009 part (I):1976
$C_c$= 0.009*(liquid limit -10)
$C_c$= 0.30*($e_o$-10)
$H_t$ =Thickness of clay layer in meter
$\lambda$ = A factor related to pore pressure parameter and ($H_t$/B)
according to IS 8009 (part-I):1976 for normally consolidated clay
$\lambda$ = 0.7 to 1.0

**Detail of settlement calculation is attached as Annex 5 in the report. According to which for proposed shallow footing which is with in allowable settlement recommended by table 1of IS 1904:1978 according to which for shallow foundation is 50mm.**

## 5.0 Conclusions and Recommendation

From the desk study, field investigations and laboratory tests following conclusions are made:

- Project site is very low susceptibility to liquefaction for Peak Bed Rock Acceleration around 200-250gal, and estimating with amplification factor of 2, design maximum horizontal acceleration is around 400gal.
- Gravel or cobble mixed with sandy infilling is observed throughout the depth of boring, DCPT test was conducted and observed values were greater than 50.
- Allowable bearing capacity is calculated from different suitable approach as discussed in report, lowest value is adopted as recommendation. Calculations for bearing capacity is in Annex 4 of this report and summary of bearing capacity is in Annex 7 of this report.
- Allowable gross bearing capacity varies with depth of footing and size of footing, bearing capacity of isolated footing (size < 5m) is recommended as 200 kPa and for Mat footing (size > 5m) is recommended as 150 kPa at depth 1.5m from ground surface.
- Estimated total settlement is round near 5 mm for pressure 200 kPa which is less than allowable settlement recommended by IS 1904:1986.
- Project site is located near Main Frontal Thrust, which arises higher possibility of impact of seismic activity in project.
- Project site is located near river, which arises need for study of flooding and its impact on project.

### Recommendations

- For gravels or boulders vibrator rollers are recommended for compaction to decrease settlement at design loads.
- Seismic activity of fault near project shall be studied with effect on project.
- All organic and silty top soil should be removed from areas to be developed prior to site grading.
- All areas of proposed development should be graded and compacted to prepare uniform surface. At least of 0.3m surface shall be scarified and re-compacted for maximum dry density up to 95% in cut.
- Load from the superstructure should to some extent be transmitted centric into the basement and/or base plate, otherwise a substantial tilts may be expected
- Ideally common fill should consist of well graded gravel with sands with fines less than 10 %, fill supporting structure shall be compacted to a minimum of 95% of modified proctor maximum dry density.
- Where space permits, the sides of the excavations shall be battered to a slope of one vertical and one horizontal (1V: 1H) to avoid collapse. Unsupported excavation is only recommended up to 3m depth. During excavation surface protection for eroding from rain water shall also be provided.

- Because of presence of seepage water and probable rise in water table in summer, side fall (collapse) is eminent. So, at the time of construction of foundation, it is strongly recommended to design the appropriate site protection measures based on the soil properties shown in this report.
- To protect the foundation reinforcement from this undesired effect by these chemicals, a cover of 75mm thick rich concrete mix to the rebar at base and sides is recommended.
- Conventional excavation equipment such as excavators, loaders and bulldozers will be sufficient for most of the excavation work. Every effort should be done to avoid soil disturbance at foundation level.
- To avoid ponding of water during excavation work for shallow foundation (Raft) and Pile cap dewatering is required. Experience has shown that small close-boarded excavation can be conveniently dealt with by conventional sump pumping techniques. However, if larger excavations (More than 2m) are to stand open for considerable period, the installation of dewatering system along with protection wall (Sheet Piles, Contiguous Pile, Soldier pile) may be required.
- Specialist contractors should be consulted in this regard during construction. Care should be taken during dewatering to ensure that fines are not removed during pumping since this could result in unpredictable settlements of the surrounding ground and associates structures.
- It is recommended that proper and efficient surface drainage be provided at the location of the structures both during and after construction. Surface water should be directed away from the edges of the excavation.
- The SANDY/GRAVELLY materials will probably be satisfactory for backfilling purposes, whereas, the CLAYEY materials will not be satisfactory for backfilling purposes. However, the final decision shall be taken during construction after complete excavation.
- Prevention from washing of filler materials from boulder excavations should be adopted.



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# Annex 1: Borehole Log

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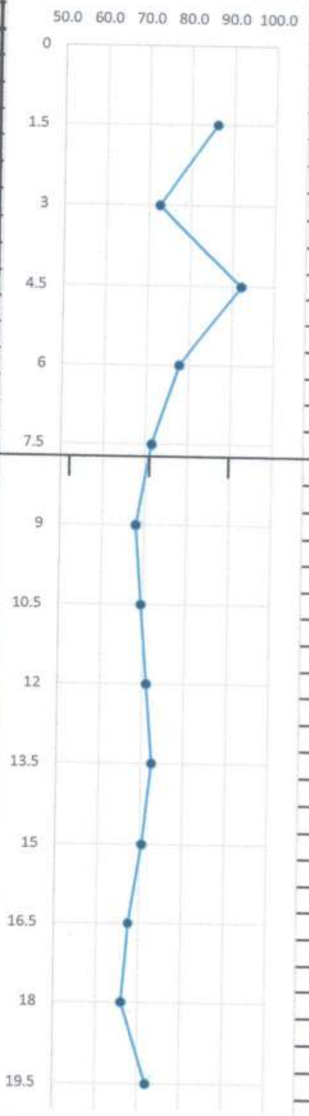
### Bore Hole Log

Project: Amlekhgunj Substation Construction Project
Location:Amlekhjung, Bara ,Nepal
Type of Boring: Rotatory drill Boring NX
Inclination of Boring: Vertical
Ground Water Table: N/A
Reduced Level:315m

Bore Hole no: 01
Date: 2022/04/22
Diameter of Boring: 100mm
Sampling Equipment: Split Sampler
Lattitude:27°16'41.4"
Longitude:84°59'34"

| S.N. | Soil Description | Symbol | Depth(m) | SPT /DCPT | DS/UDS | Number of blows for penetration of thickness (cm) 0-15 / 0-10 | 15-30 / 10_20 | 30-45 / 20_30 | Total reorded N value |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Gravel and Boulders (Sand Stone,Feldspar,Quarzite) with little fines | | 0 | | | | | | |
| 2 | | | 0.5 | | | | | | |
| 3 | | | 1 | | | | | | |
| 4 | | | 1.5 | DCPT | DS | 31 | 48 | 50 | 129 |
| 5 | | | 2 | | | | | | |
| 6 | | | 2.5 | | | | | | |
| 7 | | | 3 | DCPT | DS | 37 | 40 | 50 | 127 |
| 8 | | | 3.5 | | | | | | |
| 9 | | | 4 | | | | | | |
| 10 | | | 4.5 | SPT | DS | 28 | 42 | 50 | 92 |
| 11 | | | 5 | | | | | | |
| 12 | | | 5.5 | | | | | | |
| 13 | | | 6 | DCPT | DS | 39 | 47 | 50 | 136 |
| 14 | | | 6.5 | | | | | | |
| 15 | | | 7 | | | | | | |
| 16 | | | 7.5 | SPT | DS | 43 | 50 | 50 | 143 |
| 17 | | | 8 | | | | | | |
| 18 | | | 8.5 | | | | | | |
| 19 | | | 9 | SPT | DS | 39 | 47 | 50 | 136 |
| 20 | | | 9.5 | | | | | | |
| 21 | | | 10 | | | | | | |
| 22 | | | 10.5 | SPT | UDS | 41 | 48 | 50 | 139 |
| 23 | | | 11 | | | | | | |
| 24 | | | 11.5 | | | | | | |
| 25 | | | 12 | DCPT | DS | 42 | 50 | 50 | 142 |
| 26 | | | 12.5 | | | | | | |
| 27 | | | 13 | | | | | | |
| 28 | | | 13.5 | DCPT | DS | 45 | 50 | 50 | 145 |
| 29 | | | 14 | | | | | | |
| 30 | | | 14.5 | | | | | | |
| 31 | | | 15 | DCPT | DS | 41 | 50 | 50 | 141 |
| 32 | | | 15.5 | | | | | | |
| 33 | | | 16 | | | | | | |
| 34 | | | 16.5 | DCPT | DS | 39 | 46 | 50 | 135 |
| 35 | | | 17 | | | | | | |
| 36 | | | 17.5 | | | | | | |
| 37 | | | 18 | DCPT | DS | 40 | 42 | 50 | 132 |
| 38 | | | 18.5 | | | | | | |
| 39 | | | 19 | | | | | | |
| 40 | | | 19.5 | DCPT | DS | 44 | 50 | 50 | 144 |
| 41 | | | 20 | | | | | | |

DS: Disturbed Sample
UDS: Undisturbed Sample
N (Equivalent)value vs Depth




| | | | | | | |
|---|---|---|---|---|---|---|
| Granular Soil | Compactness | 0 to 4 | 4 to 10 | 10 to 30 | 30 to 50 | > 50 |
| | | Very Loose | Loose | Mid. Dense | Dense | Very Dense |
| Cohesive Soil | Consistancy | 0 to 2 | 2 to 8 | 8 to 16 | 16 to 32 | > 32 |
| | | Very Soft | Soft | Stiff | Very Stiff | Hard |

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# Annex 2: SPT correction

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## Correction for SPT value as per Skempton(1986)

Depth of water table(m) 1

| S.N. | Bore Hole | Depth (m) | Unit Weight of Soil (kN/m$^3$) | SPT value Recorded /equivqlent of DCPTN$_{60}$ | Hammer Efficiency $E_m$ | Bore Dia Correction $C_B$ | Sampler Correction Cs | Rod Length Correction $C_R$ | Corrected SPT Value $N_{60}$ | Overburden Correction $C_N$ | Overburden and Dialatancy Corrected SPT $(N_1)_{60}$ | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | BH-01 | 1.50 | 15.50 | 86.00 | 0.55 | 1.00 | 1.00 | 0.70 | 78.83 | 1.98 | 62.20 | DCPT |
| 2 | BH-01 | 3.00 | 20.30 | 72.57 | 0.55 | 1.00 | 1.00 | 0.75 | 66.52 | 1.34 | 40.82 | DCPT |
| 3 | BH-01 | 4.50 | 20.30 | 92.00 | 0.55 | 1.00 | 1.00 | 0.85 | 84.33 | 1.04 | 44.65 | SPT |
| 4 | BH-01 | 6.00 | 20.30 | 77.71 | 0.55 | 1.00 | 1.00 | 0.95 | 71.24 | 0.94 | 39.26 | DCPT |
| 5 | BH-01 | 7.50 | 20.30 | 71.50 | 0.55 | 1.00 | 1.00 | 0.95 | 65.54 | 0.86 | 34.25 | DCPT |
| 6 | BH-01 | 9.00 | 16.45 | 68.00 | 0.55 | 1.00 | 1.00 | 0.95 | 62.33 | 0.81 | 31.36 | DCPT |
| 7 | BH-01 | 10.50 | 15.50 | 69.50 | 0.55 | 1.00 | 1.00 | 1.00 | 63.71 | 0.74 | 31.18 | DCPT |
| 8 | BH-01 | 12.00 | 20.30 | 71.00 | 0.55 | 1.00 | 1.00 | 1.00 | 65.08 | 0.68 | 29.73 | DCPT |
| 9 | BH-01 | 13.50 | 20.30 | 72.50 | 0.55 | 1.00 | 1.00 | 1.00 | 66.46 | 0.64 | 28.79 | DCPT |
| 10 | BH-01 | 15.00 | 16.99 | 70.50 | 0.55 | 1.00 | 1.00 | 1.00 | 64.63 | 0.62 | 27.43 | DCPT |
| 11 | BH-01 | 16.50 | 20.30 | 67.50 | 0.55 | 1.00 | 1.00 | 1.00 | 61.88 | 0.61 | 26.33 | DCPT |
| 12 | BH-01 | 18.00 | 20.30 | 66.00 | 0.55 | 1.00 | 1.00 | 1.00 | 60.50 | 0.60 | 25.79 | DCPT |
| 13 | BH-01 | 19.50 | 20.30 | 72.00 | 0.55 | 1.00 | 1.00 | 1.00 | 66.00 | 0.58 | 26.75 | DCPT |

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# Annex 3: Summary of Input Data

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## Design Input Data (Summary)

Project: Amlekhgunj Substation Construction Project

Location:Amlekhjung, Bara ,Nepal

Depth of water table(m) NA

| S.N. | Bore Hole | Depth(m) | Soil Type | Field SPT | Bulk unit weight(γ)kN/m$^3$ | Specific Gravity(G) | $D_{50}$ (mm) Infilling | Moisture Content(w)% | Modulus of Deformation kN/m$^2$ | Sub Grade Modulus kN/m3 B=0.3m | $N_{60}$ | $(N1)_{60}$ | Field Based | | Lab Based | | Design | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | φ | C (kPa) | φ | C (kPa) | φ | C (kPa) |
| 1 | BH-01 | 1.5 | GM | 86 | 15.50 | 2.50 | - | - | 39939 | 151715 | 78.83 | 62.2 | 33 | - | - | - | 32.68 | - |
| 2 | BH-01 | 3 | GM | 72.57 | 20.30 | 2.38 | 0.25 | 22.28 | 33703 | 128025 | 66.52 | 40.8 | 28 | - | 27.89 | 2.28 | 28.21 | 2.28 |
| 3 | BH-01 | 4.5 | GM | 92 | 20.30 | 2.41 | 0.23 | 24.31 | 42725 | 162300 | 84.33 | 44.7 | 29 | - | 21.78 | 0.91 | 21.78 | 0.91 |
| 4 | BH-01 | 6 | GM | 77.71 | 20.30 | 2.35 | 0.22 | 21.92 | 36091 | 137098 | 71.24 | 39.3 | 28 | - | 25.64 | 0.46 | 25.64 | 0.46 |
| 5 | BH-01 | 7.5 | GM | 71.5 | 20.30 | 2.37 | 0.25 | 22.86 | 33205 | 126135 | 65.54 | 34.3 | 27 | - | 26.94 | 1.37 | 26.94 | 1.37 |
| 6 | BH-01 | 9 | GM | 68 | 16.45 | 2.47 | 0.22 | 24.12 | 31580 | 119961 | 62.33 | 31.4 | 26 | - | 21.08 | 0.91 | 21.08 | 0.91 |
| 7 | BH-01 | 10.5 | GM | 69.5 | 15.50 | 2.50 | - | - | 32276 | 122607 | 63.71 | 31.2 | 26 | - | - | - | 26.2 | - |
| 8 | BH-01 | 12 | GM | 71 | 20.30 | 2.49 | 0.25 | 18.56 | 32973 | 125253 | 65.08 | 29.7 | 26 | - | 24.33 | 0.46 | 24.33 | 0.46 |
| 9 | BH-01 | 13.5 | GM | 72.5 | 20.30 | 2.59 | - | - | 33669 | 127899 | 66.46 | 28.8 | 26 | - | - | - | 25.7 | - |
| 10 | BH-01 | 15 | GM | 70.5 | 16.99 | 2.63 | - | - | 32741 | 124371 | 64.63 | 27.4 | 25 | - | - | - | 25.41 | - |
| 11 | BH-01 | 16.5 | GM | 67.5 | 20.30 | 2.45 | - | - | 31347 | 119079 | 61.88 | 26.3 | 25 | - | - | - | 25.18 | - |
| 12 | BH-01 | 18 | GM | 66 | 20.30 | 2.47 | - | - | 30651 | 116432 | 60.50 | 25.8 | 25 | - | - | - | 25.79 | - |
| 13 | BH-01 | 19.5 | GM | 72 | 20.30 | 2.45 | 0.25 | 24.81 | 33437 | 127017 | 66.00 | 26.7 | 25 | - | 22.21 | 0.68 | 22.21 | 0.68 |

GM: Gravel-Sand-Silt mixture

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# Annex 4: Bearing Capacity Calculation For Shallow Foundation

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## Determination of bearing capacity of open shallow foundation for BH-01

Depth of water table= 1 m

( * As soil layer is permiable more than 2m depth, so water level is considered to rise suddenly during rain)

| Length of footing L(m) | Breadth of footing B(m) | Depth of footing $D_f$(m) | Corrected SPT value ($N_{60}$) | Design Shear strength parameter lab test | | Design Shear strength parameter field test | | Unit weight of soil (γ) $kN/m^3$ | Effective Surge Charge at surface of footing kPa | Bearing Capacity Factors (Table 1 of IS6403:1981 | | | Bearing Capacity Factors (Table 1 of IS6403:1981 | | | Shape Factors (Table 2 of IS6403:1981 | | | Depth Factors (cl. 5.1.2.2 of IS6403:1981 | | | Inclination Factors (cl. 5.1.2.3 of IS6403:1981 | | | Effect of water factor (W') cl. 15.1.2.4 of IS6403 | Ultimate bearing capacity general shear failure ($q_{ult}$) kPa | Net allowable bearing capacity ($q_{na}$) kPa for FOS 3.0 | Gross allowable bearing capacity ($q_{na}$) kPa for FOS 3.0 | Safe bearing capacity based on settelement 25mm (qsafe) kPa | Safe allowable bearing capacity from DCPT value kPa |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | C kPa | φ | C kPa | φ | | | Nc | Nq | $N_\gamma$ | $N_c'$ | Nq' | Nγ' | Sc | Sq | $S_\gamma$ | $d_c$ | $d_q$ | $d_\gamma$ | $i_c$ | $i_q$ | $i_\gamma$ | | | | | | |
| 0.5 | 0.5 | 1 | 46.65 | 0.8 | 26 | 0 | 29.43 | 20.30 | 20.3 | 23 | 12 | 13.2 | 13 | 5.46 | 4.35 | 1.2 | 1.2 | 0.6 | 1.2 | 1.1 | 1.1 | 1 | 1 | 1 | 0.5 | 327.16 | 109.05 | 129.35 | 963.03 | 1377.43 |
| | | 1.5 | 46.65 | 0.88 | 27.8 | 0 | 29.43 | 20.30 | 25.545 | 26 | 15 | 17.3 | 14 | 6.13 | 5.09 | 1.2 | 1.2 | 0.6 | 1.3 | 1.2 | 1.15 | 1 | 1 | 1 | 0.5 | 619.25 | 206.42 | **231.96** | **963.03** | **1836.57** |
| | | 2 | 43.78 | 0.91 | 27 | 0 | 28.83 | 20.30 | 30.79 | 24 | 14 | 15.5 | 14 | 5.83 | 4.76 | 1.2 | 1.2 | 0.6 | 1.4 | 1.2 | 1.2 | 1 | 1 | 1 | 0.5 | 776.49 | 258.83 | 289.62 | 903.87 | 2023.84 |
| | | 3 | 35.92 | 1.59 | 24.85 | 0 | 27.19 | 20.3 | 41.28 | 21 | 11 | 10.7 | 13 | 5.04 | 3.88 | 1.2 | 1.2 | 0.6 | 1.6 | 1.3 | 1.29 | 1 | 1 | 1 | 0.5 | 927.00 | 309.00 | 350.28 | 741.59 | 1702.79 |
| | | 4 | 44.65 | 0.91 | 21.78 | 0 | 29.01 | 20.3 | 51.77 | 17 | 7.9 | 7.34 | 11 | 3.94 | 2.65 | 1.2 | 1.2 | 0.6 | 1.7 | 1.4 | 1.36 | 1 | 1 | 1 | 0.5 | 943.29 | 314.43 | 366.20 | 921.83 | 1606.72 |
| | | 5 | 41.96 | 0.68 | 23.71 | 0 | 28.45 | 20.3 | 62.26 | 19 | 9.6 | 9.46 | 12 | 4.63 | 3.42 | 1.2 | 1.2 | 0.6 | 1.9 | 1.5 | 1.47 | 1 | 1 | 1 | 0.5 | 1568.31 | 522.77 | 585.03 | 866.13 | 1533.14 |
| | | 6 | 39.26 | 0.46 | 25.64 | 0 | 27.88 | 20.3 | 72.75 | 22 | 12 | 12.4 | 13 | 5.33 | 4.2 | 1.2 | 1.2 | 0.6 | 2.2 | 1.6 | 1.59 | 1 | 1 | 1 | 0.5 | 2518.30 | 839.43 | 912.18 | 810.43 | 1470.81 |
| | | 7 | 34.25 | 1.37 | 26.94 | 0 | 26.84 | 20.3 | 83.24 | 24 | 14 | 15.3 | 14 | 5.81 | 4.73 | 1.2 | 1.2 | 0.6 | 2.4 | 1.7 | 1.71 | 1 | 1 | 1 | 0.5 | 3731.32 | 1243.77 | 1327.01 | 707.07 | 1405.17 |
| | | 8 | 32.81 | 1.14 | 24.01 | 0 | 26.54 | 20.3 | 93.73 | 20 | 9.8 | 9.79 | 12 | 4.74 | 3.54 | 1.2 | 1.2 | 0.6 | 2.5 | 1.8 | 1.76 | 1 | 1 | 1 | 0.5 | 3069.15 | 1023.05 | 1116.78 | 677.25 | 1350.61 |
| | | 9 | 31.36 | 0.91 | 21.08 | 0 | 26.23 | 20.3 | 104.22 | 16 | 7.3 | 6.58 | 11 | 3.79 | 2.5 | 1.2 | 1.2 | 0.6 | 2.6 | 1.8 | 1.81 | 1 | 1 | 1 | 0.5 | 2537.25 | 845.75 | 949.97 | 647.42 | 1303.43 |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | 3 | 1 | 47.01 | 0.8 | 26 | 0 | 29.51 | 20.30 | 20.3 | 23 | 12 | 13.2 | 13 | 5.46 | 4.35 | 1.2 | 1.2 | 0.6 | 1 | 1 | 1.02 | 1 | 1 | 1 | 0.5 | 305.98 | 101.99 | 122.29 | 379.34 | 231.36 |
| | | 1.5 | 47.01 | 0.88 | 27.8 | 0 | 29.51 | 20.30 | 25.545 | 26 | 15 | 17.3 | 14 | 6.13 | 5.09 | 1.2 | 1.2 | 0.6 | 1.1 | 1 | 1.03 | 1 | 1 | 1 | 0.5 | 554.85 | 184.95 | **210.50** | **398.14** | **308.48** |
| | | 2 | 43.41 | 0.91 | 27 | 0 | 28.75 | 20.30 | 30.79 | 24 | 14 | 15.5 | 14 | 5.83 | 4.76 | 1.2 | 1.2 | 0.6 | 1.1 | 1 | 1.03 | 1 | 1 | 1 | 0.5 | 671.01 | 223.67 | 254.46 | 385.02 | 338.19 |
| | | 3 | 34.73 | 1.59 | 24.85 | 0 | 26.94 | 20.3 | 41.28 | 21 | 11 | 10.7 | 13 | 5.04 | 3.88 | 1.2 | 1.2 | 0.6 | 1.1 | 1 | 1.05 | 1 | 1 | 1 | 0.5 | 754.05 | 251.35 | 292.63 | 335.79 | 282.43 |
| | | 4 | 44.90 | 0.91 | 21.78 | 0 | 29.06 | 20.3 | 51.77 | 17 | 7.9 | 7.34 | 11 | 3.94 | 2.65 | 1.2 | 1.2 | 0.6 | 1.1 | 1.1 | 1.06 | 1 | 1 | 1 | 0.5 | 733.51 | 244.50 | 296.27 | 434.10 | 267.06 |
| | | 5 | 41.80 | 0.68 | 23.71 | 0 | 28.42 | 20.3 | 62.26 | 19 | 9.6 | 9.46 | 12 | 4.63 | 3.42 | 1.2 | 1.2 | 0.6 | 1.2 | 1.1 | 1.08 | 1 | 1 | 1 | 0.5 | 1147.91 | 382.64 | 444.90 | 404.11 | 254.79 |
| | | 6 | 38.69 | 0.46 | 25.64 | 0 | 27.77 | 20.3 | 72.75 | 22 | 12 | 12.4 | 13 | 5.33 | 4.2 | 1.2 | 1.2 | 0.6 | 1.2 | 1.1 | 1.1 | 1 | 1 | 1 | 0.5 | 1738.77 | 579.59 | 652.34 | 374.11 | 244.06 |
| | | 7 | 33.63 | 1.37 | 26.94 | 0 | 26.71 | 20.3 | 83.24 | 24 | 14 | 15.3 | 14 | 5.81 | 4.73 | 1.2 | 1.2 | 0.6 | 1.2 | 1.1 | 1.12 | 1 | 1 | 1 | 0.5 | 2444.48 | 814.83 | 898.07 | 325.18 | 232.84 |
| | | 8 | 32.57 | 1.14 | 24.01 | 0 | 26.49 | 20.3 | 93.73 | 20 | 9.8 | 9.79 | 12 | 4.74 | 3.54 | 1.2 | 1.2 | 0.6 | 1.3 | 1.1 | 1.13 | 1 | 1 | 1 | 0.5 | 1961.17 | 653.72 | 747.45 | 314.89 | 223.77 |
| | | 9 | 31.50 | 0.91 | 21.08 | 0 | 26.26 | 20.3 | 104.22 | 16 | 7.3 | 6.58 | 11 | 3.79 | 2.5 | 1.2 | 1.2 | 0.6 | 1.3 | 1.1 | 1.13 | 1 | 1 | 1 | 0.5 | 1591.80 | 530.60 | 634.82 | 304.60 | 216.14 |
| 4 | 4 | 1 | 47.01 | 0.8 | 26 | 0 | 29.51 | 20.30 | 20.3 | 23 | 12 | 13.2 | 13 | 5.46 | 4.35 | 1.2 | 1.2 | 0.6 | 1 | 1 | 1.01 | 1 | 1 | 1 | 0.5 | 306.65 | 102.22 | 122.52 | 353.08 | 173.52 |
| | | 1.5 | 47.01 | 0.88 | 27.8 | 0 | 29.51 | 20.30 | 25.545 | 26 | 15 | 17.3 | 14 | 6.13 | 5.09 | 1.2 | 1.2 | 0.6 | 1 | 1 | 1.02 | 1 | 1 | 1 | 0.5 | 553.90 | 184.63 | **210.18** | **366.53** | **231.36** |
| | | 2 | 43.41 | 0.91 | 27 | 0 | 28.75 | 20.30 | 30.79 | 24 | 14 | 15.5 | 14 | 5.83 | 4.76 | 1.2 | 1.2 | 0.6 | 1.1 | 1 | 1.03 | 1 | 1 | 1 | 0.5 | 667.77 | 222.59 | 253.38 | 350.90 | 253.64 |
| | | 3 | 34.73 | 1.59 | 24.85 | 0 | 26.94 | 20.3 | 41.28 | 21 | 11 | 10.7 | 13 | 5.04 | 3.88 | 1.2 | 1.2 | 0.6 | 1.1 | 1 | 1.04 | 1 | 1 | 1 | 0.5 | 746.81 | 248.94 | 290.22 | 320.48 | 211.82 |
| | | 4 | 44.90 | 0.91 | 21.78 | 0 | 29.06 | 20.3 | 51.77 | 17 | 7.9 | 7.34 | 11 | 3.94 | 2.65 | 1.2 | 1.2 | 0.6 | 1.1 | 1 | 1.05 | 1 | 1 | 1 | 0.5 | 723.98 | 241.33 | 293.10 | 414.31 | 200.30 |
| | | 5 | 41.80 | 0.68 | 23.71 | 0 | 28.42 | 20.3 | 62.26 | 19 | 9.6 | 9.46 | 12 | 4.63 | 3.42 | 1.2 | 1.2 | 0.6 | 1.1 | 1.1 | 1.06 | 1 | 1 | 1 | 0.5 | 1128.13 | 376.04 | 438.30 | 385.68 | 191.09 |
| | | 6 | 38.69 | 0.46 | 25.64 | 0 | 27.77 | 20.3 | 72.75 | 22 | 12 | 12.4 | 13 | 5.33 | 4.2 | 1.2 | 1.2 | 0.6 | 1.1 | 1.1 | 1.07 | 1 | 1 | 1 | 0.5 | 1701.42 | 567.14 | 639.89 | 357.05 | 183.05 |
| | | 7 | 33.63 | 1.37 | 26.94 | 0 | 26.71 | 20.3 | 83.24 | 24 | 14 | 15.3 | 14 | 5.81 | 4.73 | 1.2 | 1.2 | 0.6 | 1.2 | 1.1 | 1.09 | 1 | 1 | 1 | 0.5 | 2382.15 | 794.05 | 877.29 | 310.35 | 174.63 |
| | | 8 | 32.57 | 1.14 | 24.01 | 0 | 26.49 | 20.3 | 93.73 | 20 | 9.8 | 9.79 | 12 | 4.74 | 3.54 | 1.2 | 1.2 | 0.6 | 1.2 | 1.1 | 1.1 | 1 | 1 | 1 | 0.5 | 1907.06 | 635.69 | 729.42 | 300.53 | 167.83 |
| | | 9 | 31.50 | 0.91 | 21.08 | 0 | 26.26 | 20.3 | 104.22 | 16 | 7.3 | 6.58 | 11 | 3.79 | 2.5 | 1.2 | 1.2 | 0.6 | 1.2 | 1.1 | 1.1 | 1 | 1 | 1 | 0.5 | 1545.40 | 515.13 | 619.35 | 290.71 | 162.10 |

Tested By:
Sabin Poudel Khatri

Approved By:
Geotech Er. Aanand Mishra
NEC No. 6933 "CIVIL"

# EXPERT TESTING LABORATORY PVT. LTD.

BAFAL, LALITPUR-17

Gmail: experttestlab078@gmail.com

| Length of footing L(m) | Breadth of footing B(m) | Depth of footing $D_f$(m) | Corrected SPT value ($N_{60}$) | Design Shear strength parameter lab test C kPa | Design Shear strength parameter lab test φ | Design Shear strength parameter field test C kPa | Design Shear strength parameter field test φ | Unit weight of soil (γ) kN/m³ | Effective Surge Charge at surface of footing kPa | Bearing Capacity Factors (Table 1 of IS6403:1981) Nc | Nq | $N_\gamma$ | Bearing Capacity Factors (Table 1 of IS6403:1981) $N_c'$ | Nq' | Nγ' | Shape Factors (Table 2 of IS6403:1981) Sc | Sq | $S_\gamma$ | Depth Factors (cl. 5.1.2.2 of IS6403:1981) $d_c$ | $d_q$ | $d_\gamma$ | Incination Factors (cl. 5.1.2.3 of IS6403:1981) $i_c$ | $i_q$ | $i_\gamma$ | Effect of water factor (W') cl. 15.1.2.4 of IS6408 | Ultimate bearing capacity general shear failure ($q_{ult}$) kPa | Net allowable bearing capacity ($q_{na}$) kPa for FOS 3.0 | Gross allowable bearing capacity ($q_{na}$) kPa for FOS 3.0 | Safe bearing capacity based on settelement 40mm (qsafe) kPa | Safe allowable bearing capacity from SPT value kPa |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 5 | 1 | 47.01 | 0.8 | 26 | 0 | 29.51 | 20.30 | 20.3 | 23 | 12 | 13.2 | 13 | 5.46 | 4.35 | 1.2 | 1.2 | 0.6 | 1 | 1 | 1.01 | 1 | 1 | 1 | 0.5 | 307.85 | 102.62 | 122.92 | 337.92 | 138.82 |
| | | 1.5 | 47.01 | 0.88 | 27.8 | 0 | 29.51 | 20.30 | 25.545 | 26 | 15 | 17.3 | 14 | 6.13 | 5.09 | 1.2 | 1.2 | 0.6 | 1 | 1 | 1.02 | 1 | 1 | 1 | 0.5 | 554.38 | 184.79 | **210.34** | **348.38** | **185.09** |
| | | 2 | 43.41 | 0.91 | 27 | 0 | 28.75 | 20.30 | 30.79 | 24 | 14 | 15.5 | 14 | 5.83 | 4.76 | 1.2 | 1.2 | 0.6 | 1 | 1 | 1.02 | 1 | 1 | 1 | 0.5 | 666.76 | 222.25 | 253.04 | 331.37 | 202.91 |
| | | 3 | 34.73 | 1.59 | 24.85 | 0 | 26.94 | 20.3 | 41.28 | 21 | 11 | 10.7 | 13 | 5.04 | 3.88 | 1.2 | 1.2 | 0.6 | 1.1 | 1 | 1.03 | 1 | 1 | 1 | 0.5 | 743.11 | 247.70 | 288.98 | 311.46 | 169.46 |
| | | 4 | 44.90 | 0.91 | 21.78 | 0 | 29.06 | 20.3 | 51.77 | 17 | 7.9 | 7.34 | 11 | 3.94 | 2.65 | 1.2 | 1.2 | 0.6 | 1.1 | 1 | 1.04 | 1 | 1 | 1 | 0.5 | 718.71 | 239.57 | 291.34 | 382.68 | 160.24 |
| | | 5 | 41.80 | 0.68 | 23.71 | 0 | 28.42 | 20.3 | 62.26 | 19 | 9.6 | 9.46 | 12 | 4.63 | 3.42 | 1.2 | 1.2 | 0.6 | 1.1 | 1 | 1.05 | 1 | 1 | 1 | 0.5 | 1116.83 | 372.28 | 434.54 | 374.83 | 152.87 |
| | | 6 | 38.69 | 0.46 | 25.64 | 0 | 27.77 | 20.3 | 72.75 | 22 | 12 | 12.4 | 13 | 5.33 | 4.2 | 1.2 | 1.2 | 0.6 | 1.1 | 1.1 | 1.06 | 1 | 1 | 1 | 0.5 | 1679.75 | 559.92 | 632.67 | 347.01 | 146.44 |
| | | 7 | 33.63 | 1.37 | 26.94 | 0 | 26.71 | 20.3 | 83.24 | 24 | 14 | 15.3 | 14 | 5.81 | 4.73 | 1.2 | 1.2 | 0.6 | 1.1 | 1.1 | 1.07 | 1 | 1 | 1 | 0.5 | 2345.67 | 781.89 | 865.13 | 301.62 | 139.71 |
| | | 8 | 32.57 | 1.14 | 24.01 | 0 | 26.49 | 20.3 | 93.73 | 20 | 9.8 | 9.79 | 12 | 4.74 | 3.54 | 1.2 | 1.2 | 0.6 | 1.2 | 1.1 | 1.08 | 1 | 1 | 1 | 0.5 | 1875.18 | 625.06 | 718.79 | 292.08 | 134.26 |
| | | 9 | 31.50 | 0.91 | 21.08 | 0 | 26.26 | 20.3 | 104.22 | 16 | 7.3 | 6.58 | 11 | 3.79 | 2.5 | 1.2 | 1.2 | 0.6 | 1.2 | 1.1 | 1.08 | 1 | 1 | 1 | 0.5 | 1517.94 | 505.98 | 610.20 | 282.53 | 129.68 |
| 6 | 6 | 1 | 47.01 | 0.8 | 26 | 0 | 29.51 | 20.30 | 20.3 | 23 | 12 | 13.2 | 13 | 5.46 | 4.35 | 1.2 | 1.2 | 0.6 | 1 | 1 | 1.01 | 1 | 1 | 1 | 0.5 | 309.30 | 103.10 | 123.40 | 328.05 | 115.68 |
| | | 1.5 | 47.01 | 0.88 | 27.8 | 0 | 29.51 | 20.30 | 25.545 | 26 | 15 | 17.3 | 14 | 6.13 | 5.09 | 1.2 | 1.2 | 0.6 | 1 | 1 | 1.01 | 1 | 1 | 1 | 0.5 | 555.56 | 185.19 | **210.73** | **336.60** | **154.24** |
| | | 2 | 43.41 | 0.91 | 27 | 0 | 28.75 | 20.30 | 30.79 | 24 | 14 | 15.5 | 14 | 5.83 | 4.76 | 1.2 | 1.2 | 0.6 | 1 | 1 | 1.02 | 1 | 1 | 1 | 0.5 | 666.85 | 222.28 | 253.07 | 318.73 | 169.09 |
| | | 3 | 34.73 | 1.59 | 24.85 | 0 | 26.94 | 20.3 | 41.28 | 21 | 11 | 10.7 | 13 | 5.04 | 3.88 | 1.2 | 1.2 | 0.6 | 1 | 1 | 1.02 | 1 | 1 | 1 | 0.5 | 741.18 | 247.06 | 288.34 | 292.89 | 141.22 |
| | | 4 | 44.90 | 0.91 | 21.78 | 0 | 29.06 | 20.3 | 51.77 | 17 | 7.9 | 7.34 | 11 | 3.94 | 2.65 | 1.2 | 1.2 | 0.6 | 1.1 | 1 | 1.03 | 1 | 1 | 1 | 0.5 | 715.56 | 238.52 | 290.29 | 362.31 | 133.53 |
| | | 5 | 41.80 | 0.68 | 23.71 | 0 | 28.42 | 20.3 | 62.26 | 19 | 9.6 | 9.46 | 12 | 4.63 | 3.42 | 1.2 | 1.2 | 0.6 | 1.1 | 1 | 1.04 | 1 | 1 | 1 | 0.5 | 1109.77 | 369.92 | 432.18 | 352.48 | 127.40 |
| | | 6 | 38.69 | 0.46 | 25.64 | 0 | 27.77 | 20.3 | 72.75 | 22 | 12 | 12.4 | 13 | 5.33 | 4.2 | 1.2 | 1.2 | 0.6 | 1.1 | 1 | 1.05 | 1 | 1 | 1 | 0.5 | 1665.92 | 555.31 | 628.06 | 340.39 | 122.03 |
| | | 7 | 33.63 | 1.37 | 26.94 | 0 | 26.71 | 20.3 | 83.24 | 24 | 14 | 15.3 | 14 | 5.81 | 4.73 | 1.2 | 1.2 | 0.6 | 1.1 | 1.1 | 1.06 | 1 | 1 | 1 | 0.5 | 2322.12 | 774.04 | 857.28 | 295.87 | 116.42 |
| | | 8 | 32.57 | 1.14 | 24.01 | 0 | 26.49 | 20.3 | 93.73 | 20 | 9.8 | 9.79 | 12 | 4.74 | 3.54 | 1.2 | 1.2 | 0.6 | 1.1 | 1.1 | 1.06 | 1 | 1 | 1 | 0.5 | 1854.41 | 618.14 | 711.87 | 286.51 | 111.89 |
| | | 9 | 31.50 | 0.91 | 21.08 | 0 | 26.26 | 20.3 | 104.22 | 16 | 7.3 | 6.58 | 11 | 3.79 | 2.5 | 1.2 | 1.2 | 0.6 | 1.1 | 1.1 | 1.07 | 1 | 1 | 1 | 0.5 | 1499.97 | 499.99 | 604.21 | 277.14 | 108.07 |
| 7 | 7 | 1 | 47.01 | 0.8 | 26 | 0 | 29.51 | 20.30 | 20.3 | 23 | 12 | 13.2 | 13 | 5.46 | 4.35 | 1.2 | 1.2 | 0.6 | 1 | 1 | 1.01 | 1 | 1 | 1 | 0.5 | 310.91 | 103.64 | 123.94 | 321.13 | 99.15 |
| | | 1.5 | 47.01 | 0.88 | 27.8 | 0 | 29.51 | 20.30 | 25.545 | 26 | 15 | 17.3 | 14 | 6.13 | 5.09 | 1.2 | 1.2 | 0.6 | 1 | 1 | 1.01 | 1 | 1 | 1 | 0.5 | 557.15 | 185.72 | **211.26** | **328.35** | **132.21** |
| | | 2 | 43.41 | 0.91 | 27 | 0 | 28.75 | 20.30 | 30.79 | 24 | 14 | 15.5 | 14 | 5.83 | 4.76 | 1.2 | 1.2 | 0.6 | 1 | 1 | 1.01 | 1 | 1 | 1 | 0.5 | 667.59 | 222.53 | 253.32 | 309.90 | 144.94 |
| | | 3 | 34.73 | 1.59 | 24.85 | 0 | 26.94 | 20.3 | 41.28 | 21 | 11 | 10.7 | 13 | 5.04 | 3.88 | 1.2 | 1.2 | 0.6 | 1 | 1 | 1.02 | 1 | 1 | 1 | 0.5 | 740.26 | 246.75 | 288.03 | 279.96 | 121.04 |
| | | 4 | 44.90 | 0.91 | 21.78 | 0 | 29.06 | 20.3 | 51.77 | 17 | 7.9 | 7.34 | 11 | 3.94 | 2.65 | 1.2 | 1.2 | 0.6 | 1.1 | 1 | 1.03 | 1 | 1 | 1 | 0.5 | 713.62 | 237.87 | 289.64 | 348.12 | 114.46 |
| | | 5 | 41.80 | 0.68 | 23.71 | 0 | 28.42 | 20.3 | 62.26 | 19 | 9.6 | 9.46 | 12 | 4.63 | 3.42 | 1.2 | 1.2 | 0.6 | 1.1 | 1 | 1.03 | 1 | 1 | 1 | 0.5 | 1105.13 | 368.38 | 430.64 | 336.92 | 109.20 |
| | | 6 | 38.69 | 0.46 | 25.64 | 0 | 27.77 | 20.3 | 72.75 | 22 | 12 | 12.4 | 13 | 5.33 | 4.2 | 1.2 | 1.2 | 0.6 | 1.1 | 1 | 1.04 | 1 | 1 | 1 | 0.5 | 1656.57 | 552.19 | 624.94 | 323.80 | 104.60 |
| | | 7 | 33.63 | 1.37 | 26.94 | 0 | 26.71 | 20.3 | 83.24 | 24 | 14 | 15.3 | 14 | 5.81 | 4.73 | 1.2 | 1.2 | 0.6 | 1.1 | 1.1 | 1.05 | 1 | 1 | 1 | 0.5 | 2305.96 | 768.65 | 851.89 | 291.80 | 99.79 |
| | | 8 | 32.57 | 1.14 | 24.01 | 0 | 26.49 | 20.3 | 93.73 | 20 | 9.8 | 9.79 | 12 | 4.74 | 3.54 | 1.2 | 1.2 | 0.6 | 1.1 | 1.1 | 1.05 | 1 | 1 | 1 | 0.5 | 1840.00 | 613.33 | 707.06 | 282.56 | 95.90 |
| | | 9 | 31.50 | 0.91 | 21.08 | 0 | 26.26 | 20.3 | 104.22 | 16 | 7.3 | 6.58 | 11 | 3.79 | 2.5 | 1.2 | 1.2 | 0.6 | 1.1 | 1.1 | 1.06 | 1 | 1 | 1 | 0.5 | 1487.42 | 495.81 | 600.03 | 273.33 | 92.63 |

Tested By:
Sabin Poudel Khatri

Approved By:
Geotech Er. Aanand Mishra
NEC No. 6933 "CIVIL"

# EXPERT TESTING LABORATORY PVT. LTD.

BAFAL, LALITPUR-17

Gmail: experttestlab078@gmail.com

| Length of footing L(m) | Breadth of footing B(m) | Depth of footing $D_f$(m) | Corrected SPT value ($N_{60}$) | Design Shear strength parameter lab test | | Design Shear strength parameter field test | | Unit weight of soil (γ) kN/m³ | Effective Surge Charge at surface of footing kPa | Bearing Capacity Factors (Table 1 of IS6403:1981 | | | Bearing Capacity Factors (Table 1 of IS6403:1981 | | | Shape Factors (Table 2 of IS6403:1981 | | | Depth Factors (cl. 5.1.2.2 of IS6403:1981 | | | Inclination Factors (cl. 5.1.2.3 of IS6403:1981 | | | Effect of water factor (W') cl. 15.1.2.4 of IS6403 | Ultimate bearing capacity general shear failure ($q_{ult}$) kPa | Net allowable bearing capacity ($q_{na}$) kPa for FOS 3.0 | Gross allowable bearing capacity ($q_{na}$) kPa for FOS 3.0 | Safe bearing capacity based on settelement 40mm (qsafe) kPa | Safe allowable bearing capacity from SPT value kPa |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | C kPa | φ | C kPa | φ | | | Nc | Nq | $N_\gamma$ | $N_c'$ | Nq' | Nγ' | Sc | Sq | $S_\gamma$ | $d_c$ | $d_q$ | $d_\gamma$ | $i_c$ | $i_q$ | $i_\gamma$ | | | | | | |
| 1 | 1 | 1 | 47.01 | 0.8 | 26 | 0 | 29.51 | 20.30 | 20.3 | 23 | 12 | 13.2 | 13 | 5.46 | 4.35 | 1.2 | 1.2 | 0.6 | 1.1 | 1 | 1.05 | 1 | 1 | 1 | 0.5 | 312.48 | 104.16 | 124.46 | 637.72 | 694.08 |
| | | 1.5 | 47.01 | 0.88 | 27.8 | 0 | 29.51 | 20.30 | 25.545 | 26 | 15 | 17.3 | 14 | 6.13 | 5.09 | 1.2 | 1.2 | 0.6 | 1.2 | 1.1 | 1.08 | 1 | 1 | 1 | 0.5 | 578.01 | 192.67 | **218.22** | **637.72** | **925.44** |
| | | 2 | 43.41 | 0.91 | 27 | 0 | 28.75 | 20.30 | 30.79 | 24 | 14 | 15.5 | 14 | 5.83 | 4.76 | 1.2 | 1.2 | 0.6 | 1.2 | 1.1 | 1.1 | 1 | 1 | 1 | 0.5 | 710.88 | 236.96 | 267.75 | 588.91 | 1014.56 |
| | | 3 | 34.73 | 1.59 | 24.85 | 0 | 26.94 | 20.3 | 41.28 | 21 | 11 | 10.7 | 13 | 5.04 | 3.88 | 1.2 | 1.2 | 0.6 | 1.3 | 1.1 | 1.15 | 1 | 1 | 1 | 0.5 | 821.62 | 273.87 | 315.15 | 471.12 | 847.29 |
| | | 4 | 44.90 | 0.91 | 21.78 | 0 | 29.06 | 20.3 | 51.77 | 17 | 7.9 | 7.34 | 11 | 3.94 | 2.65 | 1.2 | 1.2 | 0.6 | 1.4 | 1.2 | 1.18 | 1 | 1 | 1 | 0.5 | 816.32 | 272.11 | 323.88 | 609.07 | 801.19 |
| | | 5 | 41.80 | 0.68 | 23.71 | 0 | 28.42 | 20.3 | 62.26 | 19 | 9.6 | 9.46 | 12 | 4.63 | 3.42 | 1.2 | 1.2 | 0.6 | 1.5 | 1.2 | 1.24 | 1 | 1 | 1 | 0.5 | 1314.65 | 438.22 | 500.48 | 566.98 | 764.37 |
| | | 6 | 38.69 | 0.46 | 25.64 | 0 | 27.77 | 20.3 | 72.75 | 22 | 12 | 12.4 | 13 | 5.33 | 4.2 | 1.2 | 1.2 | 0.6 | 1.6 | 1.3 | 1.3 | 1 | 1 | 1 | 0.5 | 2048.73 | 682.91 | 755.66 | 524.89 | 732.19 |
| | | 7 | 33.63 | 1.37 | 26.94 | 0 | 26.71 | 20.3 | 83.24 | 24 | 14 | 15.3 | 14 | 5.81 | 4.73 | 1.2 | 1.2 | 0.6 | 1.7 | 1.4 | 1.35 | 1 | 1 | 1 | 0.5 | 2956.92 | 985.64 | 1068.88 | 456.24 | 698.53 |
| | | 8 | 32.57 | 1.14 | 24.01 | 0 | 26.49 | 20.3 | 93.73 | 20 | 9.8 | 9.79 | 12 | 4.74 | 3.54 | 1.2 | 1.2 | 0.6 | 1.8 | 1.4 | 1.38 | 1 | 1 | 1 | 0.5 | 2402.90 | 800.97 | 894.70 | 441.80 | 671.32 |
| | | 9 | 31.50 | 0.91 | 21.08 | 0 | 26.26 | 20.3 | 104.22 | 16 | 7.3 | 6.58 | 11 | 3.79 | 2.5 | 1.2 | 1.2 | 0.6 | 1.8 | 1.4 | 1.4 | 1 | 1 | 1 | 0.5 | 1969.00 | 656.33 | 760.55 | 427.36 | 648.41 |
| 1 | 1.5 | 1 | 47.01 | 0.8 | 26 | 0 | 29.51 | 20.30 | 20.3 | 23 | 12 | 13.2 | 13 | 5.46 | 4.35 | 1.3 | 1.3 | 0.4 | 1.1 | 1 | 1.03 | 1 | 1 | 1 | 0.5 | 332.65 | 110.88 | 131.18 | 497.41 | 462.72 |
| | | 1.5 | 47.01 | 0.88 | 27.8 | 0 | 29.51 | 20.30 | 25.545 | 26 | 15 | 17.3 | 14 | 6.13 | 5.09 | 1.3 | 1.3 | 0.4 | 1.1 | 1.1 | 1.05 | 1 | 1 | 1 | 0.5 | 610.52 | 203.51 | **229.05** | **542.26** | **616.96** |
| | | 2 | 43.41 | 0.91 | 27 | 0 | 28.75 | 20.30 | 30.79 | 24 | 14 | 15.5 | 14 | 5.83 | 4.76 | 1.3 | 1.3 | 0.4 | 1.1 | 1.1 | 1.07 | 1 | 1 | 1 | 0.5 | 745.72 | 248.57 | 279.36 | 500.75 | 676.37 |
| | | 3 | 34.73 | 1.59 | 24.85 | 0 | 26.94 | 20.3 | 41.28 | 21 | 11 | 10.7 | 13 | 5.04 | 3.88 | 1.3 | 1.3 | 0.4 | 1.2 | 1.1 | 1.1 | 1 | 1 | 1 | 0.5 | 851.52 | 283.84 | 325.12 | 400.60 | 564.86 |
| | | 4 | 44.90 | 0.91 | 21.78 | 0 | 29.06 | 20.3 | 51.77 | 17 | 7.9 | 7.34 | 11 | 3.94 | 2.65 | 1.3 | 1.3 | 0.4 | 1.2 | 1.1 | 1.12 | 1 | 1 | 1 | 0.5 | 838.12 | 279.37 | 331.14 | 517.89 | 534.13 |
| | | 5 | 41.80 | 0.68 | 23.71 | 0 | 28.42 | 20.3 | 62.26 | 19 | 9.6 | 9.46 | 12 | 4.63 | 3.42 | 1.3 | 1.3 | 0.4 | 1.3 | 1.2 | 1.16 | 1 | 1 | 1 | 0.5 | 1332.09 | 444.03 | 506.29 | 482.10 | 509.58 |
| | | 6 | 38.69 | 0.46 | 25.64 | 0 | 27.77 | 20.3 | 72.75 | 22 | 12 | 12.4 | 13 | 5.33 | 4.2 | 1.3 | 1.3 | 0.4 | 1.4 | 1.2 | 1.2 | 1 | 1 | 1 | 0.5 | 2049.17 | 683.06 | 755.81 | 446.31 | 488.13 |
| | | 7 | 33.63 | 1.37 | 26.94 | 0 | 26.71 | 20.3 | 83.24 | 24 | 14 | 15.3 | 14 | 5.81 | 4.73 | 1.3 | 1.3 | 0.4 | 1.5 | 1.2 | 1.24 | 1 | 1 | 1 | 0.5 | 2922.73 | 974.24 | 1057.48 | 387.94 | 465.69 |
| | | 8 | 32.57 | 1.14 | 24.01 | 0 | 26.49 | 20.3 | 93.73 | 20 | 9.8 | 9.79 | 12 | 4.74 | 3.54 | 1.3 | 1.3 | 0.4 | 1.5 | 1.3 | 1.25 | 1 | 1 | 1 | 0.5 | 2361.93 | 787.31 | 881.04 | 375.66 | 447.55 |
| | | 9 | 31.50 | 0.91 | 21.08 | 0 | 26.26 | 20.3 | 104.22 | 16 | 7.3 | 6.58 | 11 | 3.79 | 2.5 | 1.3 | 1.3 | 0.4 | 1.5 | 1.3 | 1.27 | 1 | 1 | 1 | 0.5 | 1927.45 | 642.48 | 746.70 | 363.39 | 432.27 |
| 0.5 | 0.5 | 1 | 47.01 | 0.8 | 26 | 0 | 29.51 | 20.30 | 20.3 | 23 | 12 | 13.2 | 13 | 5.46 | 4.35 | 1.2 | 1.2 | 0.6 | 1.2 | 1.1 | 1.1 | 1 | 1 | 1 | 0.5 | 327.16 | 109.05 | 129.35 | 970.54 | 1388.16 |
| | | 1.5 | 47.01 | 0.88 | 27.8 | 0 | 29.51 | 20.30 | 25.545 | 26 | 15 | 17.3 | 14 | 6.13 | 5.09 | 1.2 | 1.2 | 0.6 | 1.3 | 1.2 | 1.15 | 1 | 1 | 1 | 0.5 | 619.25 | 206.42 | **231.96** | **970.54** | **1850.89** |
| | | 2 | 43.41 | 0.91 | 27 | 0 | 28.75 | 20.30 | 30.79 | 24 | 14 | 15.5 | 14 | 5.83 | 4.76 | 1.2 | 1.2 | 0.6 | 1.4 | 1.2 | 1.2 | 1 | 1 | 1 | 0.5 | 776.49 | 258.83 | 289.62 | 896.24 | 2029.12 |
| | | 3 | 34.73 | 1.59 | 24.85 | 0 | 26.94 | 20.3 | 41.28 | 21 | 11 | 10.7 | 13 | 5.04 | 3.88 | 1.2 | 1.2 | 0.6 | 1.6 | 1.3 | 1.29 | 1 | 1 | 1 | 0.5 | 927.00 | 309.00 | 350.28 | 716.99 | 1694.58 |
| | | 4 | 44.90 | 0.91 | 21.78 | 0 | 29.06 | 20.3 | 51.77 | 17 | 7.9 | 7.34 | 11 | 3.94 | 2.65 | 1.2 | 1.2 | 0.6 | 1.7 | 1.4 | 1.36 | 1 | 1 | 1 | 0.5 | 943.29 | 314.43 | 366.20 | 926.93 | 1602.38 |
| | | 5 | 41.80 | 0.68 | 23.71 | 0 | 28.42 | 20.3 | 62.26 | 19 | 9.6 | 9.46 | 12 | 4.63 | 3.42 | 1.2 | 1.2 | 0.6 | 1.9 | 1.5 | 1.47 | 1 | 1 | 1 | 0.5 | 1568.31 | 522.77 | 585.03 | 862.87 | 1528.74 |
| | | 6 | 38.69 | 0.46 | 25.64 | 0 | 27.77 | 20.3 | 72.75 | 22 | 12 | 12.4 | 13 | 5.33 | 4.2 | 1.2 | 1.2 | 0.6 | 2.2 | 1.6 | 1.59 | 1 | 1 | 1 | 0.5 | 2518.30 | 839.43 | 912.18 | 798.82 | 1464.38 |
| | | 7 | 33.63 | 1.37 | 26.94 | 0 | 26.71 | 20.3 | 83.24 | 24 | 14 | 15.3 | 14 | 5.81 | 4.73 | 1.2 | 1.2 | 0.6 | 2.4 | 1.7 | 1.71 | 1 | 1 | 1 | 0.5 | 3731.32 | 1243.77 | 1327.01 | 694.35 | 1397.06 |
| | | 8 | 32.57 | 1.14 | 24.01 | 0 | 26.49 | 20.3 | 93.73 | 20 | 9.8 | 9.79 | 12 | 4.74 | 3.54 | 1.2 | 1.2 | 0.6 | 2.5 | 1.8 | 1.76 | 1 | 1 | 1 | 0.5 | 3069.15 | 1023.05 | 1116.78 | 672.37 | 1342.64 |
| | | 9 | 31.50 | 0.91 | 21.08 | 0 | 26.26 | 20.3 | 104.22 | 16 | 7.3 | 6.58 | 11 | 3.79 | 2.5 | 1.2 | 1.2 | 0.6 | 2.6 | 1.8 | 1.81 | 1 | 1 | 1 | 0.5 | 2537.25 | 845.75 | 949.97 | 650.39 | 1296.82 |

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# Annex 5: Settlement Calculation for Shallow Foundation

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## Shettlement Calculation For BH-01

Project: Amlekhgunj Substation Construction Project

Location: Amlekhjung, Bara ,Nepal

Ground Water Level(m) 1

Size of Footing : 2mX2m

Depth of foundation (m)= 1.5

Stress from foundation for settlement calculation(qu) kN/m$^2$= 200

Unit weight of Back fill 18

| S.N. | Depth of Layer(m) | Thickness of layer (m) | Soil Type | Corrected SPT($N_{60}$) | Bulk unit weight(γ)kN/m$^3$ | Effective Stress at base of footing (kN/m$^2$) | Over Burden Stress (kN/m$^2$) | Initial Void Ratio($e_o$) | $D_{50}$ | $q_c/N$ | Cone penetration resistance value ($q_c$) kPa | Modulus of Elasticity of Soil ($E_s$) | Vertical Strian Influence Factor ($I_z$) | $I_z*\Delta z/E_s$ | Esi*Δz |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.0-3.0 | 1 | GM | 69.6 | 20.30 | 200.00 | 81.20 | 0.80 | 0.25 | 6.20 | 42332.84 | 105832.09 | 0.11 | 0.000001 | 105832.09 |
| 2 | 3.0-4.0 | 1 | GM | 71.0 | 20.30 | 200.00 | 101.50 | 0.80 | 0.23 | 6.20 | 43169.14 | 107922.85 | 0.14 | 0.000001 | 107922.85 |
| 3 | 4.0-5.0 | 1 | GM | 79.9 | 20.30 | 200.00 | 121.80 | 0.80 | 0.23 | 6.30 | 49368.83 | 123422.06 | 0.15 | 0.000001 | 123422.06 |
| 4 | 5.0-6.0 | 1 | GM | 77.8 | 20.30 | 200.00 | 142.10 | 0.80 | 0.25 | 5.80 | 44258.52 | 110646.29 | 0.25 | 0.000002 | 110646.29 |
| 5 | 6.0-7.0 | 1 | GM | 69.8 | 20.30 | 200.00 | 162.40 | 0.80 | 0.24 | 6.20 | 42462.26 | 106155.66 | 0.38 | 0.000004 | 106155.66 |
| 6 | 7.0-8.0 | 1 | GM | 66.2 | 20.30 | 200.00 | 182.70 | 0.80 | 0.22 | 6.10 | 39593.01 | 98982.54 | 0.48 | 0.000005 | 98982.54 |
| 7 | 8.0-9.0 | 1 | GM | 62.9 | 20.30 | 200.00 | 203.00 | 0.80 | 0.25 | 6.00 | 37026.62 | 92566.55 | 0.48 | 0.000005 | 92566.55 |
| 8 | 9.0-10.0 | 1 | GM | 61.9 | 20.30 | 200.00 | 223.30 | 0.80 | 0.27 | 6.30 | 38240.61 | 95601.52 | 0.30 | 0.000003 | 95601.52 |
| | | | | | | | | | | | | | | 0.000022 | 46729.42 |

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# Annex 6: Liquefaction Calculation

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## Liquifaction analysis from BH-01 for PGA=0.36g , M=7.5 and GWT being at 1m from ground

| S.N. | Depth(m) | Corrected SPT(N60) | Soil Type | % of Fine (FC) | Unit weight of Soil(kN/m2) | Total vertical stress($\sigma_v$) kN/m2 | Effective vertical stress($\sigma_v$')kN/m2 | Over burden corrected SPT$(N_1)_{60}$ | Equivalent clean sand blow count $(N_1)_{60cs}$ | Stress reducttion coefficient ($r_d$) | Magnitude Scaling Factor(MSF) | Cyclic Stress Ratio(CSR) | Cyclic Resistance Ratio(CRR) | Factor of Saftey (FS) | Liquefaction potential Index (LPI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 78.83 | GM | 7.21 | 20.30 | 20.3 | 20.3 | 62.68 | 62.856 | 0.999 | 1.000 | 0.2338 | 2.09E+25 | 0 | 0 |
| 2 | 2 | 72.68 | GM | 7.40 | 20.30 | 40.6 | 40.6 | 51.08 | 51.287 | 0.991 | 1.000 | 0.2319 | 1.29E+12 | 5.6E+12 | 0 |
| 3 | 3 | 66.52 | GM | 7.30 | 20.3 | 60.9 | 60.9 | 39.47 | 39.658 | 0.982 | 1.000 | 0.2297 | 48993.16 | 213269 | 0 |
| 4 | 4 | 75.43 | GM | 7.20 | 20.3 | 81.2 | 71.39 | 42.18 | 42.354 | 0.972 | 1.000 | 0.2586 | 1013291 | 3918250 | 0 |
| 5 | 5 | 84.33 | GM | 8.60 | 20.3 | 101.5 | 81.88 | 44.90 | 45.466 | 0.961 | 1.000 | 0.2787 | 63846897 | 2.3E+08 | 0 |
| 6 | 6 | 71.24 | GM | 9.62 | 20.3 | 121.8 | 92.37 | 38.69 | 39.674 | 0.949 | 1.000 | 0.2928 | 49820.62 | 170144 | 0 |
| 7 | 7 | 68.39 | GM | 9.80 | 20.3 | 142.1 | 102.86 | 36.16 | 37.223 | 0.937 | 1.000 | 0.3028 | 4738.383 | 15650.5 | 0 |
| 8 | 8 | 63.94 | GM | 10.00 | 20.3 | 162.4 | 113.35 | 32.57 | 33.719 | 0.924 | 1.000 | 0.3096 | 294.449 | 950.989 | 0 |
| 9 | 9 | 62.33 | GM | 8.60 | 20.3 | 182.7 | 123.84 | 31.50 | 32.071 | 0.910 | 1.000 | 0.3141 | 98.56008 | 313.746 | 0 |
| 10 | 10 | 63.71 | GM | 9.62 | 20.3 | 203 | 134.33 | 31.50 | 32.480 | 0.896 | 1.000 | 0.3168 | 127.8157 | 403.414 | 0 |
| 11 | 11 | 64.40 | GM | 9.80 | 20.3 | 223.3 | 144.82 | 30.45 | 31.505 | 0.882 | 1.000 | 0.3181 | 69.58982 | 218.772 | 0 |
| 12 | 12 | 65.08 | GM | 10.00 | 20.3 | 243.6 | 155.31 | 29.39 | 30.540 | 0.867 | 1.000 | 0.3182 | 39.70606 | 124.782 | 0 |
| 13 | 13 | 66.46 | GM | 8.60 | 20.3 | 263.9 | 165.8 | 28.53 | 29.095 | 0.852 | 1.000 | 0.3174 | 18.39742 | 57.9641 | 0 |
| 14 | 14 | 65.54 | GM | 8.80 | 20.3 | 284.2 | 176.29 | 28.01 | 28.647 | 0.837 | 1.000 | 0.3158 | 14.73276 | 46.6458 | 0 |
| 15 | 15 | 64.63 | GM | 9.80 | 20.3 | 304.5 | 186.78 | 27.48 | 28.543 | 0.822 | 1.000 | 0.3137 | 14.00567 | 44.6463 | 0 |
| 16 | 16 | 61.88 | GM | 10.50 | 20.3 | 324.8 | 197.27 | 25.97 | 27.350 | 0.808 | 1.000 | 0.3111 | 8.064827 | 25.9241 | 0 |
| 17 | 17 | 61.88 | GM | 9.40 | 20.3 | 345.1 | 207.76 | 25.97 | 26.855 | 0.793 | 1.000 | 0.3081 | 6.50864 | 21.1236 | 0 |
| | | | | | | | | | | | | | | | 0 |

**As liquefaction potential Index for depth up to 9m is 0 so there is very low possibility of liquefaction.**

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# Annex 7: Summary of Gross Allowable Bearing Capacity kPa

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## Summary of recommended bearing capacity in kPa for shallow footing

**Project: Amlekhgunj Substation Construction Project**
**Location:Amlekhjung, Bara ,Nepal**

| SN | Bore Hole | Depth of Footing(m) | Size of Footing | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2m X2m | 3m X 3m | 4m X 4m | 5m X 5m | 6m X 6m | 7m X 7m | 1m X 1m | 1m X 1.5m | 0.5mX0.5m |
| 1 | BH-01 | 1 | 129.35 | 122.29 | 122.52 | 122.92 | 115.68 | 99.15 | 124.46 | 131.18 | 129.35 |
| 2 | BH-01 | 1.5 | 231.96 | 210.50 | 210.18 | 185.09 | 154.24 | 132.21 | 218.22 | 229.05 | 231.96 |
| 2 | BH-01 | 2 | 289.62 | 254.46 | 253.38 | 202.91 | 169.09 | 144.94 | 267.75 | 279.36 | 289.62 |
| 3 | BH-01 | 3 | 350.28 | 282.43 | 211.82 | 169.46 | 141.22 | 121.04 | 315.15 | 325.12 | 350.28 |
| 4 | BH-01 | 4 | 366.20 | 267.06 | 200.30 | 160.24 | 133.53 | 114.46 | 323.88 | 331.14 | 366.20 |
| 5 | BH-01 | 5 | 585.03 | 254.79 | 191.09 | 152.87 | 127.40 | 109.20 | 500.48 | 482.10 | 585.03 |

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# Annex 8: Direct Shear Test Results

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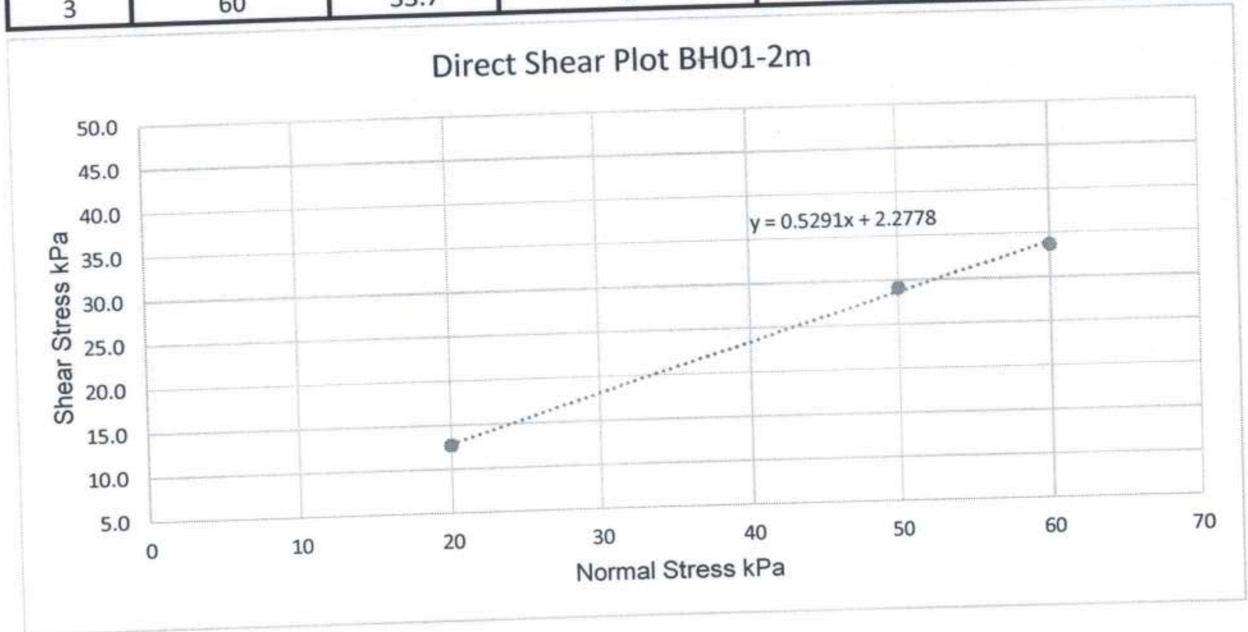
## Direct shear test results of infilling sands in gravel cobbel deposit

| | |
|---|---|
| Project: Amlekhgunj Substation Construction Project | Location:Amlekhjung, Bara ,Nepal |
| Test Method: IS 2720 part 13:1986 | Specimen Plan dimension: 0.06m X 0.06m |
| Bore hole No: BH01 | Thickness of specimen:25mm |
| Depth(m) : 3.0m | PRG factor: 0.00328 |
| Soil type:SP-SM | Rate of loading: 1.14 mm/m |

| S.No. | Normal Stress ($kN/m^2$) | Shear Strength ($kN/m^2$) | Shear Displacement(mm) | Cohesion 'C' ($kN/m^2$) | Internal friction angle (φ) degree | Remarks |
|---|---|---|---|---|---|---|
| 1 | 20 | 12.8 | 7 | 2.28 | 27.89 | |
| 2 | 50 | 29.2 | 5 | | | |
| 3 | 60 | 33.7 | 6 | | | |

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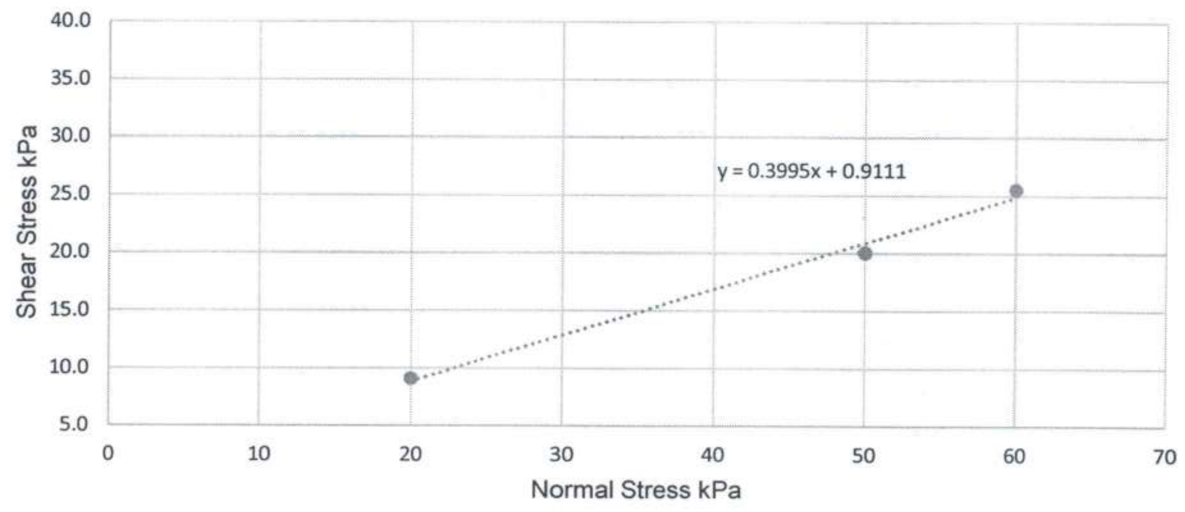
## Direct shear test results of infilling sands in gravel cobbel deposit

| | |
|---|---|
| Project: Amlekhgunj Substation Construction Project | Location:Amlekhjung, Bara ,Nepal |
| Test Method: IS 2720 part 13:1986 | Specimen Plan dimension: 0.06m X 0.06m |
| Bore hole No: BH01 | Thickness of specimen:25mm |
| Depth(m) : 4.5m | PRG factor: 0.00328 |
| Soil type:SP-SM | Rate of loading: 1.14 mm/m |

| S.No. | Normal Stress ($kN/m^2$) | Shear Strength ($kN/m^2$) | Shear Displacement(mm) | Cohesion 'C' ($kN/m^2$) | Internal friction angle (φ) degree | Remarks |
|---|---|---|---|---|---|---|
| 1 | 20 | 9.1 | 4 | 0.91 | 21.78 | |
| 2 | 50 | 20.0 | 5.5 | | | |
| 3 | 60 | 25.5 | 7 | | | |

Direct Shear Plot BH01-3.5m

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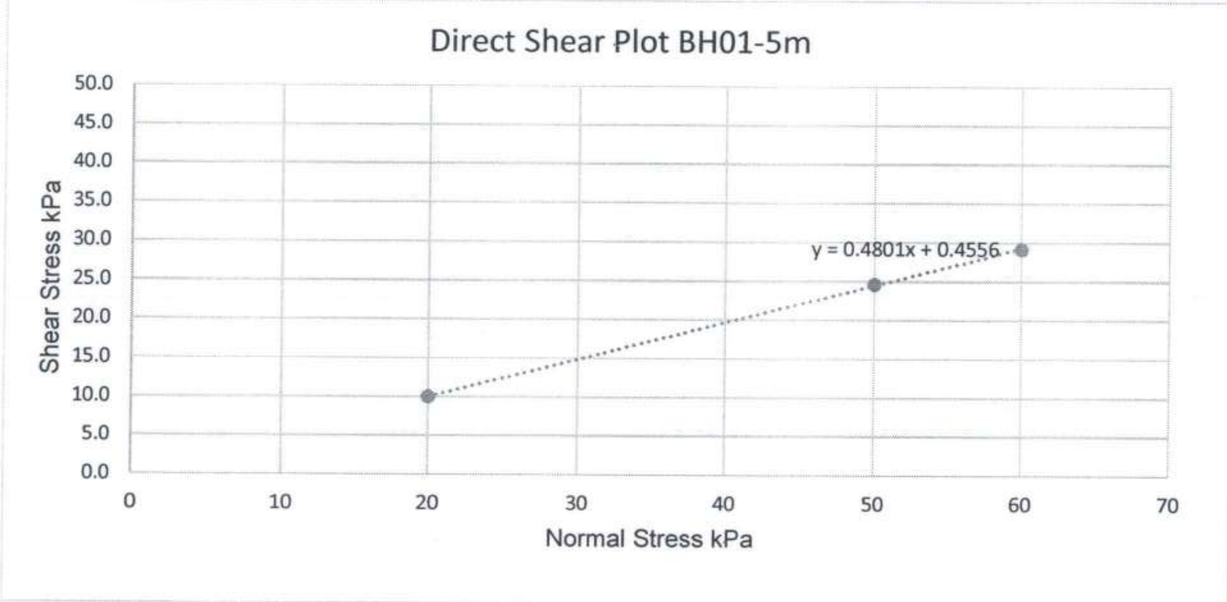
## Direct shear test results of infilling sands in gravel/cobbel deposit

| | |
|---|---|
| Project: Amlekhgunj Substation Construction Project | Location:Amlekhjung, Bara ,Nepal |
| Test Method: IS 2720 part 13:1986 | Specimen Plan dimension: 0.06m X 0.06m |
| Bore hole No: BH01 | Thickness of specimen:25mm |
| Depth(m) : 6m | PRG factor: 0.00328 |
| Soil type:SP & SM | Rate of loading: 1.14 mm/m |

| S.No. | Normal Stress ($kN/m^2$) | Shear Strength ($kN/m^2$) | Shear Displacement(mm) | Cohesion 'C' ($kN/m^2$) | Internal friction angle ($\varphi$) degree | Remarks |
|---|---|---|---|---|---|---|
| 1 | 20 | 10.0 | 3.5 | | | |
| 2 | 50 | 24.6 | 5.5 | 0.46 | 25.64 | |
| 3 | 60 | 29.2 | 7 | | | |

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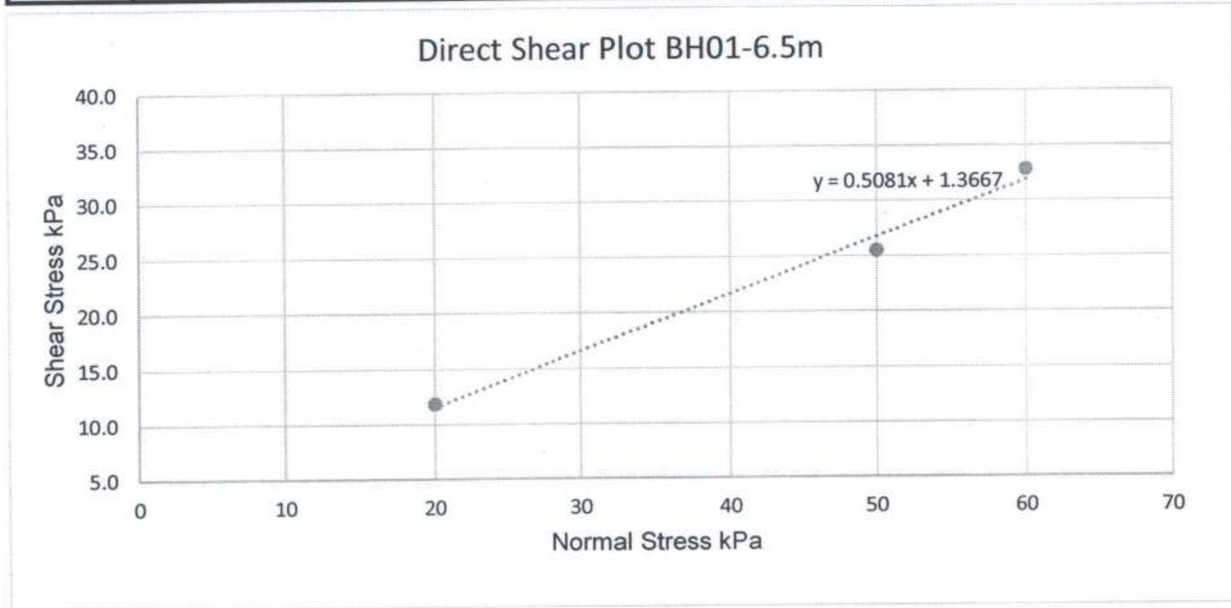
## Direct shear test results of infilling sands in gravel cobbel deposit

| | |
|---|---|
| Project: Amlekhgunj Substation Construction Project | Location:Amlekhjung, Bara ,Nepal |
| Test Method: IS 2720 part 13:1986 | Specimen Plan dimension: 0.06m X 0.06m |
| Bore hole No: BH01 | Thickness of specimen:25mm |
| Depth(m) : 7.5m | PRG factor: 0.00328 |
| Soil type:SP & SM | Rate of loading: 1.14 mm/m |

| S.No. | Normal Stress ($kN/m^2$) | Shear Strength ($kN/m^2$) | Shear Displacement(mm) | Cohesion 'C' ($kN/m^2$) | Internal friction angle (φ) degree | Remarks |
|---|---|---|---|---|---|---|
| 1 | 20 | 11.8 | 5 | 1.37 | 26.94 | |
| 2 | 50 | 25.5 | 7 | | | |
| 3 | 60 | 32.8 | 7 | | | |

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## Direct shear test results of infilling sands in gravel cobbel deposit

| | |
|---|---|
| Project: Amlekhgunj Substation Construction Project | Location:Amlekhjung, Bara ,Nepal |
| Test Method: IS 2720 part 13:1986 | Specimen Plan dimension: 0.06m X 0.06m |
| Bore hole No: BH01 | Thickness of specimen:25mm |
| Depth(m) : 9m | PRG factor: 0.00328 |
| Soil type:SP-SM | Rate of loading: 1.14 mm/m |

| S.No. | Normal Stress ($kN/m^2$) | Shear Strength ($kN/m^2$) | Shear Displacement(mm) | Cohesion 'C' ($kN/m^2$) | Internal friction angle ($\varphi$) degree | Remarks |
|---|---|---|---|---|---|---|
| 1 | 20 | 9.1 | 4 | | | |
| 2 | 50 | 18.2 | 5 | 0.91 | 21.08 | |
| 3 | 60 | 25.5 | 7 | | | |


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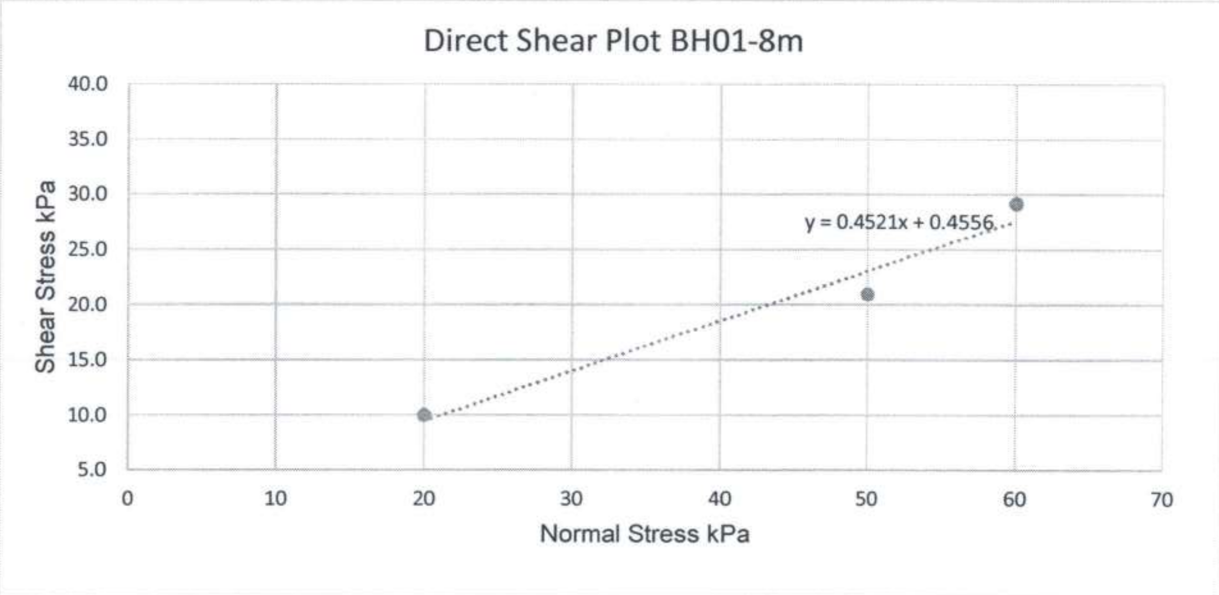
## Direct shear test results of infilling sands in gravel cobbel deposit

| | |
|---|---|
| Project: Amlekhgunj Substation Construction Project | Location:Amlekhjung, Bara ,Nepal |
| Test Method: IS 2720 part 13:1986 | Specimen Plan dimension: 0.06m X 0.06m |
| Bore hole No: BH01 | Thickness of specimen:25mm |
| Depth(m) : 12m | PRG factor: 0.00328 |
| Soil type:SP-SM | Rate of loading: 1.14 mm/m |

| S.No. | Normal Stress ($kN/m^2$) | Shear Strength ($kN/m^2$) | Shear Displacement(mm) | Cohesion 'C' ($kN/m^2$) | Internal friction angle ($\varphi$) degree | Remarks |
|---|---|---|---|---|---|---|
| 1 | 20 | 10.0 | 4 | | | |
| 2 | 50 | 21.0 | 5 | 0.46 | 24.33 | |
| 3 | 60 | 29.2 | 7 | | | |




Tested By:
Sabin Poudel Khatri

Approved By:
Geotech Er. Aanand Mishra
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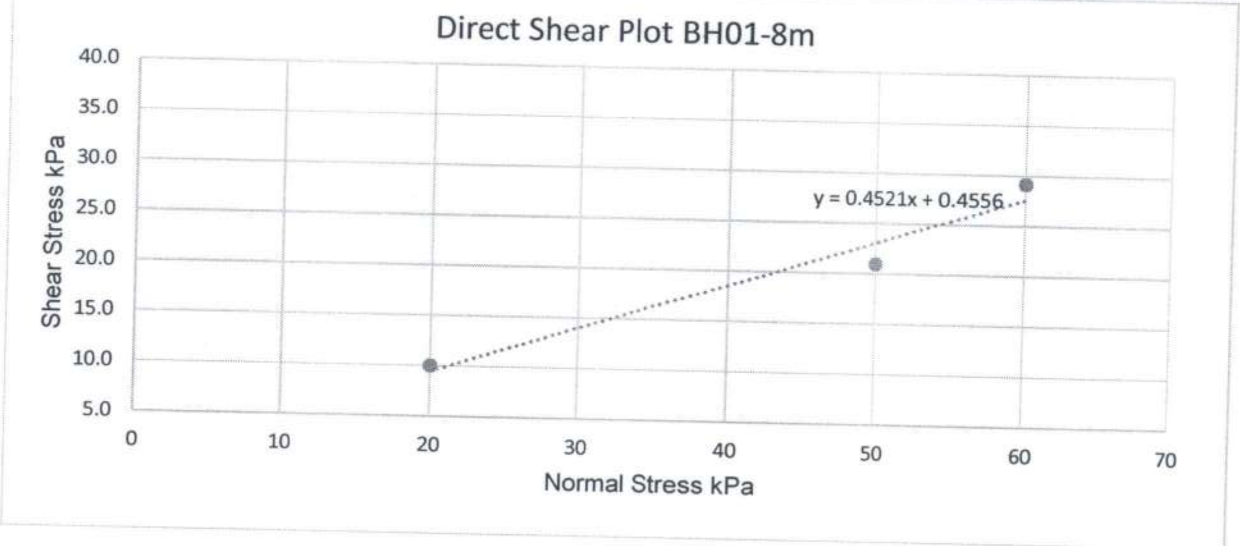
### Direct shear test results of infilling sands in gravel cobbel deposit

| | |
|---|---|
| Project: Amlekhgunj Substation Construction Project | Location:Amlekhjung, Bara ,Nepal |
| Test Method: IS 2720 part 13:1986 | Specimen Plan dimension: 0.06m X 0.06m |
| Bore hole No: BH01 | Thickness of specimen:25mm |
| Depth(m) : 19.5m | PRG factor: 0.00328 |
| Soil type:SP-SM | Rate of loading: 1.14 mm/m |

| S.No. | Normal Stress $(kN/m^2)$ | Shear Strength $(kN/m^2)$ | Shear Displacement(mm) | Cohesion 'C' $(kN/m^2)$ | Internal friction angle (φ) degree | Remarks |
|---|---|---|---|---|---|---|
| 1 | 20 | 9.6 | 4 | 0.68 | 22.21 | |
| 2 | 50 | 18.2 | 5 | | | |
| 3 | 60 | 27.3 | 7 | | | |

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# Annex 9: Sieve Analysis Results

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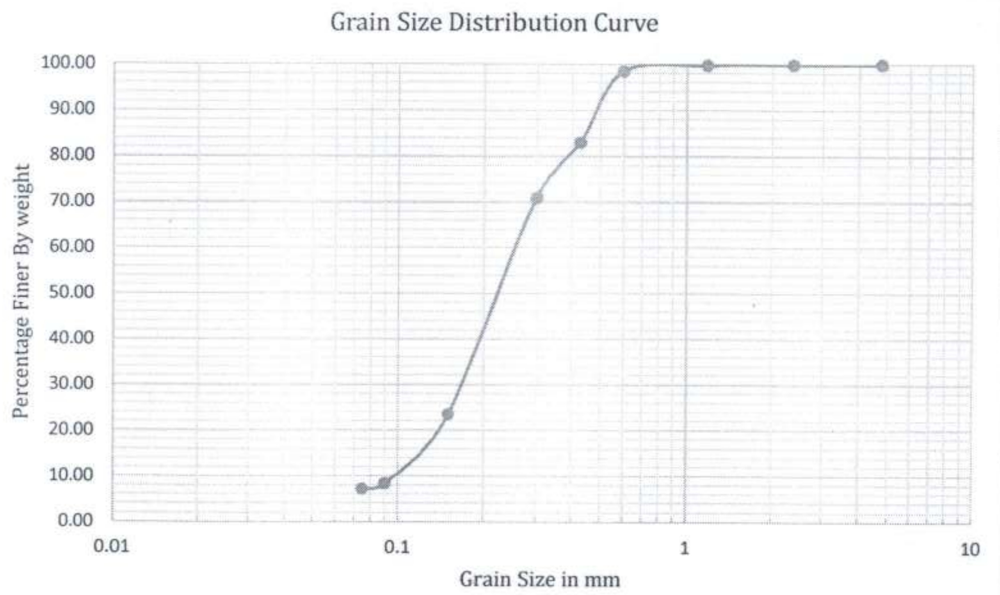
## Grain Size Analysis

Test Method: IS 2720(Part-4):1985
Project: Amlekhgunj Substation Construction Project
Location:Amlekhjung, Bara ,Nepal
Date of test:2022_6_28

Bore Hole No: BH-01
Depth:3m
Soil type : Sand as filling materials of boulders

| S.N. | Sieve Size (mm) | Retained weight (kg) | Passing Weight (kg) | % finer by weight |
|---|---|---|---|---|
| 1 | 4.75 | 0 | 396.58 | 100.00 |
| 2 | 2.36 | 0.46 | 396.12 | 99.88 |
| 3 | 1.18 | 0.48 | 395.64 | 99.76 |
| 4 | 0.6 | 5 | 390.64 | 98.50 |
| 5 | 0.425 | 61.5 | 329.14 | 82.99 |
| 6 | 0.3 | 47.88 | 281.26 | 70.92 |
| 7 | 0.15 | 188.14 | 93.12 | 23.48 |
| 8 | 0.09 | 60 | 33.12 | 8.35 |
| 9 | 0.075 | 4.52 | 28.6 | 7.21 |
| 10 | 0 | 28.6 | 0 | 0 |
| | Total | 396.58 | | |




| | | |
|---|---|---|
| | Gravel % (> 4.75mm)= | 0.00 |
| | Sand % (<4.75mm & >0.075mm)= | 92.79 |
| | Silt and Clays (< 0.075mm)= | 7.21 |

| | | | |
|---|---|---|---|
| $D_{10}$ = 0.0965 | $D_{30}$ = 0.1706 | $D_{60}$ = 0.265 | |
| Coefficient of uniformity = $C_U = D_{60} / D_{10}$ = | 2.750 | $D_{50}$ = | 0.253 |
| Coefficient of curvature = $C_C$ = = $\frac{D_{30}^2}{D_{60} D_{10}}$ | 1.136 | | |

**Soil Type (IS 1498:1970) :SP-SM**

SP: Poorly graded Sand
SM : Sandy Silts

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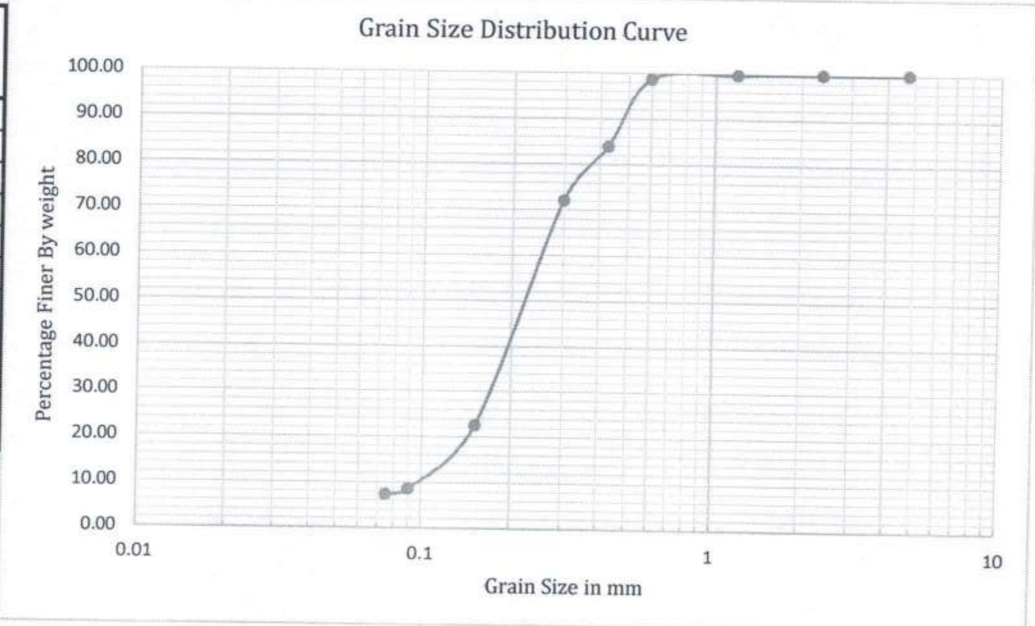
# Grain Size Analysis

Test Method: IS 2720(Part-4):1985
Project: Amlekhgunj Substation Construction Project
Location:Amlekhjung, Bara ,Nepal
Date of test:2022_6_28

Bore Hole No: BH-01
Depth:4.5m
Soil type : Sand as filling materials of boulders

| S.N. | Sieve Size (mm) | Retained weight (kg) | Passing Weight (kg) | % finer by weight |
|---|---|---|---|---|
| 1 | 4.75 | 0 | 477.5 | 100.00 |
| 2 | 2.36 | 0.25 | 477.25 | 99.95 |
| 3 | 1.18 | 1.12 | 476.13 | 99.71 |
| 4 | 0.6 | 4.67 | 471.46 | 98.74 |
| 5 | 0.425 | 70.51 | 400.95 | 83.97 |
| 6 | 0.3 | 56.88 | 344.07 | 72.06 |
| 7 | 0.15 | 236.32 | 107.75 | 22.57 |
| 8 | 0.09 | 66.84 | 40.91 | 8.57 |
| 9 | 0.075 | 5.6 | 35.31 | 7.39 |
| 10 | 0 | 35.31 | 0 | 0 |
| | Total | 477.5 | | |




| | | | |
|---|---|---|---|
| | Gravel % (> 4.75mm)= | | 0.00 |
| | Sand % (<4.75mm & >0.075mm)= | | 92.61 |
| | Silt and Clays (< 0.075mm)= | | 7.39 |

| | | | | | |
|---|---|---|---|---|---|
| $D_{10}$ = | 0.0961 | $D_{30}$ = | 0.1725 | $D_{60}$ = | 0.263 |
| Coefficient of uniformity = $C_U = D_{60} / D_{10}$ = | | | 2.740 | $D_{50}$ = | 0.233 |
| Coefficient of curvature = $C_C$ = = $\frac{D_{30}^2}{D_{10} \cdot D_{60}}$ | | | 1.175 | | |

**Soil Type (IS 1498:1970) :SP-SM**

SP: Poorly graded Sand
SM : Sandy Silts

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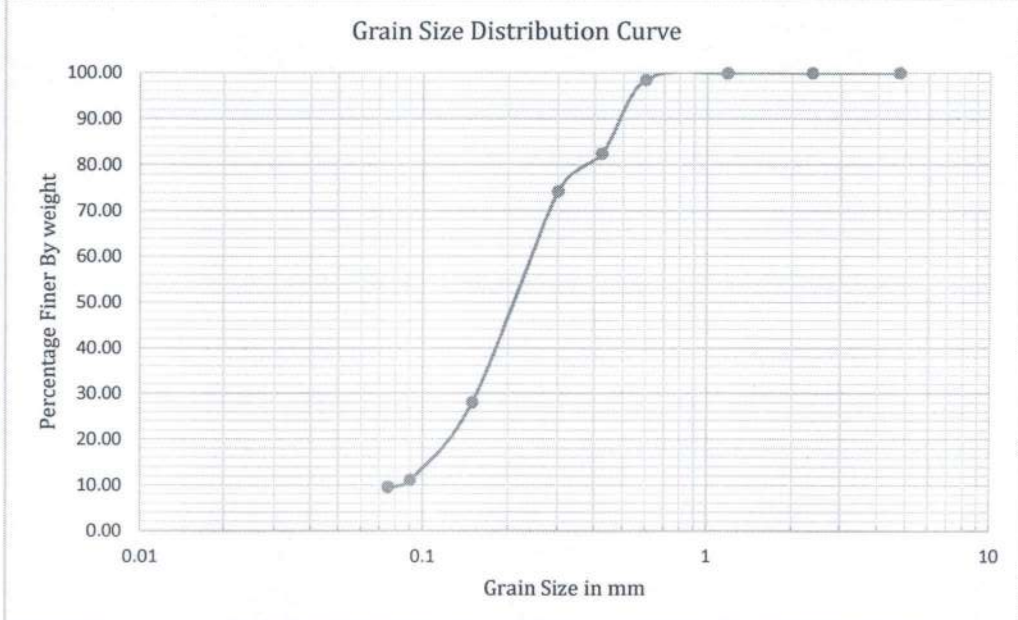
# Grain Size Analysis

Test Method: IS 2720(Part-4):1985
Project: Amlekhgunj Substation Construction Project
Location:Amlekhjung, Bara ,Nepal
Date of test:2022_6_28

Bore Hole No: BH-01
Depth:6m
Soil type : Sand as filling materials of boulders

| S.N. | Sieve Size (mm) | Retained weight (kg) | Passing Weight (kg) | % finer by weight |
|---|---|---|---|---|
| 1 | 4.75 | 0 | 422.71 | 100.00 |
| 2 | 2.36 | 0.13 | 422.58 | 99.97 |
| 3 | 1.18 | 0.27 | 422.31 | 99.91 |
| 4 | 0.6 | 6.02 | 416.29 | 98.48 |
| 5 | 0.43 | 67.87 | 348.42 | 82.43 |
| 6 | 0.3 | 34.56 | 313.86 | 74.25 |
| 7 | 0.15 | 195.3 | 118.56 | 28.05 |
| 9 | 0.09 | 71.5 | 47.06 | 11.13 |
| 8 | 0.075 | 6.38 | 40.68 | 9.62 |
| 10 | 0 | 40.68 | 0 | 0 |
| | Total | 422.71 | | |




| | | | |
|---|---|---|---|
| | Gravel % (> 4.75mm)= | | 0.00 |
| | Sand % (<4.75mm & >0.075mm)= | | 90.38 |
| | Silt and Clays (< 0.075mm)= | | 9.62 |

| | | | | | |
|---|---|---|---|---|---|
| $D_{10}$ = | 0.0787 | $D_{30}$ = | 0.1563 | $D_{60}$ = | 0.254 |
| Coefficient of uniformity = $C_U = D_{60} / D_{10}$ = | | | 3.222 | $D_{50}$ = | 0.221 |
| Coefficient of curvature = $C_C$ = = $\frac{D_{30}^2}{D_{60} \cdot D_{10}}$ | | | 1.223 | | |

**Soil Type (IS 1498:1970) :SP-SM**

SP: Poorly graded Sand
SM : Sandy Silts

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# Grain Size Analysis

Test Method: IS 2720(Part-4):1985

Project: Amlekhgunj Substation Construction Project

Location:Amlekhjung, Bara ,Nepal

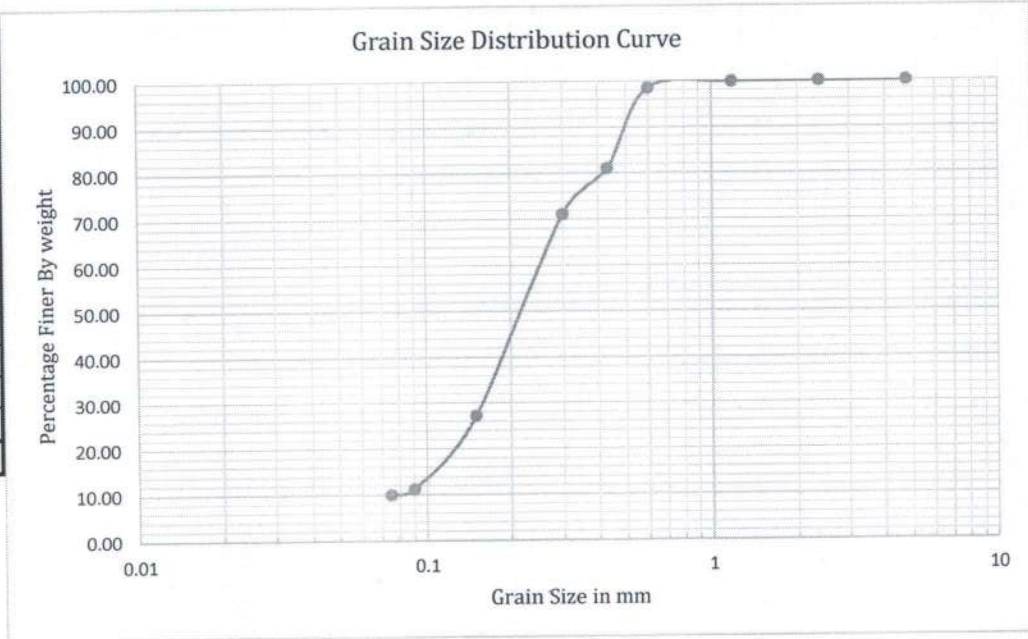
Date of test:2022_6_28

Bore Hole No: BH-01

Depth:7.5m

Soil type : Sand as filling materials of boulders

| S.N. | Sieve Size (mm) | Retained weight (kg) | Passing Weight (kg) | % finer by weight |
|---|---|---|---|---|
| 1 | 4.75 | 0 | 591.38 | 100.00 |
| 2 | 2.36 | 0 | 591.38 | 100.00 |
| 3 | 1.18 | 0.81 | 590.57 | 99.86 |
| 4 | 0.6 | 8.16 | 582.41 | 98.48 |
| 5 | 0.43 | 103.01 | 479.4 | 81.06 |
| 6 | 0.3 | 58.74 | 420.66 | 71.13 |
| 6 | 0.15 | 259.74 | 160.92 | 27.21 |
| 9 | 0.09 | 94.6 | 66.32 | 11.21 |
| 7 | 0.075 | 7.1 | 59.22 | 10.01 |
| 8 | 0 | 59.22 | 0 | 0 |
| | Total | 591.38 | | |




| | | | |
|---|---|---|---|
| | Gravel % (> 4.75mm)= | | 0.00 |
| | Sand % (<4.75mm & >0.075mm)= | | 89.99 |
| | Silt and Clays (< 0.075mm)= | | 10.01 |

| | | | | | |
|---|---|---|---|---|---|
| $D_{10}$ = | 0.0749 | $D_{30}$ = | 0.1595 | $D_{60}$ = | 0.262 |
| Coefficient of uniformity = $C_U = D_{60} / D_{10}$ = | | | 3.498 | $D_{50}$ = | 0.248 |
| Coefficient of curvature = $C_C$ = = $\frac{D_{30}^2}{D_{60} \cdot D_{10}}$ | | | 1.297 | | |

**Soil Type (IS 1498:1970) :SP-SM**

SP: Poorly graded Sand

SM : Sandy Silts

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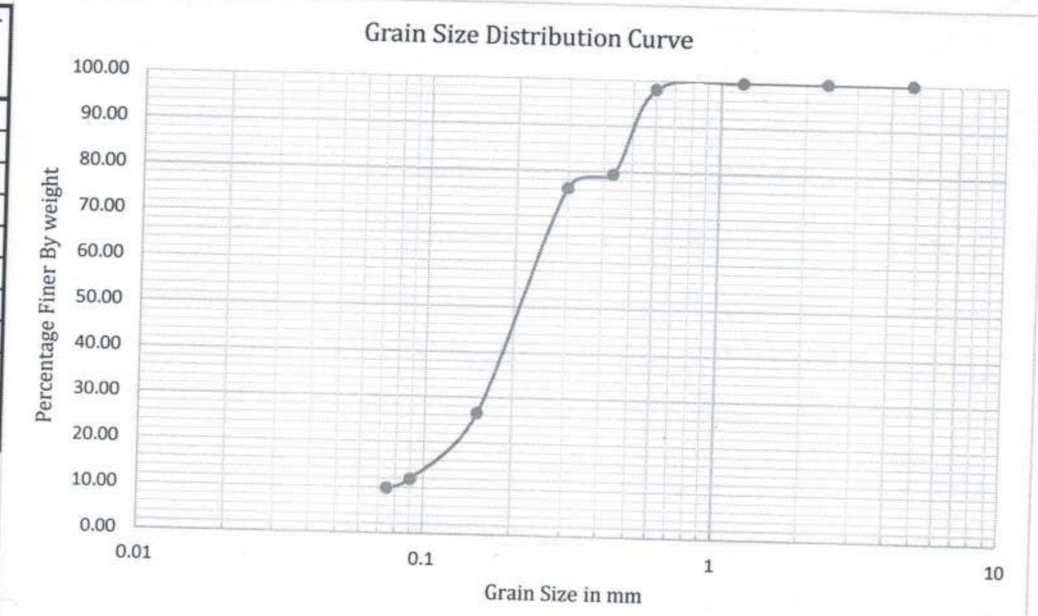
# Grain Size Analysis

Test Method: IS 2720(Part-4):1985
Project: Amlekhgunj Substation Construction Project
Location:Amlekhjung, Bara ,Nepal
Date of test:2022_6_28

Bore Hole No: BH-01
Depth:9m
Soil type : Sand as filling materials of boulders

| S.N. | Sieve Size (mm) | Retained weight (kg) | Passing Weight (kg) | % finer by weight |
|---|---|---|---|---|
| 1 | 4.75 | 0 | 456.34 | 100.00 |
| 2 | 2.36 | 0.31 | 456.03 | 99.93 |
| 3 | 1.18 | 0.57 | 455.46 | 99.81 |
| 4 | 0.6 | 7.88 | 447.58 | 98.08 |
| 5 | 0.43 | 85.2 | 362.38 | 79.41 |
| 6 | 0.3 | 40.03 | 322.35 | 76.26 |
| 7 | 0.15 | 201.5 | 120.85 | 26.48 |
| 8 | 0.09 | 70.77 | 50.08 | 11.85 |
| 9 | 0.075 | 5.3 | 44.78 | 9.81 |
| 10 | 0 | 44.78 | 0 | 0 |
| | Total | 456.34 | | |




| | | |
|---|---|---|
| Gravel % (> 4.75mm)= | | 0.00 |
| Sand % (<4.75mm & >0.075mm)= | | 90.19 |
| Silt and Clays (< 0.075mm)= | | 9.81 |

| | | | | | |
|---|---|---|---|---|---|
| $D_{10}$ = | 0.0764 | $D_{30}$ = | 0.1606 | $D_{60}$ = | 0.251 |
| Coefficient of uniformity = $C_U = D_{60} / D_{10}$ = | | | 3.286 | $D_{50}$ = | 0.221 |
| Coefficient of curvature = $C_C$ = = $\frac{D_{30}^2}{D_{60} \cdot D_{10}}$ | | | 1.345 | | |

**Soil Type (IS 1498:1970) :SP-SM**

SP: Poorly graded Sand
SM : Sandy Silts

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# Grain Size Analysis

Test Method: IS 2720(Part-4):1985

Project: Amlekhgunj Substation Construction Project

Location:Amlekhjung, Bara ,Nepal

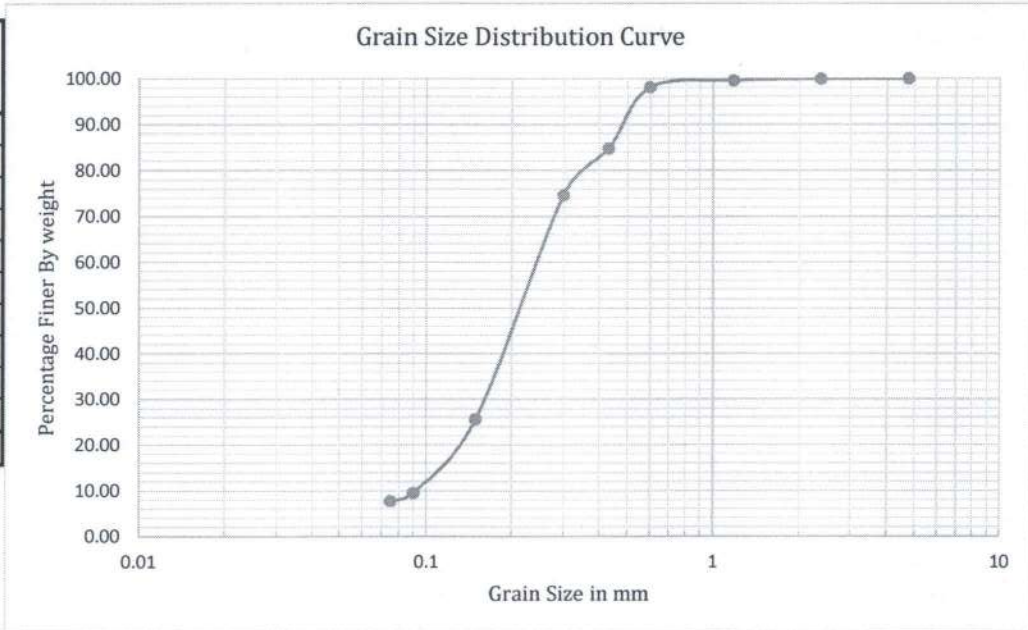
Date of test:2022_6_28

Bore Hole No: BH-01

Depth:12m

Soil type : Sand as filling materials of boulders

| S.N. | Sieve Size (mm) | Retained weight (kg) | Passing Weight (kg) | % finer by weight |
|---|---|---|---|---|
| 1 | 4.75 | 0 | 566.15 | 100.00 |
| 2 | 2.36 | 0.34 | 565.81 | 99.94 |
| 3 | 1.18 | 2.11 | 563.7 | 99.57 |
| 4 | 0.6 | 8.15 | 555.55 | 98.13 |
| 5 | 0.43 | 75.36 | 480.19 | 84.82 |
| 6 | 0.3 | 57.57 | 422.62 | 74.65 |
| 7 | 0.15 | 277.7 | 144.92 | 25.60 |
| 8 | 0.09 | 90.88 | 54.04 | 9.55 |
| 9 | 0.075 | 10.16 | 43.88 | 7.75 |
| 10 | 0 | 43.88 | 0 | 0 |
| | Total | 566.15 | | |




| | | | |
|---|---|---|---|
| | Gravel % (> 4.75mm)= | | 0.00 |
| | Sand % (<4.75mm & >0.075mm)= | | 92.25 |
| | Silt and Clays (< 0.075mm)= | | 7.75 |

| | | | | | |
|---|---|---|---|---|---|
| $D_{10}$ = | 0.0917 | $D_{30}$ = | 0.1635 | $D_{60}$ = | 0.286 |
| Coefficient of uniformity = $C_U = D_{60} / D_{10}$ = | | | 3.122 | $D_{50}$ = | 0.248 |
| Coefficient of curvature = $C_C$ = = $\frac{D_{30}^2}{D_{60} D_{10}}$ | | | 1.018 | | |

**Soil Type (IS 1498:1970) :SP-SM**

SP: Poorly graded Sand

SM : Sandy Silts

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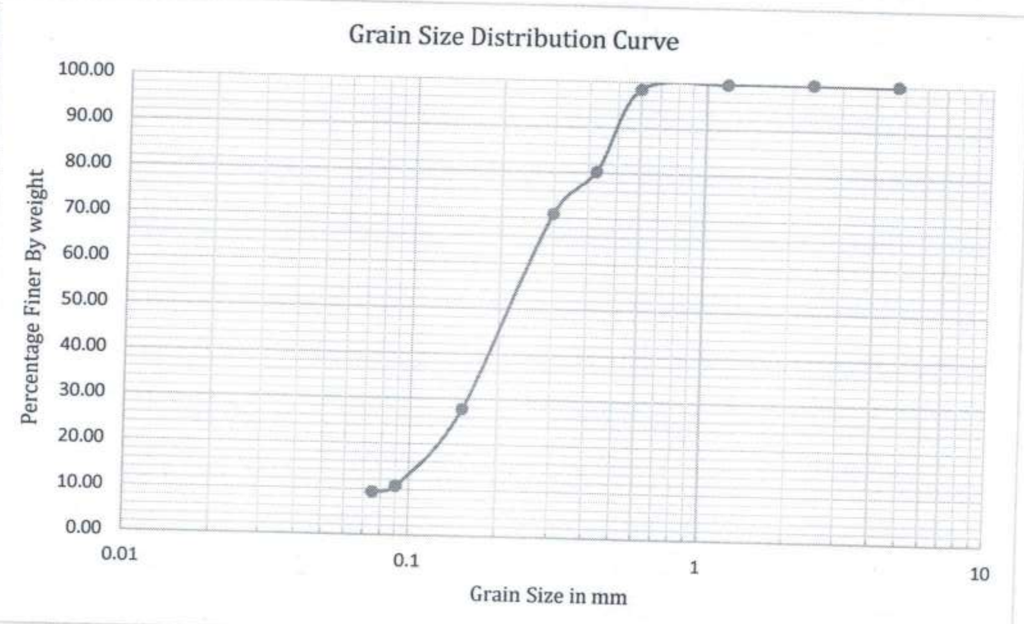
# Grain Size Analysis

Test Method: IS 2720(Part-4):1985
Project: Amlekhgunj Substation Construction Project
Location:Amlekhjung, Bara ,Nepal
Date of test:2022_6_28

Bore Hole No: BH-01
Depth:20m
Soil type : Sand as filling materials of boulders

| S.N. | Sieve Size (mm) | Retained weight (kg) | Passing Weight (kg) | % finer by weight |
|---|---|---|---|---|
| 1 | 4.75 | 0 | 671.19 | 100.00 |
| 2 | 2.36 | 0 | 671.19 | 100.00 |
| 3 | 1.18 | 1.22 | 669.97 | 99.82 |
| 4 | 0.6 | 9.57 | 660.4 | 98.39 |
| 5 | 0.43 | 121.82 | 538.58 | 80.24 |
| 6 | 0.3 | 62.7 | 475.88 | 70.90 |
| 6 | 0.15 | 289.5 | 186.38 | 27.77 |
| 9 | 0.09 | 114.5 | 71.88 | 10.71 |
| 7 | 0.075 | 8.88 | 63 | 9.39 |
| 8 | 0 | 63 | 0 | 0 |
| | Total | 671.19 | | |




| | | |
|---|---|---|
| Gravel % (> 4.75mm)= | | 0.00 |
| Sand % (<4.75mm & >0.075mm)= | | 90.61 |
| Silt and Clays (< 0.075mm)= | | 9.39 |

| | | | | | |
|---|---|---|---|---|---|
| $D_{10}$ = | 0.0820 | $D_{30}$ = | 0.1578 | $D_{60}$ = | 0.262 |
| Coefficient of uniformity = $C_U = D_{60} / D_{10}$ = | | | 3.198 | $D_{50}$ = | 0.247 |
| Coefficient of curvature = $C_C$ = = $\frac{D_{30}^2}{D_{10} \cdot D_{60}}$ | | | 1.159 | | |

**Soil Type (IS 1498:1970) :SP-SM**

SP: Poorly graded Sand
SM : Sandy Silts

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# Annex 10: Moisture Content Analysis Results

EXPERT TESTING LABORATORY PVT. LTD.
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# Moisture Content Determination (Natural)

Infilling materials gavel and boulder deposits

**Project: Amlekhgunj Substation Construction Project**

**Location:Amlekhjung, Bara ,Nepal**

**Test Method: IS 2720(part II):1973**

**Date of test:2022_6_28**

**Oven Temperature: 100°C**

**Duration of Drying: 24hrs.**

| Sample Type (Bore hole) | Depth (m) | Soil Type | can+wet soil(gm) | can+dry soil(gm) | Empty can wt.(gm) | Wt. of water (gm) | Mositure content % |
|---|---|---|---|---|---|---|---|
| BH-01 | 3 | SP-SM | 114.31 | 105.59 | 66.46 | 8.72 | 22.28 |
| BH-01 | 4.5 | SP-SM | 166.44 | 155.29 | 109.43 | 11.15 | 24.31 |
| BH-01 | 6 | SP-SM | 137.43 | 129.29 | 92.16 | 8.14 | 21.92 |
| BH-01 | 7.5 | SP-SM | 162.15 | 152.26 | 108.99 | 9.89 | 22.86 |
| BH-01 | 9 | SP-SM | 107.52 | 99.94 | 68.52 | 7.58 | 24.12 |
| BH-01 | 12 | SP-SM | 167.01 | 155.29 | 92.16 | 11.72 | 18.56 |
| BH-01 | 19.5 | SP-SM | 113.25 | 104.65 | 69.98 | 8.60 | 24.81 |

Tested By:
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# Annex 11: Bulk Density Results

EXPERT TESTING LABORATORY PVT. LTD.
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# Bulk Density Determination

Infilling materials gavel and boulder deposits

**Project: Amlekhgunj Substation Construction Project**
**Location:Amlekhjung, Bara ,Nepal**
**Test Method: IS 2720(part XXVIII):1973**

**Date of test:2022_6_28**
**Room Temperature: 27°C**

| Sample Type (Bore hole) | Depth (m) | Soil Type | Volume of Conatiner $cm^3$ | Wt. of container+ soil(gm) | Empty container wt.(gm) | Bulk Density (gm/cc) | Natural Mositure Content % | Dry Density (gm/cc) |
|---|---|---|---|---|---|---|---|---|
| BH-01 | 3 | SP-SM | 106.18 | 193.11 | 15.01 | 1.68 | 22.28 | 1.37 |
| BH-01 | 4.5 | SP-SM | 106.18 | 195.03 | 15.01 | 1.70 | 24.31 | 1.36 |
| BH-01 | 6 | SP-SM | 106.18 | 192.69 | 15.01 | 1.67 | 21.92 | 1.37 |
| BH-01 | 7.5 | SP-SM | 106.18 | 185.36 | 15.01 | 1.60 | 22.86 | 1.31 |
| BH-01 | 9 | SP-SM | 106.18 | 198.85 | 15.01 | 1.73 | 24.12 | 1.39 |
| BH-01 | 12 | SP-SM | 106.18 | 197.32 | 15.01 | 1.72 | 18.56 | 1.45 |
| BH-01 | 19.5 | SP-SM | 106.18 | 199.44 | 15.01 | 1.74 | 24.81 | 1.39 |

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# Annex 12: Specific Gravity Results

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# Specific Gravity Determination

Infilling materials gavel and boulder deposits

**Project: Amlekhgunj Substation Construction Project**
**Location:Amlekhjung, Bara ,Nepal**
**Test Method: IS 2720(part III):1973**

**Date of test:2022_6_28**
**Oven Temperature: 100oC**
**Duration of Drying: 24hrs.**

| Sample Type (Bore hole) | Depth (m) | Soil Type | Natural moisture content % | Wt. of density bottle+dry soil(gm) | Wt. of bottle+dry soil+water(gm) | Wt. of density bottle+water(gm) | Wt. of empty bottle(gm) | Specific Gravity |
|---|---|---|---|---|---|---|---|---|
| BH-01 | 3 | SP-SM | 22.28 | 446.00 | 909.80 | 852.50 | 349.70 | 2.47 |
| BH-01 | 4.5 | SP-SM | 24.31 | 442.33 | 908.17 | 852.50 | 349.67 | 2.50 |
| BH-01 | 6 | SP-SM | 21.92 | 486.00 | 934.17 | 852.50 | 349.67 | 2.49 |
| BH-01 | 7.5 | SP-SM | 22.86 | 472.83 | 928.17 | 852.50 | 349.67 | 2.59 |
| BH-01 | 9 | SP-SM | 24.12 | 481.00 | 933.83 | 852.50 | 349.67 | 2.63 |
| BH-01 | 12 | SP-SM | 18.56 | 457.00 | 916.00 | 852.50 | 349.67 | 2.45 |
| BH-01 | 19.5 | SP-SM | 24.81 | 463.67 | 920.33 | 852.50 | 349.67 | 2.47 |

Tested By:
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Approved By:
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# Annex 13: Photographs


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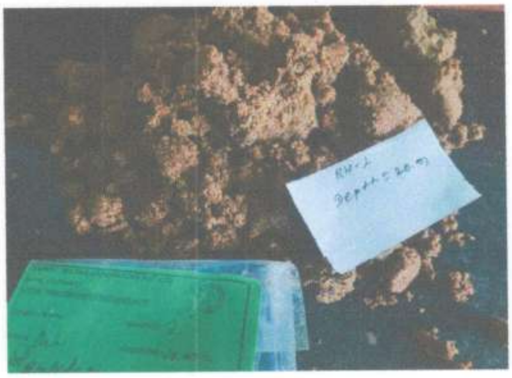

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