REPORT

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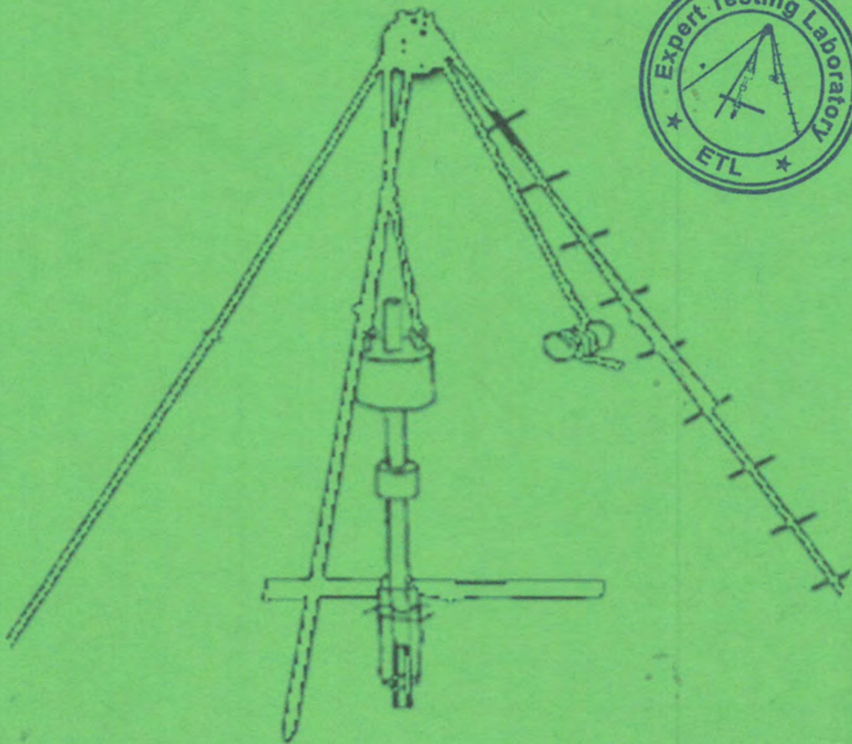

SOIL INVESTIGATION WORK OF CHOVAR-PATAN-CHAPAGAUN UNDERGROUND 132 K.V TRANSMISSION LINE PROJECT

SUBMITTED TO:

CLIENT:
NEA, PMD
Kathmandu

SUBMITTED BY:

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SOIL INVESTIGATION

REPORT

OF

Chovar-Patan-Chapagaun Underground 132 K.V. Transmission Line Project

AT

Patan Sub-Station, Lagankhel

NEPAL

Client: Nepal Electricity Authority

Prepared By: Expert Testing Laboratory Pvt. Ltd.

Date: 2022-03-20(2078/12/06)

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ACKNOWLEDGEMENT

Expert testing Laboratory Pvt. Ltd., Bafal, and Lalitpur-17 is very much grateful to M/s Ukesh Shrestha Project Manager of Chovar-Patan-Chapagaun Underground 132 K.V. Transmission Line Project NEA for entrusting the job of doing Soil Investigation Works for Patan GIS Substation Works reveal the facts and figures relating to the Soil Investigation Works for the structures build to be.

We hope this report will bring some useful parameters for Natural Moisture content, Specific Gravity, Grain size analysis, Direct Shear test, Atterberg Test, Bulk and Dry Density .This report shall also be useful in finding the Seismicity , liquefaction Analysis, Bearing Capacity of Soil , Settlement analysis for the GIS building.

Last but not the least, we hope for an early and successful completion of the project.

Dharmveer Pradhan
(Managing Director)
Expert Testing Laboratory
Pvt. Ltd

TABLE OF CONTENT

Expert Testing Laboratory ETL

List of Figures

Expert Testing Laboratory ETL

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 new Patan sub-station at Lagankhel for the Chovar-patan-Chapagau underground 132 KV transmission line project. The investigation characterizes the subsurface conditions and develops the necessary requirement for the proposed safe bearing capacity of the foundation. The Proposed Project area is located at about 250m SW of lagankhel bus park and 230m South of Patan Hospital, in Lalitpur metropolitan city, as in figure 1.1 and 1.2.

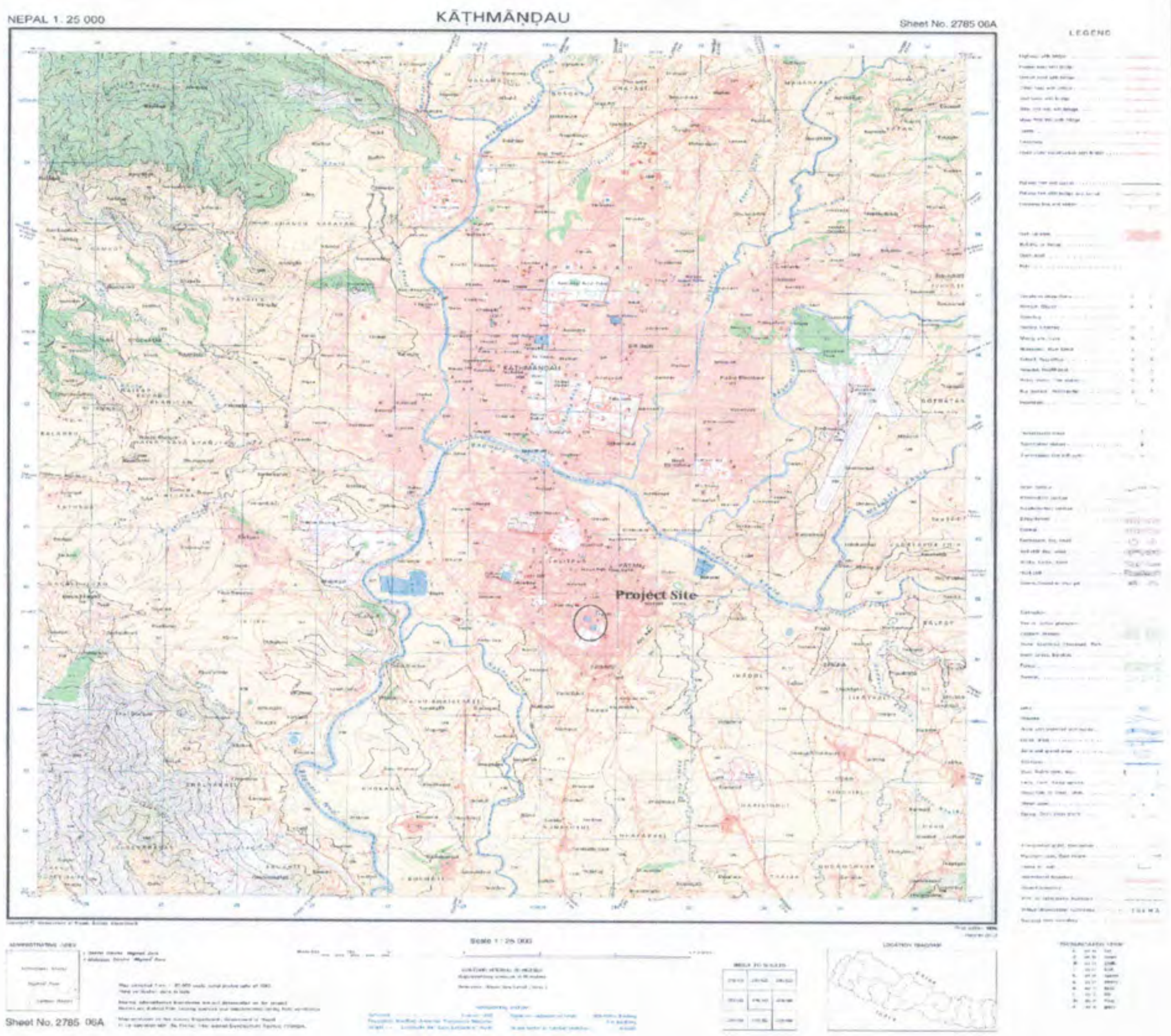

Figure 1-1a Topographic map of the of the project area

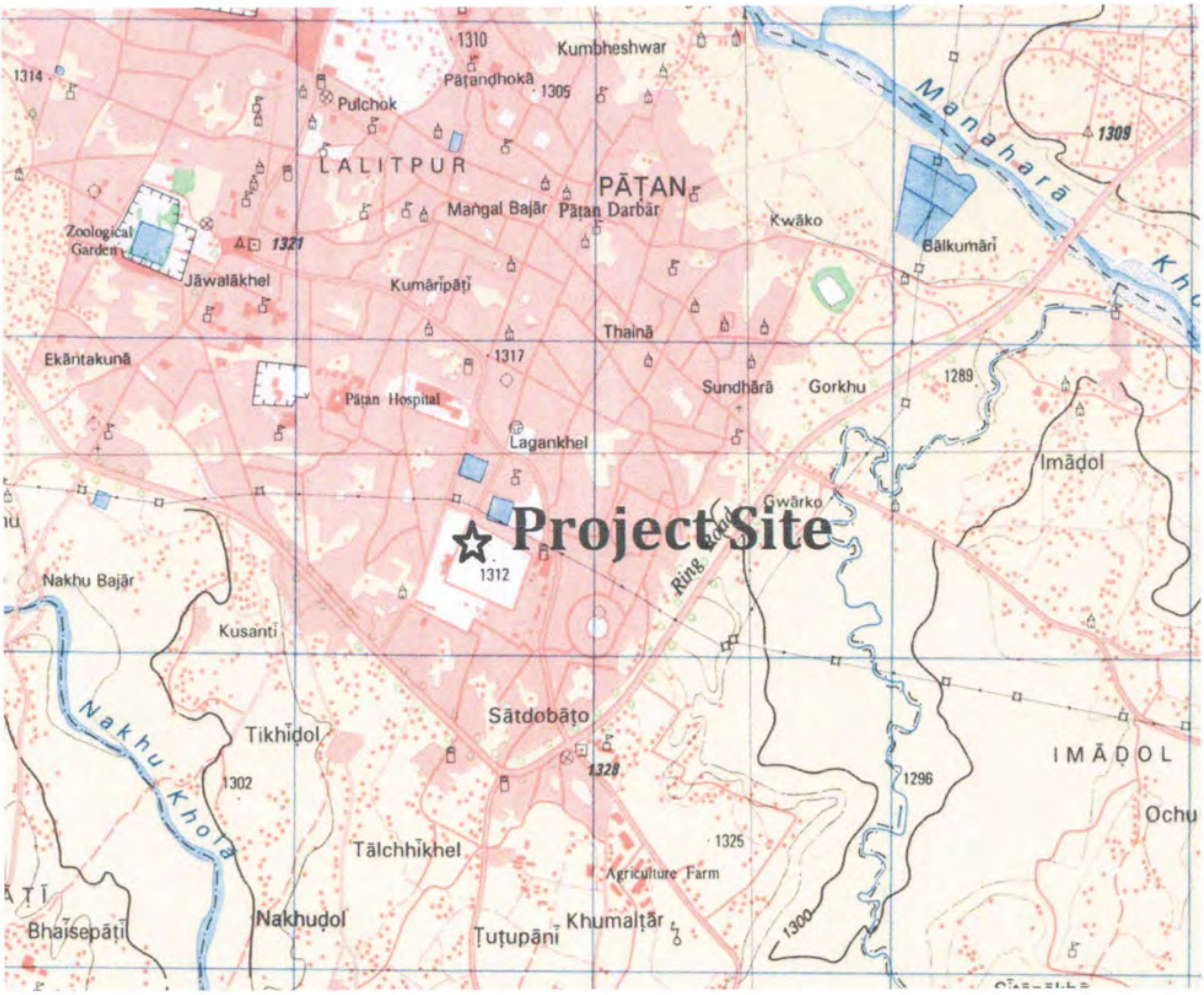

Figure 1-2 Map of soil investigation area

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 soil investigation work was carried out between first and second week of December 2021. The total quantity of soil investigation included one borehole of 20m depth as per agreement. Standard Penetration Tests (SPT) was conducted at 1.5m depth interval to furnish the compactness of the soil strata at field. Disturbed and undisturbed samples were collected for further laboratory investigations.

2. SCOPE OF INVESTIGATION

The scope of work includes the following:

- Making 100 mm nominal diameter bore holes each of 20.0 m depth at three 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.

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 building site is comprised of the medium- to coarse-grained salt-and-pepper sandstone with large cross lamination, calcareous sand lenses, convolute bedding, dark grey siltstone, and mudstone (Shrestha et al. 2019). Plant fossils are also present in the finely laminated clay bed and upper portion of the investigated area also comprises of mud- to sand-supported pebble to cobble conglomerates as shown in Figure 4.1.

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 March 5-14, 2021. Drilling works were carried out using one set of percussion and rotatory drilling machine. The sides of the boreholes were lined with 150mm 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.

3.2.2 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.

3.2.3 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 to be at 4m depth.

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, CBR test, free swell tests and consolidation tests.

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 and moisture content at 4m depth is 10%.

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 and specific gravity of soil at 4m depth is 2.44.

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. Atterberg limit test was conducted for the soil samples with greater amount of fine percentage, summary of Atterberg Limit test is given in Annex 13 of this report.

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.

If the samples are cohesive, they will be sheared at a relatively fast rate (duration of tests less than 10 minutes) to maintain un-drained condition. 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 (ϕ) 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 and cohesion and frictional angle observed from direct shear test for sample of 4m depth is 2.523kPa and 30.49°.

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 and bulk density at 4m depth is 1.67.

3.3.7 Free Swell Index Test

The possibility of damage to structures due to swelling of expensive clays need be identified, at the outset, by an investigation of those soils likely to possess undesirable expansion characteristics. Inferential testing is resorted to reflect the potential of the system to swell under different simulated conditions. Actual magnitude of swelling pressures developed depends upon the dry density, initial water content, surcharge loading and several other environmental factors. Free swell index determination of soil helps to identify the potential of a soil to swell which might need further detailed investigation regarding swelling and swelling pressures under different field conditions. It is determined for samples obtained from split spoon sampler and undisturbed samples referring IS 2720(part-40) 1977 Summary of free swell test is given in Annex 15 of this report and maximum free swell is observed to be 18.75% at 13.5m depth.

3.3.8 Laboratory determination of CBR

California Bearing Ratio (CBR) is defined as the ratio expressed in percentage of force per unit area required penetrating a soil mass with a circular plunger of 50 mm diameter at the rate of 1.25 mm/min to that required for corresponding penetration in a standard material. Tests are performed out on natural or compacted soils in water soaked or un-soaked conditions and the results so obtained are compared with the curves of standard test. It is determined for samples obtained from split spoon sampler and undisturbed samples referring IS 2720(part-16) 1987.

$$\text{CBR \%} = \frac{\textit{corrected unit (or total)test load from the load penetration curve}}{\textit{unit (or total)standard load for the same depth of penetration as per code}}$$

Summary of laboratory CBR test is given in Annex 16 of this report. And observed CBR is 25.376%.

3.3.9 Determination of consolidation properties

When a compressive load is applied to soil mass, a decrease in its volume takes place, the decrease in volume of soil mass under stress is known as compression and the property of soil mass pertaining to its tendency to decrease in volume under pressure is known as compressibility. In a saturated soil mass having its void filled with incompressible water, decrease in volume or compression can take place when water is expelled out of the voids. Such a compression resulting from a long time static load and the consequent escape of pore water is termed as consolidation. Then the load is applied on the saturated soil mass, the entire load is carried by pore water in the beginning. As the water begins escaping from the voids, the hydrostatic pressure in water gets gradually dissipated and the load is shifted to the soil particles which increases effective stress on them, as a result the soil mass decrease in volume. The rate of escape of water depends on the permeability of the soil. It is determined for samples obtained from split spoon sampler and undisturbed samples referring IS 2720(part-15) 1986.

Coefficient of consolidation (c_v) = $\frac{0.848*(\frac{Hav}{2})^2}{t_{90}}$ from square root of time plot

H_{av} = average specimen thickness for load increment (mm)

t_{90} = time required for 90 % consolidation from square root of time plot

Summary of consolidation test is given in Annex 14 of this report. And coefficient of consolidation for poorly graded sand at depth of 12m is observed 0.0026 cm²/min, for poorly graded sand with clayey sand at depth 18m is observed 0.0084 cm²/min and for clayey sand at 20m depth is observed 0.0093 cm²/min.

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.

σ_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

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

Geological map of the project area is shown in Fig. 4.1. The map is an extract from The Engineering and Environmental map of the Kathmandu valley published by the Department of Geology and Mines of the Government of Nepal.

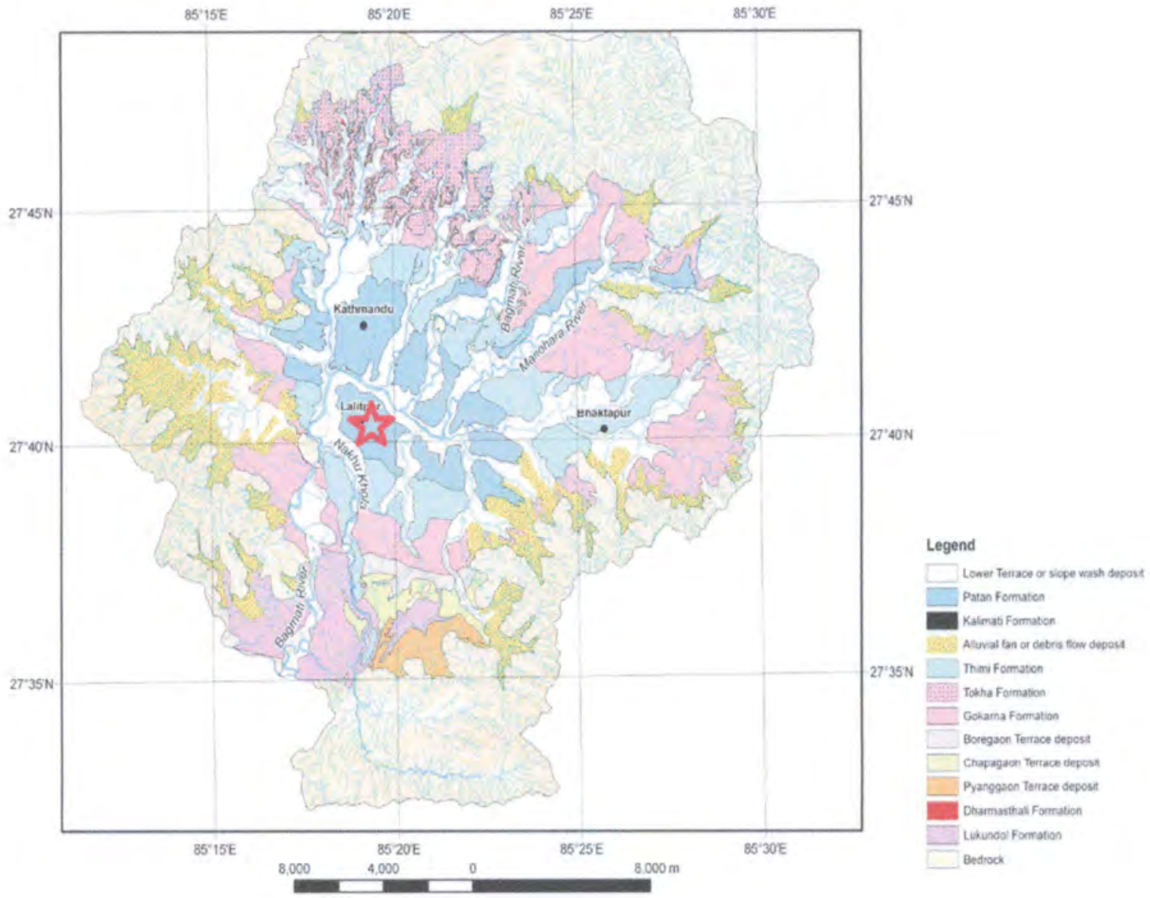

Figure 4-1 Fluvio-Lacustrine deposits of the Kathmandu valley: Megh Raj Dhital, Geology of the Nepal Himalaya

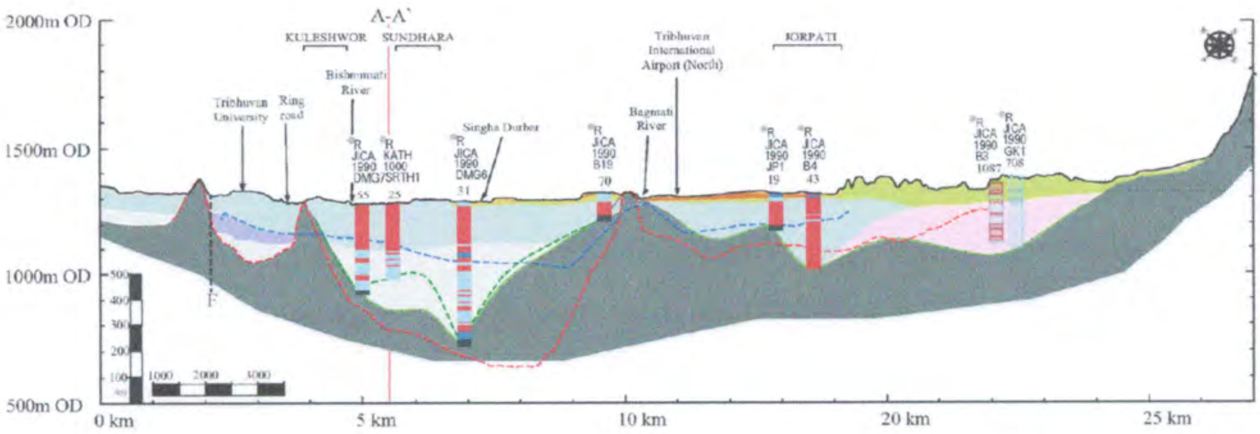

Figure 4-2 Gelogical cross sectional map of Kathmandu Valley from Charlottee EL Gilder et. al. 2019

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.

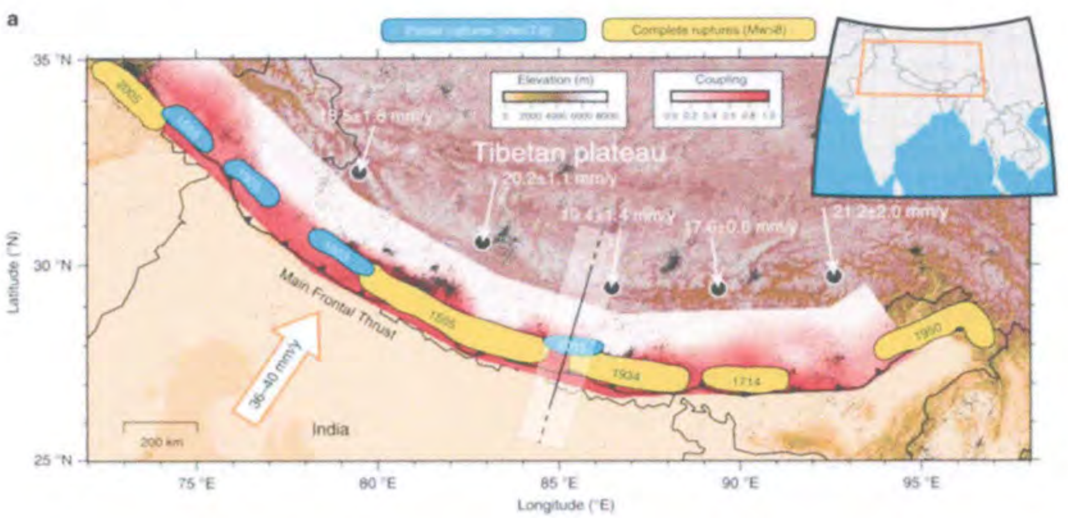

Figure 4-3 Topographic relief coupling modes and historical seismicity: Stevens V. and Avouac J. (2015)

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).

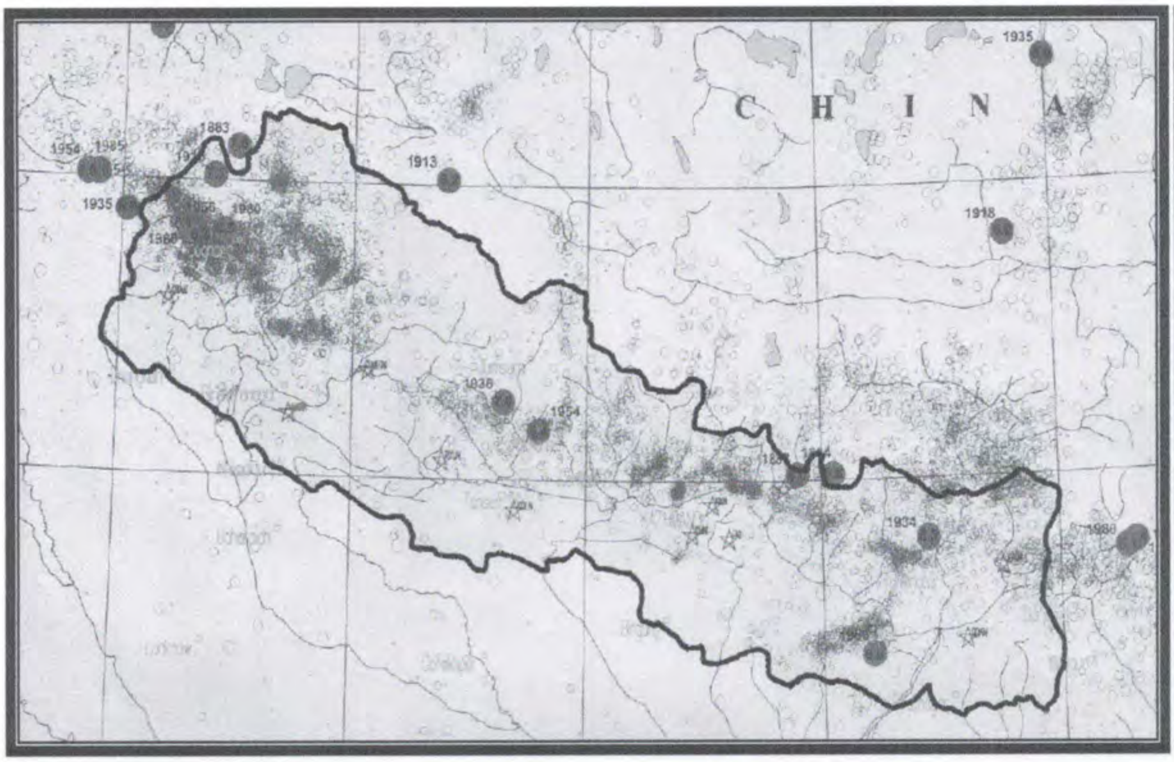

Figure 4-4 Historical events of earthquakes: Micro seismic epicenter map of Nepal and surrounding: DOMG,GON 1997

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.

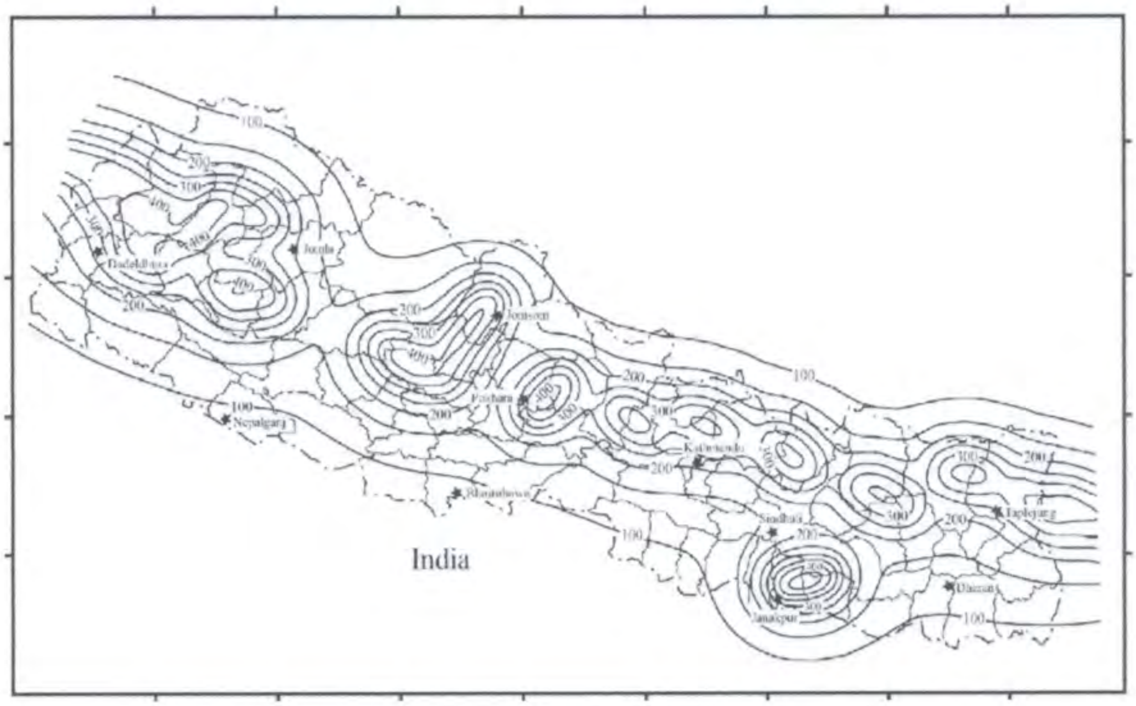

Figure 4-5 Probabilistic seismic hazard assessment map of Nepal : DOMG,GON

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,

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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.

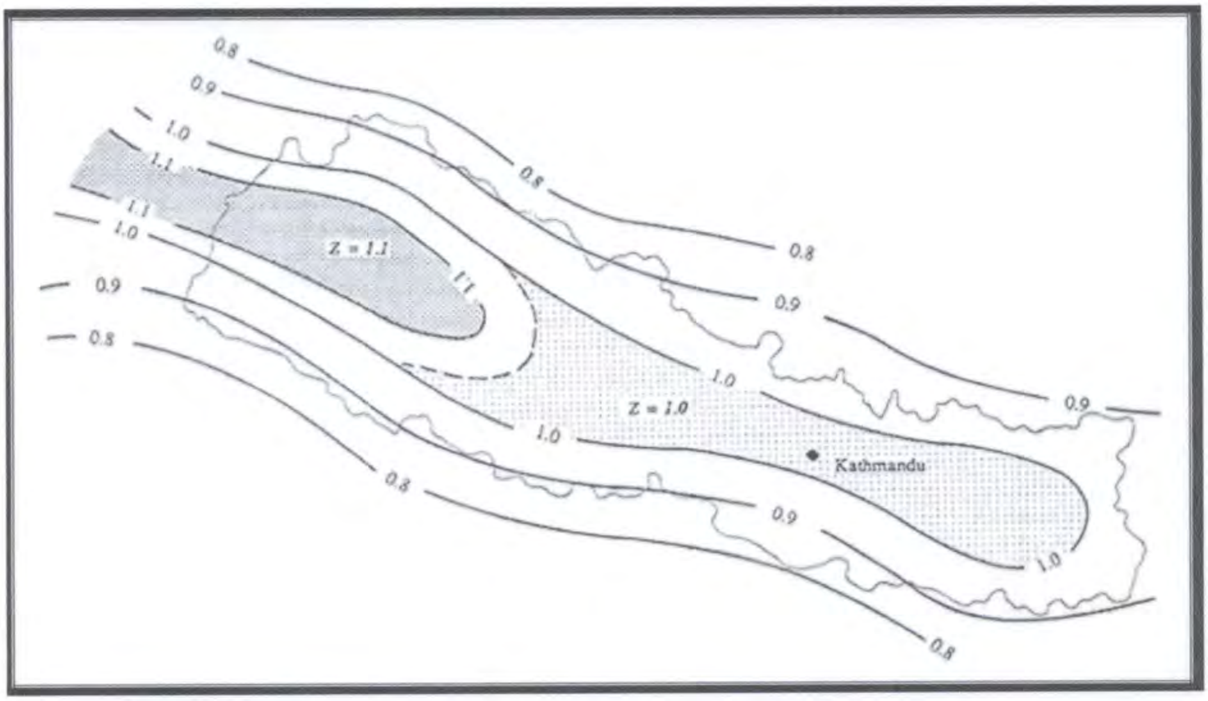


Figure 4-6 Seismic zoning map : UNDP/UNCHS Habitat 1994

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. Propose building site is located in high liquefaction susceptibility from reference of Direndra Piya et. al. (2006) and Narayan P. Marasaini (2014) as shown in figure 4.7.

The present site consists of sandy strata and the ground water table being encountered typically at nearly 3.0-5.0m below general ground level, so site may susceptible to liquefaction. Thus liquefaction potential analysis is performed in the site.

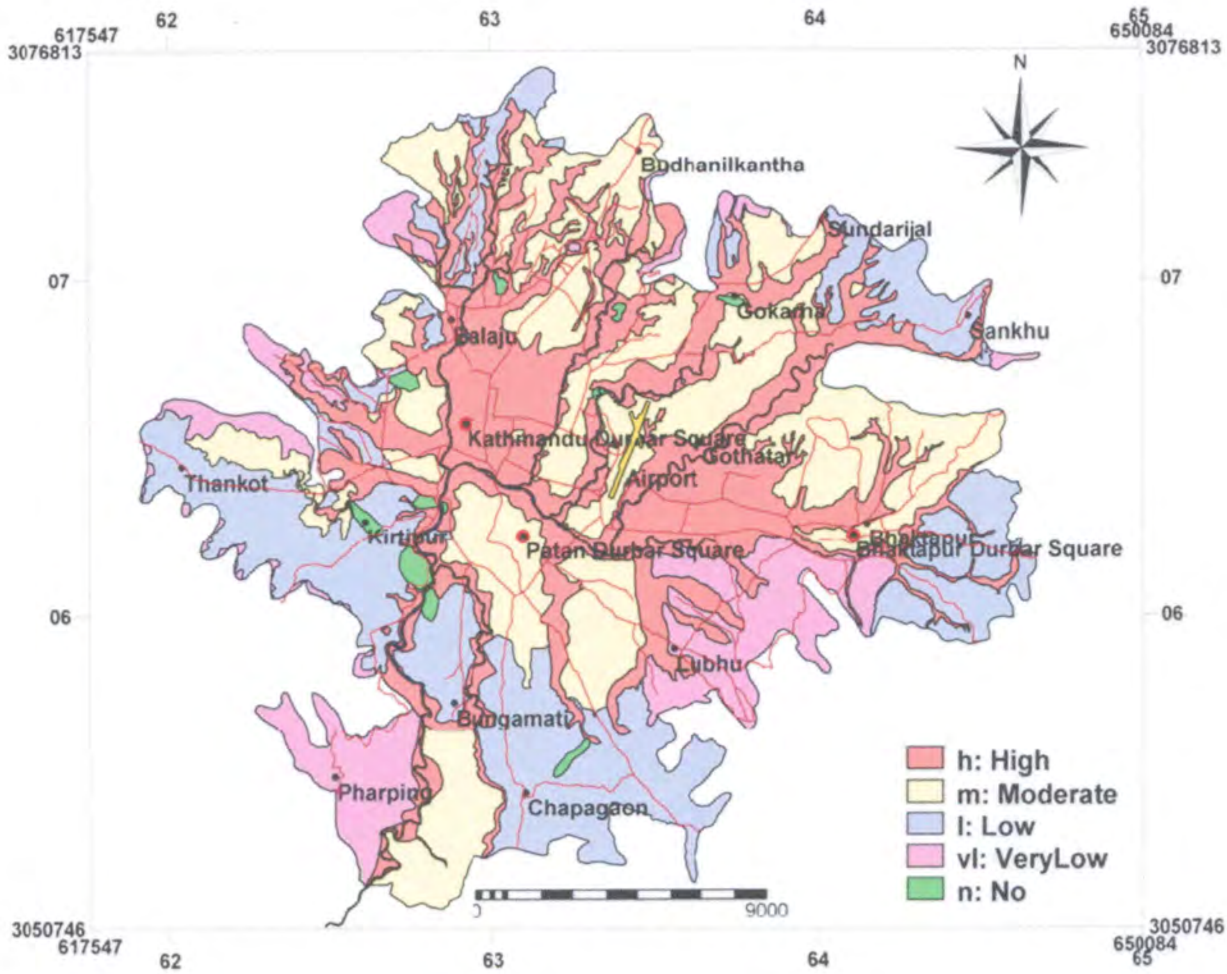


Figure 4-7 Liquefaction susceptibility map of the Kathmandu Valley: Birendra Piya et. al. 2006

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

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

α_{max} = peak horizontal acceleration of ground = 0.36g

g = gravitational acceleration m^2/sec

σ_{vc} and σ'_{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

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

For c-Φ soil,
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 γ is the bulk unit weight of soil and bearing capacity factors N_c, N_q, N_γ are determined using table 1 of IS 6403:1981 for internal frictional angle of soil ϕ whereas bearing capacity factors N'_c, N'_q, N'_γ 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_γ 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_γ are depth factor according to IS 6403:1981 they can be determined as below

$d_c = 1+0.2*\frac{D_f}{B}\sqrt{N_\phi}$

$d_q = d_\gamma = 1$ for $\phi < 10^o$

$d_q = d_\gamma = 1+0.1*\frac{D_f}{B}\sqrt{N_\phi}$ for $\phi > 10^o$

$N_\phi = \tan^2(\pi/4+\phi/2)$

D_f = Depth of foundation and B= width of foundation

i_c, i_q, i_γ are inclination factor for inclination of loading to the vertical (α) 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.

q_{allow} = 71.8*N kPa	(Meyerhoff, 1956)
q_{allow} = 47.8*N kPa	(Terzaghi and Peck, 1967)
q_{allow} = 34.0*N kPa	(Strounf and Butler, 1975)

All these empirical formulas for the allowable end bearing capacity were proposed by different researchers and practitioners assuming a factor of safety of 2.5. All uncertainty is embedded in the factor of safety (FS).

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

$$Q_{safe} = 11.98 * N_{60} * \left(\frac{3.28\,B+1}{3.28B}\right)^2 * f_d * \left(\frac{S}{25}\right) * R_{w1}$$

Where, N_{60}= Corrected average SPT N value

B = Width of footing (m)

S = Allowable settlement (100mm)

f_d = Depth factor= $1+0.33(D_f/B) \leqslant 1.33$

R_{w1}= water correction factor, for water table at just below footing=0.5

Length of footing L(m)	Breadth of footing B(m)	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
2	2	834.71	144.78	290.77
3	3	676.55	132.29	290.77
4	4	667.12	126.26	290.77
5	5	681.58	122.71	290.77
6	6	678.55	120.37	290.77
7	7	676.75	114.50	290.77
8	8	675.71	110.19	290.77

Note: It is recommended that net allowable bearing capacity of soil should be taken as **120 kN/m²** for the design purpose.

4.8 Settlement analysis of shallow foundation

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

a.) Elastic, or immediate settlement

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 = γ*D_f

q_n=q_u-q_o

q_u=Stress at level of foundation from foundation kPa

D_f= Depth of foundation (m)

γ = unit weight of soil (kN/m^3)

Δz=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}) .

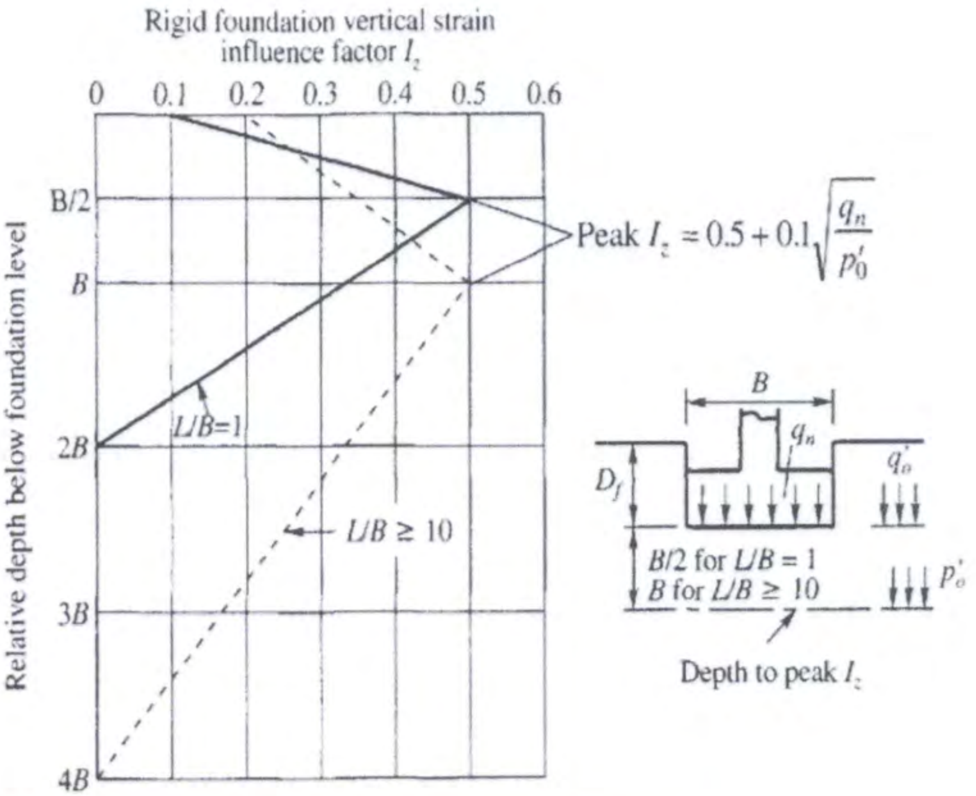


Figure 4-8 Equation for strain influence factor: Schmertmann's et al. (1978)

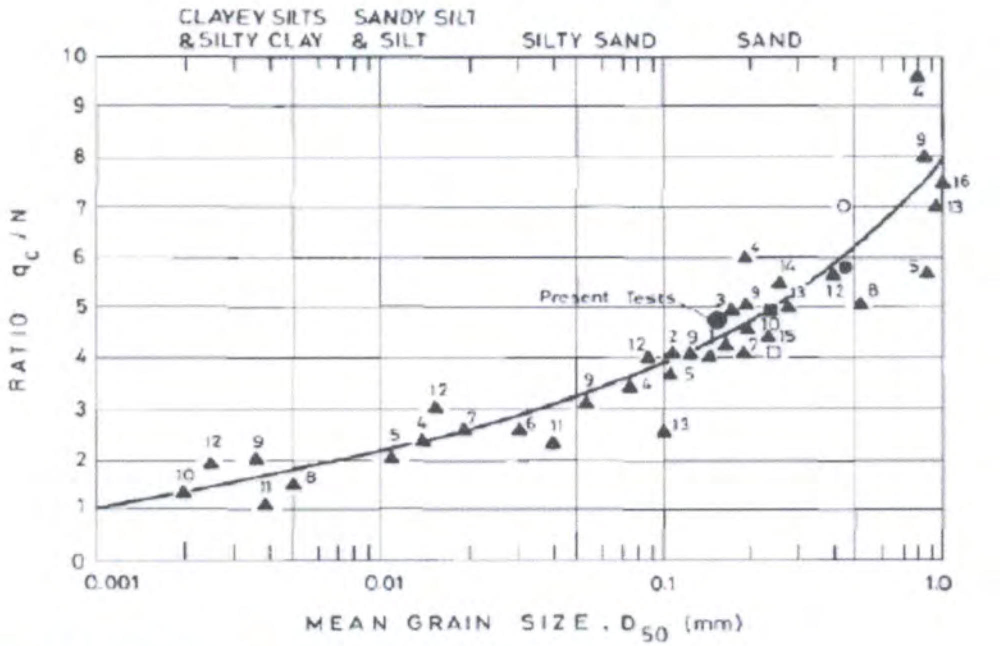


Figure 4-9 Relation between q_c/N and D_{50} : Ismael and Jeraagh 1986

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.

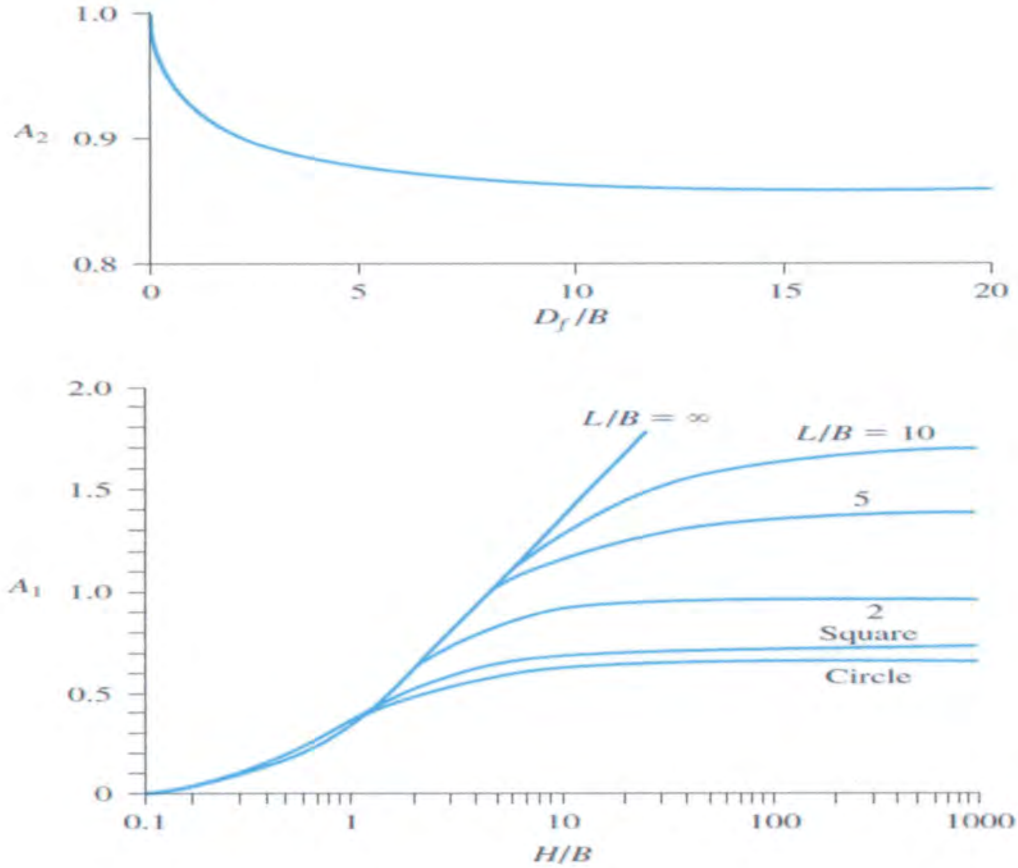


Figure 4-10 Values of A1 and A2 for elastic settlement calculation: Christian, J. T. and and Carrier,W. D. (1978).

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, as found in site from field investigation and from Ranjan Kumar Dahal and Arjun Aryal (2002) at project site there is very thick layer of clay beneath the 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

ΔP =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

λ = A factor related to pore pressure parameter and (H_t/B)

according to IS 8009 (part-I):1976 for normally consolidated clay

λ = 0.7 to 1.0

Detail of settlement calculation is attached as Annex 5 in the report according to which for proposed shallow footing (3mX3m) provided at depth of footing 4m and for pressure from footing 150 kPa total settlement is estimated as 42.848 mm which in with in allowable settlement recommended by table 1of IS 1904:1978 according to which for shallow foundation is 50mm.

4.9 Allowable bearing capacity for bored cast in-situ concrete piles using Static Analysis

The ultimate load capacity of a single pile may be obtained by using static analysis, the accuracy being dependent on the reliability of the soil properties for various strata. When computing capacity by static formula, the shear strength parameters obtained from borehole data and laboratory tests of disturbed samples and undisturbed samples. Bearing capacity of one bore cast in-situ pile is determined using equation below

For cohesionless soil

$$Q_u = A_p\left(\frac{1}{2}D * \gamma * N_\gamma + P_D N_q\right) + \sum_{i=1}^{n} k_i p_{di} tan\delta_i A_{si}$$

For cohesive soil

$$Q_u = A_p * (N_c * C_p) + \sum_{i=1}^{n} \alpha_i c_i A_{si}$$

Where,

D = diameter of pile shaft, in m;

A_p = cross-sectional area of pile tip, in m^2

γ = effective unit weight of the soil at pile tip, in kN/m^3

N_γ = bearing capacity factors depending upon angle of internal friction, ϕ at pile tip it can be determined from general shear failure referring IS 6403

N_q = bearing capacity factors depending upon angle of internal friction, ϕ at pile tip factor will depend on the nature of soil, type of pile, the L/B ratio and its method of construction. The values applicable for bored piles are given in figure 4-12

N_c = bearing capacity factor, may be taken as 9;

c_p = average cohesion at pile tip, in kN/m^2

$\sum_{i=1}^{n}$ = Summation for layers 1-n in which the pile is installed and which contribute positive skin friction;

K_i = coefficient of earth pressure applicable for the i^th layer, $\frac{1-sin\emptyset}{1+sin\emptyset}$

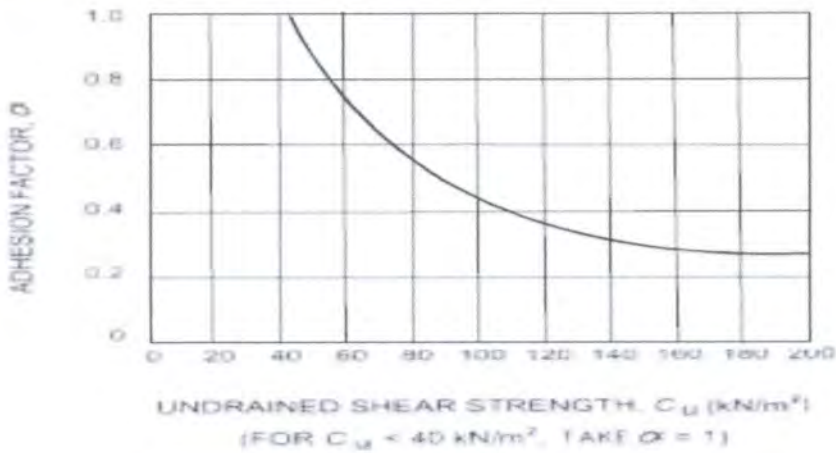
P_{Di} = effective overburden pressure for the i^th layer, in kN/m^2

δ_i = angle of wall friction between pile and soil for the i^th layer=(0.5 to 0.8)*ϕ

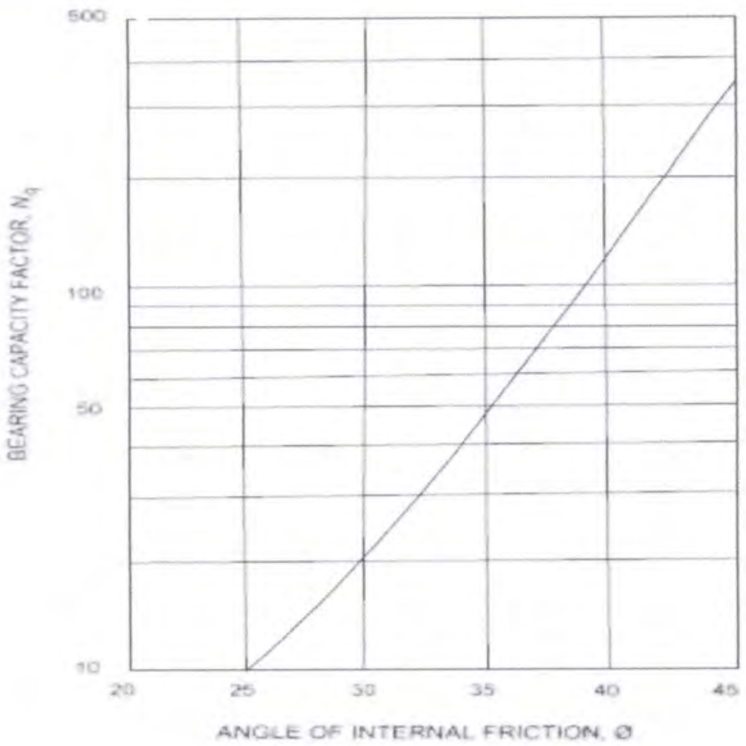
α_i = adhesion factor for the i^th layer depending on the consistency of soil can be determined using figure 4-11 , using undrained shear strength 6.25N kPa from Terzaghi and Peck (1967)

c_i = average cohesion for the i^th layer, in kN/m^2

A_{si} = surface area of pile shaft in the i^th layer, in m^2



4-11 VARIATION OF a WITH Cu (IS 2911 part 1-sec 2: 2010)



4-12 BEARING CAPACITY FACTOR, Nq FOR BORED PILES (IS 2911 part 1-sec 2: 2010)

For determining allowable bearing capacity, ultimate bearing capacity is divided by factor of safety, according to IS 2911-part1-sec 2:2010 factor of safety is taken as 2.0 for static formula.

Detail of bearing capacity calculation is attached as Annex 7 in the report according to which for bored cast in-situ concrete piles of diameter 500mm and length 10m is found to be 125kN/m2. For other diameters and lengths of piles bearing capacity can be determined from equations above.

4.10 Allowable bearing capacity for bored cast in-situ concrete piles using Standard Penetration Test (SPT) values

The correlation suggested by Meyerhof using standard penetration resistance, N in saturated cohesionless soil to estimate the ultimate load capacity of bored pile is given below. The ultimate load capacity of pile (Qu), in kN, is given as:

For cohesionless soil;

$$Q_u = 13N\frac{L}{B}\,A_p + \frac{\bar{N}A_s}{0.5}$$

For cohesive soil;

$$Q_u = 10N\frac{L}{B}\,A_p + \frac{\bar{N}A_s}{0.6}$$

Where,

N = average N value at pile tip

L = length of penetration of pile in the bearing strata, in m

B = diameter or minimum width of pile in m;

A_p = cross-sectional area of pile tip, in m^2;

N = average N along the pile shaft; and

A_s = surface area of pile shaft, in m^2.

For determining allowable bearing capacity, ultimate bearing capacity is divided by factor of safety, according to IS 2911-part1-sec 2:2010 factor of safety is taken as 4.0 for static formula.

Detail of bearing capacity calculation is attached as Annex 7 in the report according to which for bored cast in-situ concrete piles of diameter 500mm and length 10m is found to be 205 kN/m2. For other diameters and lengths of piles bearing capacity can be determined from equations above.

5.0 Conclusions and Recommendation

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

- Project site is susceptible to liquefaction, based on MAP prepared by Department of Mines and Geology, Peak Bed Rock Acceleration for Kathmandu Valley is around 200-250gal, and estimating with amplification factor of 2, design maximum horizontal acceleration is around 400gal.
- Sandy gravel soil followed by poorly graded to clayey sand strata lies on project site within drilling depth
- Project site is moderately susceptible towards liquefaction, to a depth of 4 m from general ground level.
- Soil stratification is found as back fill of brown sandy silt from 0 to 1.0m, followed by sandy gravel up to 6.0m, at this depth very high value of SPT was observed. From depth 6.0m to 12.0 m a grey to black sandy soil with gravels was observed. Beneath grey to black sandy soil with gravels layer a very thick layer of clayey sand was observed.
- At level of proposed foundation corrected SPT N value is 16, soil type is poorly graded sand having D_{50}=0.489, cohesion 2.52 kPa and frictional angle 30.49°.
- Allowable bearing capacity is taken as minimum 120 kPa for shallow footing and estimated total settlement is 42.09 mm which is less than allowable settlement recommended by IS 1904:1986.
- Allowable bearing capacity of 500mm diameter bored cast in-situ pile of length 10m is found to be 125 kPa.
- Maximum coefficient of consolidation was found to be 0.0093 cm^2/min at 20m depth and maximum free swell index was observed to be 18.75% for soil at depth of 13.5m.
- Ground water table was observed to be at **4m** from ground surface.

Recommendations

- To decrease risk of liquefaction different methods can be applied among which certain suitable methods are sand compaction piles, vibration compaction and bentonite suspension grouting.
- 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.

- Where space permits, the sides of the excavations shall be battered to a slope of two vertical and one horizontal (2V: 1H) to avoid collapse. If these recommended side sloped cannot be achieved for insufficient lateral space or for any other reason, lateral support system (shoring system) for the sides of the excavation will be required and should be considered to maintain safe working conditions.
- It is expected that the excavation work for shallow foundation (Raft) and Pile cap will be below the water table, so 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.
- As soil strata consist layer of sand with gravel followed by poorly graded sand then by clayey sand so, for EQUIPMEMNT foundations dynamic loading shall be reduced.
- As weaker strata is beneath sandy gravel so skin friction shall be considered major contribution for strength in pile foundation.
- As free swell is less than 20, so effect of soil expansiveness can be considered very low

Expert Testing Laboratory ETL

Annex 1: Borehole Log

EXPERT TESTING LABORATORY PVT. LTD.

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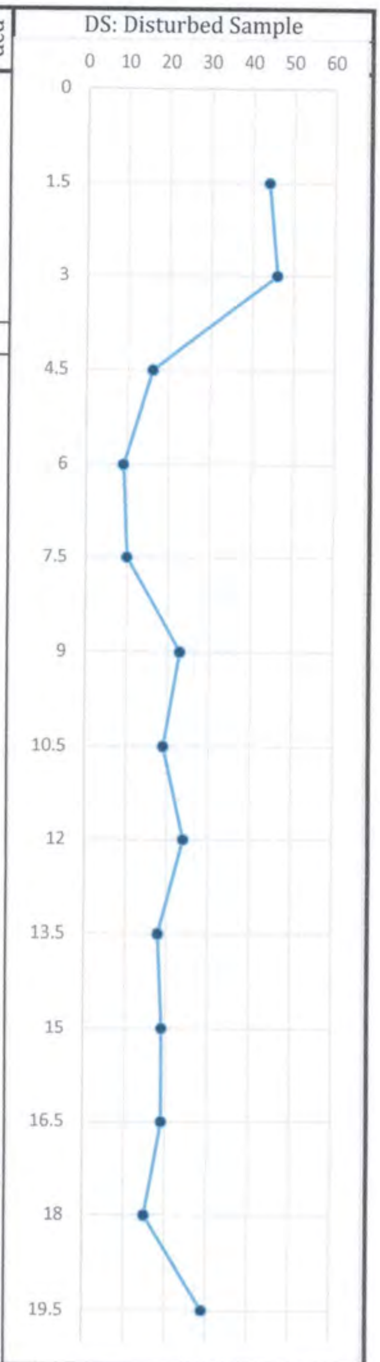
Bore Hole Log

Project:Chovar-Patan-Chapagaun under ground 132 kV
Location: Patan Sub-station, lagankhel
Type of Boring: Rotatory Boring
Inclination of Boring: Vertical
Ground Water Table: 4m from ground

Bore Hole no: 01
Date: 2022/03/10
Diameter of Boring: 85mm
Sampling Equipment: Split Sampler
Lattitude:
Longitude:

S.N.	Soil Descripti	Symb	Depth	Thicknes s of	Ground	Number of blows for 0-15	15-30	30-45	Total reorded
1	Brown sandysilt		0		4m from ground				
2			0.5						
3			1						
4	Sandy Gravel		1.5			15	19	25	44
5			2						
6			2.5						
7			3			25	25	21	46
8			3.5						
9			4						
10			4.5			24	10	6	16
11			5						
12			5.5						
13			6			8	4	5	9
14	Grey to black sandy soil with gravels		6.5						
15			7						
16			7.5			5	5	5	10
17			8						
18			8.5						
19			9			13	13	10	23
20			9.5						
21			10						
22			10.5			10	8	11	19
23			11						
24			11.5						
25			12			8	9	15	24
26	Silty Clay Blackish medium stiff slightly organic slity clay		12.5						
27			13						
28			13.5			5	8	10	18
29			14						
30			14.5						
31			15			8	10	9	19
32			15.5						
33			16						
34			16.5			7	11	8	19
35			17						
36			17.5						
37			18			7	7	8	15
38			18.5						
39			19						
40			19.5			13	11	18	29
41			20						



Tested By:
Er. Deepak Kumar Mahaseth

Approved By:
GeoTech Er. Aanand Mishra
Nec No. 6933"CIVIL"

Annex 2: SPT correction

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Correction for SPT value as per Skempton(1986)

Depth of water table(m) 4

S.N.	Bore Hole	Depth (m)	Unit Weight of Soil (kN/m³)	SPT value Recorded N_{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	1.5	19.3311	44	0.55	1	1	0.7	40.3333	1.85706	33.72	
2	BH-01	3	18.3682	46	0.55	1	1	0.75	42.1667	1.34712	28.80	
3	BH-01	4.5	17.8386	16	0.55	1	1	0.85	14.6667	1.14671	14.30	
4	BH-01	6	17.0682	9	0.55	1	1	0.95	8.25	1.08495	8.50	
5	BH-01	7.5	16.5025	10	0.55	1	1	0.95	9.16667	1.02209	8.90	
6	BH-01	9	18.1274	23	0.55	1	1	0.95	21.0833	0.89547	16.47	
7	BH-01	10.5	17.646	19	0.55	1	1	1	17.4167	0.86212	15.01	
8	BH-01	12	17.2668	24	0.55	1	1	1	22	0.80638	16.37	
9	BH-01	13.5	16.5446	18	0.55	1	1	1	16.5	0.79497	13.12	
10	BH-01	15	15.9006	19	0.55	1	1	1	17.4167	0.76284	13.29	
11	BH-01	16.5	18.2057	19	0.55	1	1	1	17.4167	0.71461	12.45	
12	BH-01	18	17.4714	15	0.55	1	1	1	13.75	0.70844	9.74	
13	BH-01	19.5	15.6659	29	0.55	1	1	1	26.5833	0.64761	16.11	

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Annex 3: Summary of Input Data

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Design Input Data (Summary)

Project:Chovar-Patan-Chapagaun under ground 132 kV transmission line

Location: Patan Sub-station, lagankhel

Ground Water Level 4m

S.N.	Bore Hole	Depth(m)	Soil Type	Field SPT	Bulk unit weight(γ)kN/m^3	Specific Gravity(G)	D_{50} (mm)	Moisture Content(w)%	Liquid Limit(LL)	Initial Void Ratio(e)	Saturated unit weight(γ_{sat})kN/m^3	$(N1)_{60}$	Field Based φ	Field Based C (kPa)	Lab Based φ	Lab Based C (kPa)	Design φ	Design C (kPa)
1	BH-01	1.5	SW	44	19.33	2.44	2.902	9.20	10	0.355	10.41	33.72	26.73	0	30.78	1.12	30.78	1.121
2	BH-01	3	SW-SM	46	18.37	2.4	0.598	10	10	0.41	10.36	28.8	25.7	0	30.49	2.52	30.49	2.523
3	BH-01	4.5	SW-SM	16	18.37	2.40	0.489	10.00	10	0.41	10.36	14.3	22.67	0	30.49	0.70	30.49	0.701
4	BH-01	6	SW	9	17.84	2.44	0.135	8.92	10	0.463	10.43	8.503	21.46	0	31.95	0.98	31.95	0.981
5	BH-01	7.5	SC	10	17.07	2.46	0.355	24.18		0.756	10.05	8.901	21.54	0	36.74	1.05	36.74	1.051
6	BH-01	9	SP	23	16.5	2.48	0.247	20.00		0.766	10.1	16.47	23.12	0	33.93	3.01	33.93	3.014
7	BH-01	10.5	SP	19	18.13	2.34	0.253	18.98		0.509	10.1	15.01	22.82	0	28.04	2.80	28.04	2.803
8	BH-01	12	SP	24	17.65	2.41	0.231	19.29		0.596	10.1	16.37	23.1	0	32.24	1.40	32.24	1.402
9	BH-01	13.5	SP	18	17.27	2.59	0.295	30.88		0.923	10	13.12	22.42	82.85	6.60	4.21	6.596	4.205
10	BH-01	15	SP-SC	19	16.54	2.25	0.199	25.00		0.666	10.02	13.29	22.46	83.94	28.51	7.99	28.51	7.99
11	BH-01	16.5	SP	19	15.9	2.48	0.202	25.71		0.923	10.03	12.45	22.28	78.5	18.77	7.64	18.77	7.639
12	BH-01	18	SP	15	18.21	2.47	0.134	24.14		0.649	10.05	9.741	21.72	60.96	11.87	8.06	11.87	8.06
13	BH-01	19.5	SP-SC	29	17.47	2.42	0.131	26.72		0.722	10.02	16.11	23.05	102.2	3.41	5.40	3.409	5.397

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Annex 4: Bearing Capacity Calculation For Shallow Foundation

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Determination of bearing capacity of open shallow foundation

Depth of water table= 4 m

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_γ	N_c'	Nq'	Nγ'	Sc	Sq	S_γ	d_c	d_q	d_γ	i_c	i_q	i_γ						
2	2	1	33.72	0	30	0		19.33	19.331	30	18	22.4	16	7.38	6.65	1.2	1.2	0.6	1.1	1	1.03	1	1	1	0.5	421.26	140.42	159.75	499.96	1146.33
		2	33.72	1.12	30.78	0	26.7	19.33	38.662	33	21	26.4	17	7.9	7.32	1.2	1.2	0.6	1.1	1.1	1.05	1	1	1	0.5	18.33	6.11	44.77	570.77	1146.33
		3	28.8	2.52	30.49	0	25.7	18.37	57.03	32	20	24.9	17	7.7	7.07	1.2	1.2	0.6	1.2	1.1	1.08	1	1	1	0.5	2206.68	735.56	792.59	487.58	979.25
		4	21.55	1.61	30.49	0	24.2	18.37	75.399	32	20	24.9	17	7.7	7.07	1.2	1.2	0.6	1.2	1.1	1.11	1	1	1	0.5	1922.68	640.89	716.29	364.80	732.65
		5	14.30	0.7	30.1	0	22.7	18.37	83.957	30	19	22.9	16	7.44	6.74	1.2	1.2	0.6	1.3	1.1	1.13	1	1	1	0.5	2250.40	750.13	834.09	242.01	486.05
		6	8.50	0.98	31.95	0	21.5	17.84	91.985	36	24	32.4	18	8.68	8.33	1.2	1.2	0.6	1.3	1.2	1.16	1	1	1	0.5	3542.19	1180.73	1272.72	143.95	289.11
		7	8.90	1.05	36.74	0	21.5	17.07	99.243	56	44	69.4	24	13.1	14.5	1.2	1.2	0.6	1.4	1.2	1.21	1	1	1	0.5	7569.20	2523.07	2622.31	150.68	302.62
		8	12.68	2.03	35.34	0	22.3	16.79	106.22	48	35	52.2	21	11.3	11.8	1.2	1.2	0.6	1.5	1.2	1.23	1	1	1	0.5	7009.77	2336.59	2442.81	214.73	431.26
		9	16.47	3.01	33.93	0	23.1	16.5	112.91	43	30	42.6	20	10	10.1	1.2	1.2	0.6	1.5	1.3	1.25	1	1	1	0.5	6760.94	2253.65	2366.56	278.78	559.90
		10	15.01	2.8	28.04	0	22.8	18.13	121.23	26	15	17.9	15	6.22	5.19	1.2	1.2	0.6	1.5	1.3	1.26	1	1	1	0.5	4070.66	1356.89	1478.11	254.07	510.26
		11	15.01	2.8	28.04	0	22.8	18.13	129.55	26	15	17.9	15	6.22	5.19	1.2	1.2	0.6	1.6	1.3	1.28	1	1	1	0.5	4556.67	1518.89	1648.44	254.07	510.26
		12	16.37	1.4	32.24	0	23.1	17.65	137.38	37	25	33.9	18	8.88	8.58	1.2	1.2	0.6	1.7	1.3	1.33	1	1	1	0.5	8261.46	2753.82	2891.20	277.13	556.59
		13	13.12	4.21	6.596	82.8	22.4	17.27	144.84	7.1	1.9	0.7	6.3	1.51	0.4	1.2	1.2	0.6	1.3	1	1	1	1	1	0.5	279.31	93.10	237.94	222.06	445.98
		14	13.12	4.21	6.596	82.8	22.4	17.27	152.3	7.1	1.9	0.7	6.3	1.51	0.4	1.2	1.2	0.6	1.4	1	1	1	1	1	0.5	298.03	99.34	251.64	222.06	445.98
		15	13.29	7.99	28.51	83.9	22.5	16.54	159.03	27	16	19	15	6.4	5.39	1.2	1.2	0.6	1.8	1.4	1.39	1	1	1	0.5	6715.50	2238.50	2397.53	224.92	451.73
		16	12.45	7.64	18.77	78.5	22.3	15.9	165.12	14	5.8	4.72	9.8	3.3	2.03	1.2	1.2	0.6	1.7	1.3	1.34	1	1	1	0.5	2176.07	725.36	890.48	210.70	423.17
		17	12.45	7.64	18.77	78.5	22.3	15.9	171.21	14	5.8	4.72	9.8	3.3	2.03	1.2	1.2	0.6	1.7	1.4	1.36	1	1	1	0.5	2336.98	778.99	950.21	210.70	423.17
		18	9.74	8.06	11.87	61	21.7	18.21	179.61	9.3	3	1.76	7.6	2.11	0.91	1.2	1.2	0.6	1.6	1.3	1.31	1	1	1	0.5	1187.04	395.68	575.29	164.91	331.20
		19	16.11	5.4	3.409	102	23	17.47	187.27	6.1	1.4	0.31	5.8	1.26	0.21	1.2	1.2	0.6	1.4	1	1	1	1	1	0.5	209.71	69.90	257.17	272.69	547.67

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Determination of bearing capacity of open shallow foundation

Depth of water table= 4 m

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_γ	N_c'	Nq'	Nγ'	Sc	Sq	S_γ	d_c	d_q	d_γ	i_c	i_q	i_γ						
		1	34.8	0	30	0		17.83	17.827	30	18	22.4	16	7.38	6.65	1.2	1.2	0.6	1	1	1.02	1	1	1	0.5	389.07	129.69	147.52	449.27	1183.18
		2	34.8	1.12	30.78	0	27	17.83	35.653	33	21	26.4	17	7.9	7.32	1.2	1.2	0.6	1.1	1	1.04	1	1	1	0.5	21.30	7.10	42.75	493.80	1183.18
		3	28.75	2.52	30.49	0	25.7	18.45	44.295	32	20	24.9	17	7.7	7.07	1.2	1.2	0.6	1.1	1.1	1.05	1	1	1	0.5	2534.10	844.70	889.00	444.78	977.59
		4	21.77	1.61	30.49	0	24.2	18.45	52.938	32	20	24.9	17	7.7	7.07	1.2	1.2	0.6	1.1	1.1	1.07	1	1	1	0.5	1870.82	623.61	676.55	336.77	740.20
		5	14.79	0.7	30.1	0	22.8	18.45	61.58	30	19	22.9	16	7.44	6.74	1.2	1.2	0.6	1.2	1.1	1.09	1	1	1	0.5	2174.74	724.91	786.49	228.76	502.80
		6	8.55	0.98	31.95	0	21.5	16.59	68.363	36	24	32.4	18	8.68	8.33	1.2	1.2	0.6	1.2	1.1	1.11	1	1	1	0.5	3147.47	1049.16	1117.52	**132.29**	**290.77**
		7	8.98	1.05	36.74	0	21.6	16.83	75.381	56	44	69.4	24	13.1	14.5	1.2	1.2	0.6	1.3	1.1	1.14	1	1	1	0.5	7046.53	2348.84	2424.23	138.99	305.48
		8	12.78	2.03	35.34	0	22.4	16.44	82.013	48	35	52.2	21	11.3	11.8	1.2	1.2	0.6	1.3	1.2	1.15	1	1	1	0.5	6442.25	2147.42	2229.43	197.74	434.61
		9	16.58	3.01	33.93	0	23.1	16.06	88.26	43	30	42.6	20	10	10.1	1.2	1.2	0.6	1.3	1.2	1.17	1	1	1	0.5	6136.74	2045.58	2133.84	256.49	563.74
3	3	10	14.90	2.8	28.04	0	22.8	17.36	95.807	26	15	17.9	15	6.22	5.19	1.2	1.2	0.6	1.3	1.2	1.17	1	1	1	0.5	3634.66	1211.55	1307.36	230.55	506.73
		11	14.90	2.8	28.04	0	22.8	17.36	103.35	26	15	17.9	15	6.22	5.19	1.2	1.2	0.6	1.4	1.2	1.19	1	1	1	0.5	4044.84	1348.28	1451.63	230.55	506.73
		12	16.41	1.4	32.24	0	23.1	18.15	111.7	37	25	33.9	18	8.88	8.58	1.2	1.2	0.6	1.4	1.2	1.22	1	1	1	0.5	7791.94	2597.31	2709.01	253.90	558.06
		13	13.10	4.21	6.596	82.7	22.4	16.89	118.78	7.1	1.9	0.7	6.3	1.51	0.4	1.2	1.2	0.6	1.2	1	1	1	1	1	0.5	270.29	90.10	208.87	202.57	445.23
		14	13.10	4.21	6.596	82.7	22.4	16.89	125.86	7.1	1.9	0.7	6.3	1.51	0.4	1.2	1.2	0.6	1.2	1	1	1	1	1	0.5	288.30	96.10	221.96	202.57	445.23
		15	13.04	7.99	28.51	82.3	22.4	16.68	132.73	27	16	19	15	6.4	5.39	1.2	1.2	0.6	1.5	1.3	1.26	1	1	1	0.5	6113.28	2037.76	2170.49	201.72	443.36
		16	12.40	7.64	18.77	78.2	22.3	17.54	140.46	14	5.8	4.72	9.8	3.3	2.03	1.2	1.2	0.6	1.5	1.2	1.23	1	1	1	0.5	2167.43	722.48	862.93	191.81	421.59
		17	12.40	7.64	18.77	78.2	22.3	17.54	148.19	14	5.8	4.72	9.8	3.3	2.03	1.2	1.2	0.6	1.5	1.2	1.24	1	1	1	0.5	2319.03	773.01	921.20	191.81	421.59
		18	9.61	8.06	11.87	60.1	21.7	18.57	156.95	9.3	3	1.76	7.6	2.11	0.91	1.2	1.2	0.6	1.4	1.2	1.21	1	1	1	0.5	1106.18	368.73	525.68	148.61	326.63
		19	16.09	5.4	3.409	102	23	18.87	166.01	6.1	1.4	0.31	5.8	1.26	0.21	1.2	1.2	0.6	1.3	1	1	1	1	1	0.5	217.00	72.33	238.34	248.88	547.02

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Determination of bearing capacity of open shallow foundation

Depth of water table= 4 m

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 40mm (qsafe) kPa	Safe allowable bearing capacity from SPT value kPa
				C kPa	φ	C kPa	φ			Nc	Nq	N_γ	N_c'	Nq'	Nγ'	Sc	Sq	S_γ	d_c	d_q	d_γ	i_c	i_q	i_γ						
4	4	1	34.8	0	30	0		17.83	17.827	30	18	22.4	16	7.38	6.65	1.2	1.2	0.6	1	1	1.01	1	1	1	0.5	390.78	130.26	148.09	418.17	1183.18
		2	34.8	1.12	30.78	0	27	17.83	35.653	33	21	26.4	17	7.9	7.32	1.2	1.2	0.6	1.1	1	1.03	1	1	1	0.5	25.10	8.37	44.02	450.04	1183.18
		3	28.75	2.52	30.49	0	25.7	18.45	44.295	32	20	24.9	17	7.7	7.07	1.2	1.2	0.6	1.1	1	1.04	1	1	1	0.5	2874.44	958.15	1002.44	398.17	977.59
		4	21.77	1.61	30.49	0	24.2	18.45	52.938	32	20	24.9	17	7.7	7.07	1.2	1.2	0.6	1.1	1.1	1.05	1	1	1	0.5	1842.54	614.18	667.12	321.42	740.20
		5	14.79	0.7	30.1	0	22.8	18.45	61.58	30	19	22.9	16	7.44	6.74	1.2	1.2	0.6	1.1	1.1	1.07	1	1	1	0.5	2133.56	711.19	772.77	218.33	502.80
		6	8.55	0.98	31.95	0	21.5	16.59	68.363	36	24	32.4	18	8.68	8.33	1.2	1.2	0.6	1.2	1.1	1.08	1	1	1	0.5	3073.85	1024.62	1092.98	**126.26**	**290.77**
		7	8.98	1.05	36.74	0	21.6	16.83	75.381	56	44	69.4	24	13.1	14.5	1.2	1.2	0.6	1.2	1.1	1.1	1	1	1	0.5	6842.90	2280.97	2356.35	132.65	305.48
		8	12.78	2.03	35.34	0	22.4	16.44	82.013	48	35	52.2	21	11.3	11.8	1.2	1.2	0.6	1.2	1.1	1.12	1	1	1	0.5	6232.09	2077.36	2159.37	188.72	434.61
		9	16.58	3.01	33.93	0	23.1	16.06	88.26	43	30	42.6	20	10	10.1	1.2	1.2	0.6	1.3	1.1	1.13	1	1	1	0.5	5915.71	1971.90	2060.16	244.79	563.74
		10	14.90	2.8	28.04	0	22.8	17.36	95.807	26	15	17.9	15	6.22	5.19	1.2	1.2	0.6	1.3	1.1	1.13	1	1	1	0.5	3501.49	1167.16	1262.97	220.04	506.73
		11	14.90	2.8	28.04	0	22.8	17.36	103.35	26	15	17.9	15	6.22	5.19	1.2	1.2	0.6	1.3	1.1	1.14	1	1	1	0.5	3883.98	1294.66	1398.02	220.04	506.73
		12	16.41	1.4	32.24	0	23.1	18.15	111.7	37	25	33.9	18	8.88	8.58	1.2	1.2	0.6	1.3	1.2	1.17	1	1	1	0.5	7443.07	2481.02	2592.72	242.33	558.06
		13	13.10	4.21	6.596	82.7	22.4	16.89	118.78	7.1	1.9	0.7	6.3	1.51	0.4	1.2	1.2	0.6	1.2	1	1	1	1	1	0.5	268.32	89.44	208.22	193.33	445.23
		14	13.10	4.21	6.596	82.7	22.4	16.89	125.86	7.1	1.9	0.7	6.3	1.51	0.4	1.2	1.2	0.6	1.2	1	1	1	1	1	0.5	286.18	95.39	221.26	193.33	445.23
		15	13.04	7.99	28.51	82.3	22.4	16.68	132.73	27	16	19	15	6.4	5.39	1.2	1.2	0.6	1.4	1.2	1.19	1	1	1	0.5	5788.62	1929.54	2062.27	192.52	443.36
		16	12.40	7.64	18.77	78.2	22.3	17.54	140.46	14	5.8	4.72	9.8	3.3	2.03	1.2	1.2	0.6	1.3	1.2	1.17	1	1	1	0.5	2062.53	687.51	827.97	183.07	421.59
		17	12.40	7.64	18.77	78.2	22.3	17.54	148.19	14	5.8	4.72	9.8	3.3	2.03	1.2	1.2	0.6	1.4	1.2	1.18	1	1	1	0.5	2201.48	733.83	882.01	183.07	421.59
		18	9.61	8.06	11.87	60.1	21.7	18.57	156.95	9.3	3	1.76	7.6	2.11	0.91	1.2	1.2	0.6	1.3	1.2	1.15	1	1	1	0.5	1055.40	351.80	508.75	141.83	326.63
		19	16.09	5.4	3.409	102	23	18.87	166.01	6.1	1.4	0.31	5.8	1.26	0.21	1.2	1.2	0.6	1.2	1	1	1	1	1	0.5	214.45	71.48	237.50	237.53	547.02

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Depth of water table= 4 m

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 40mm (qsafe) kPa	Safe allowable bearing capacity from SPT value kPa
				C kPa	φ	C kPa	φ			Nc	Nq	N_γ	N_c'	Nq'	Nγ'	Sc	Sq	S_γ	d_c	d_q	d_γ	i_c	i_q	i_γ						
		1	34.8	0	30	0		17.83	17.827	30	18	22.4	16	7.38	6.65	1.2	1.2	0.6	1	1	1.01	1	1	1	0.5	393.15	131.05	148.88	400.21	1183.18
		2	34.8	1.12	30.78	0	27	17.83	35.653	33	21	26.4	17	7.9	7.32	1.2	1.2	0.6	1	1	1.02	1	1	1	0.5	28.94	9.65	45.30	424.99	1183.18
		3	28.75	2.52	30.49	0	25.7	18.45	54.105	32	20	24.9	17	7.7	7.07	1.2	1.2	0.6	1.1	1	1.03	1	1	1	0.5	3222.37	1074.12	1128.23	371.61	977.59
		4	21.77	1.61	30.49	0	24.2	18.45	72.558	32	20	24.9	17	7.7	7.07	1.2	1.2	0.6	1.1	1	1.04	1	1	1	0.5	1827.06	609.02	681.58	296.87	740.20
		5	14.79	0.7	30.1	0	22.8	18.45	81.2	30	19	22.9	16	7.44	6.74	1.2	1.2	0.6	1.1	1.1	1.05	1	1	1	0.5	2110.23	703.41	784.61	212.19	502.80
		6	8.55	0.98	31.95	0	21.5	16.59	87.983	36	24	32.4	18	8.68	8.33	1.2	1.2	0.6	1.1	1.1	1.07	1	1	1	0.5	3031.62	1010.54	1098.52	**122.71**	**290.77**
		7	8.98	1.05	36.74	0	21.6	16.83	95.001	56	44	69.4	24	13.1	14.5	1.2	1.2	0.6	1.2	1.1	1.08	1	1	1	0.5	6724.88	2241.63	2336.63	128.92	305.48
		8	12.78	2.03	35.34	0	22.4	16.44	101.63	48	35	52.2	21	11.3	11.8	1.2	1.2	0.6	1.2	1.1	1.09	1	1	1	0.5	6109.12	2036.37	2138.00	183.41	434.61
		9	16.58	3.01	33.93	0	23.1	16.06	107.88	43	30	42.6	20	10	10.1	1.2	1.2	0.6	1.2	1.1	1.1	1	1	1	0.5	5785.64	1928.55	2036.43	237.91	563.74
5	5	10	14.90	2.8	28.04	0	22.8	17.36	115.43	26	15	17.9	15	6.22	5.19	1.2	1.2	0.6	1.2	1.1	1.1	1	1	1	0.5	3422.67	1140.89	1256.32	213.85	506.73
		11	14.90	2.8	28.04	0	22.8	17.36	122.97	26	15	17.9	15	6.22	5.19	1.2	1.2	0.6	1.2	1.1	1.11	1	1	1	0.5	3788.54	1262.85	1385.82	213.85	506.73
		12	16.41	1.4	32.24	0	23.1	18.15	131.32	37	25	33.9	18	8.88	8.58	1.2	1.2	0.6	1.3	1.1	1.13	1	1	1	0.5	7235.78	2411.93	2543.24	235.51	558.06
		13	13.10	4.21	6.596	82.7	22.4	16.89	138.4	7.1	1.9	0.7	6.3	1.51	0.4	1.2	1.2	0.6	1.1	1	1	1	1	1	0.5	267.18	89.06	227.46	187.90	445.23
		14	13.10	4.21	6.596	82.7	22.4	16.89	145.48	7.1	1.9	0.7	6.3	1.51	0.4	1.2	1.2	0.6	1.1	1	1	1	1	1	0.5	284.95	94.98	240.47	187.90	445.23
		15	13.04	7.99	28.51	82.3	22.4	16.68	152.35	27	16	19	15	6.4	5.39	1.2	1.2	0.6	1.3	1.2	1.16	1	1	1	0.5	5594.95	1864.98	2017.33	187.11	443.36
		16	12.40	7.64	18.77	78.2	22.3	17.54	160.08	14	5.8	4.72	9.8	3.3	2.03	1.2	1.2	0.6	1.3	1.1	1.14	1	1	1	0.5	1999.88	666.63	826.71	177.92	421.59
		17	12.40	7.64	18.77	78.2	22.3	17.54	167.81	14	5.8	4.72	9.8	3.3	2.03	1.2	1.2	0.6	1.3	1.1	1.14	1	1	1	0.5	2131.24	710.41	878.22	177.92	421.59
		18	9.61	8.06	11.87	60.1	21.7	18.57	176.57	9.3	3	1.76	7.6	2.11	0.91	1.2	1.2	0.6	1.2	1.1	1.12	1	1	1	0.5	1025.03	341.68	518.24	137.84	326.63
		19	16.09	5.4	3.409	102	23	18.87	185.63	6.1	1.4	0.31	5.8	1.26	0.21	1.2	1.2	0.6	1.2	1	1	1	1	1	0.5	212.94	70.98	256.61	230.85	547.02

Tested By:
Er. Deepak Kumar Mahaseth

Approved By:
GeoTech Er. Aanand Mishra
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Determination of bearing capacity of open shallow foundation

Depth of water table= 4 m

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	$N_γ$	Bearing Capacity Factors (Table 1 of IS6403:1981) N_c'	Nq'	Nγ'	Shape Factors (Table 2 of IS6403:1981) Sc	Sq	$S_γ$	Depth Factors (cl. 5.1.2.2 of IS6403:1981) d_c	d_q	$d_γ$	Inclination Factors (cl. 5.1.2.3 of IS6403:1981) i_c	i_q	$i_γ$	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
		1	34.8	0	30	0		17.83	17.827	30	18	22.4	16	7.38	6.65	1.2	1.2	0.6	1	1	1.01	1	1	1	0.5	395.85	131.95	149.78	388.53	1183.18
		2	34.8	1.12	30.78	0	27	17.83	35.653	33	21	26.4	17	7.9	7.32	1.2	1.2	0.6	1	1	1.02	1	1	1	0.5	32.79	10.93	46.58	408.78	1183.18
		3	28.75	2.52	30.49	0	25.7	18.45	54.105	32	20	24.9	17	7.7	7.07	1.2	1.2	0.6	1.1	1	1.03	1	1	1	0.5	3574.10	1191.37	1245.47	354.49	977.59
		4	21.77	1.61	30.49	0	24.2	18.45	72.558	32	20	24.9	17	7.7	7.07	1.2	1.2	0.6	1.1	1	1.04	1	1	1	0.5	1817.99	606.00	678.55	281.08	740.20
		5	14.79	0.7	30.1	0	22.8	18.45	81.2	30	19	22.9	16	7.44	6.74	1.2	1.2	0.6	1.1	1	1.04	1	1	1	0.5	2095.82	698.61	779.81	199.54	502.80
		6	8.55	0.98	31.95	0	21.5	16.59	87.983	36	24	32.4	18	8.68	8.33	1.2	1.2	0.6	1.1	1.1	1.05	1	1	1	0.5	3005.09	1001.70	1089.68	**120.37**	**290.77**
		7	8.98	1.05	36.74	0	21.6	16.83	95.001	56	44	69.4	24	13.1	14.5	1.2	1.2	0.6	1.1	1.1	1.07	1	1	1	0.5	6649.67	2216.56	2311.56	126.46	305.48
		8	12.78	2.03	35.34	0	22.4	16.44	101.63	48	35	52.2	21	11.3	11.8	1.2	1.2	0.6	1.2	1.1	1.08	1	1	1	0.5	6029.74	2009.91	2111.55	179.92	434.61
		9	16.58	3.01	33.93	0	23.1	16.06	107.88	43	30	42.6	20	10	10.1	1.2	1.2	0.6	1.2	1.1	1.08	1	1	1	0.5	5701.06	1900.35	2008.23	233.37	563.74
6	6	10	14.90	2.8	28.04	0	22.8	17.36	115.43	26	15	17.9	15	6.22	5.19	1.2	1.2	0.6	1.2	1.1	1.09	1	1	1	0.5	3371.01	1123.67	1239.10	209.77	506.73
		11	14.90	2.8	28.04	0	22.8	17.36	122.97	26	15	17.9	15	6.22	5.19	1.2	1.2	0.6	1.2	1.1	1.09	1	1	1	0.5	3725.81	1241.94	1364.91	209.77	506.73
		12	16.41	1.4	32.24	0	23.1	18.15	131.32	37	25	33.9	18	8.88	8.58	1.2	1.2	0.6	1.2	1.1	1.11	1	1	1	0.5	7099.28	2366.43	2497.74	231.02	558.06
		13	13.10	4.21	6.596	82.7	22.4	16.89	138.4	7.1	1.9	0.7	6.3	1.51	0.4	1.2	1.2	0.6	1.1	1	1	1	1	1	0.5	266.46	88.82	227.22	184.31	445.23
		14	13.10	4.21	6.596	82.7	22.4	16.89	145.48	7.1	1.9	0.7	6.3	1.51	0.4	1.2	1.2	0.6	1.1	1	1	1	1	1	0.5	284.16	94.72	240.20	184.31	445.23
		15	13.04	7.99	28.51	82.3	22.4	16.68	152.35	27	16	19	15	6.4	5.39	1.2	1.2	0.6	1.3	1.1	1.13	1	1	1	0.5	5466.80	1822.27	1974.62	183.54	443.36
		16	12.40	7.64	18.77	78.2	22.3	17.54	160.08	14	5.8	4.72	9.8	3.3	2.03	1.2	1.2	0.6	1.2	1.1	1.11	1	1	1	0.5	1958.35	652.78	812.86	174.53	421.59
		17	12.40	7.64	18.77	78.2	22.3	17.54	167.81	14	5.8	4.72	9.8	3.3	2.03	1.2	1.2	0.6	1.2	1.1	1.12	1	1	1	0.5	2084.64	694.88	862.69	174.53	421.59
		18	9.61	8.06	11.87	60.1	21.7	18.57	176.57	9.3	3	1.76	7.6	2.11	0.91	1.2	1.2	0.6	1.2	1.1	1.1	1	1	1	0.5	1004.87	334.96	511.53	135.22	326.63
		19	16.09	5.4	3.409	102	23	18.87	185.63	6.1	1.4	0.31	5.8	1.26	0.21	1.2	1.2	0.6	1.1	1	1	1	1	1	0.5	211.95	70.65	256.28	226.45	547.02

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Determination of bearing capacity of open shallow foundation

Depth of water table= 4 m

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_γ	N_c'	Nq'	Nγ'	Sc	Sq	S_γ	d_c	d_q	d_γ	i_c	i_q	i_γ						
		1	34.8	0	30	0		17.83	17.827	30	18	22.4	16	7.38	6.65	1.2	1.2	0.6	1	1	1.01	1	1	1	0.5	398.74	132.91	150.74	380.32	1183.18
		2	34.8	1.12	30.78	0	27	17.83	35.653	33	21	26.4	17	7.9	7.32	1.2	1.2	0.6	1	1	1.02	1	1	1	0.5	36.65	12.22	47.87	397.45	1183.18
		3	28.75	2.52	30.49	0	25.7	18.45	54.105	32	20	24.9	17	7.7	7.07	1.2	1.2	0.6	1	1	1.02	1	1	1	0.5	3928.00	1309.33	1363.44	342.53	977.59
		4	21.77	1.61	30.49	0	24.2	18.45	72.558	32	20	24.9	17	7.7	7.07	1.2	1.2	0.6	1.1	1	1.03	1	1	1	0.5	1812.58	604.19	676.75	270.07	740.20
		5	14.79	0.7	30.1	0	22.8	18.45	81.2	30	19	22.9	16	7.44	6.74	1.2	1.2	0.6	1.1	1	1.04	1	1	1	0.5	2086.51	695.50	776.70	190.73	502.80
		6	8.55	0.98	31.95	0	21.5	16.59	87.983	36	24	32.4	18	8.68	8.33	1.2	1.2	0.6	1.1	1	1.05	1	1	1	0.5	2987.52	995.84	1083.82	**114.50**	**290.77**
		7	8.98	1.05	36.74	0	21.6	16.83	95.001	56	44	69.4	24	13.1	14.5	1.2	1.2	0.6	1.1	1.1	1.06	1	1	1	0.5	6598.92	2199.64	2294.64	124.72	305.48
		8	12.78	2.03	35.34	0	22.4	16.44	101.63	48	35	52.2	21	11.3	11.8	1.2	1.2	0.6	1.1	1.1	1.07	1	1	1	0.5	5975.28	1991.76	2093.39	177.44	434.61
		9	16.58	3.01	33.93	0	23.1	16.06	107.88	43	30	42.6	20	10	10.1	1.2	1.2	0.6	1.1	1.1	1.07	1	1	1	0.5	5642.47	1880.82	1988.70	230.16	563.74
7	7	10	14.90	2.8	28.04	0	22.8	17.36	115.43	26	15	17.9	15	6.22	5.19	1.2	1.2	0.6	1.1	1.1	1.07	1	1	1	0.5	3334.88	1111.63	1227.05	206.88	506.73
		11	14.90	2.8	28.04	0	22.8	17.36	122.97	26	15	17.9	15	6.22	5.19	1.2	1.2	0.6	1.2	1.1	1.08	1	1	1	0.5	3681.77	1227.26	1350.23	206.88	506.73
		12	16.41	1.4	32.24	0	23.1	18.15	131.32	37	25	33.9	18	8.88	8.58	1.2	1.2	0.6	1.2	1.1	1.09	1	1	1	0.5	7003.23	2334.41	2465.73	227.84	558.06
		13	13.10	4.21	6.596	82.7	22.4	16.89	138.4	7.1	1.9	0.7	6.3	1.51	0.4	1.2	1.2	0.6	1.1	1	1	1	1	1	0.5	265.97	88.66	227.06	181.78	445.23
		14	13.10	4.21	6.596	82.7	22.4	16.89	145.48	7.1	1.9	0.7	6.3	1.51	0.4	1.2	1.2	0.6	1.1	1	1	1	1	1	0.5	283.63	94.54	240.03	181.78	445.23
		15	13.04	7.99	28.51	82.3	22.4	16.68	152.35	27	16	19	15	6.4	5.39	1.2	1.2	0.6	1.2	1.1	1.11	1	1	1	0.5	5376.07	1792.02	1944.37	181.01	443.36
		16	12.40	7.64	18.77	78.2	22.3	17.54	160.08	14	5.8	4.72	9.8	3.3	2.03	1.2	1.2	0.6	1.2	1.1	1.1	1	1	1	0.5	1928.89	642.96	803.04	172.12	421.59
		17	12.40	7.64	18.77	78.2	22.3	17.54	167.81	14	5.8	4.72	9.8	3.3	2.03	1.2	1.2	0.6	1.2	1.1	1.1	1	1	1	0.5	2051.56	683.85	851.66	172.12	421.59
		18	9.61	8.06	11.87	60.1	21.7	18.57	176.57	9.3	3	1.76	7.6	2.11	0.91	1.2	1.2	0.6	1.2	1.1	1.09	1	1	1	0.5	990.55	330.18	506.75	133.35	326.63
		19	16.09	5.4	3.409	102	23	18.87	185.63	6.1	1.4	0.31	5.8	1.26	0.21	1.2	1.2	0.6	1.1	1	1	1	1	1	0.5	211.26	70.42	256.05	223.33	547.02

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Determination of bearing capacity of open shallow foundation

Depth of water table= 4 m

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_γ	N_c'	Nq'	Nγ'	Sc	Sq	S_γ	d_c	d_q	d_γ	i_c	i_q	i_γ						
8	8	1	34.8	0	30	0		17.83	17.827	30	18	22.4	16	7.38	6.65	1.2	1.2	0.6	1	1	1.01	1	1	1	0.5	401.75	133.92	151.74	374.25	1183.18
		2	34.8	1.12	30.78	0	27	17.83	35.653	33	21	26.4	17	7.9	7.32	1.2	1.2	0.6	1	1	1.01	1	1	1	0.5	40.52	13.51	49.16	389.07	1183.18
		3	28.75	2.52	30.49	0	25.7	18.45	54.105	32	20	24.9	17	7.7	7.07	1.2	1.2	0.6	1	1	1.02	1	1	1	0.5	4283.25	1427.75	1481.86	333.72	977.59
		4	21.77	1.61	30.49	0	24.2	18.45	72.558	32	20	24.9	17	7.7	7.07	1.2	1.2	0.6	1.1	1	1.03	1	1	1	0.5	1809.45	603.15	675.71	261.96	740.20
		5	14.79	0.7	30.1	0	22.8	18.45	81.2	30	19	22.9	16	7.44	6.74	1.2	1.2	0.6	1.1	1	1.03	1	1	1	0.5	2080.38	693.46	774.66	184.24	502.80
		6	8.55	0.98	31.95	0	21.5	16.59	87.983	36	24	32.4	18	8.68	8.33	1.2	1.2	0.6	1.1	1	1.04	1	1	1	0.5	2975.57	991.86	1079.84	**110.19**	**290.77**
		7	8.98	1.05	36.74	0	21.6	16.83	95.001	56	44	69.4	24	13.1	14.5	1.2	1.2	0.6	1.1	1.1	1.05	1	1	1	0.5	6563.45	2187.82	2282.82	119.59	305.48
		8	12.78	2.03	35.34	0	22.4	16.44	101.63	48	35	52.2	21	11.3	11.8	1.2	1.2	0.6	1.1	1.1	1.06	1	1	1	0.5	5936.39	1978.80	2080.43	175.59	434.61
		9	16.58	3.01	33.93	0	23.1	16.06	107.88	43	30	42.6	20	10	10.1	1.2	1.2	0.6	1.1	1.1	1.06	1	1	1	0.5	5600.12	1866.71	1974.59	227.76	563.74
		10	14.90	2.8	28.04	0	22.8	17.36	115.43	26	15	17.9	15	6.22	5.19	1.2	1.2	0.6	1.1	1.1	1.06	1	1	1	0.5	3308.45	1102.82	1218.24	204.73	506.73
		11	14.90	2.8	28.04	0	22.8	17.36	122.97	26	15	17.9	15	6.22	5.19	1.2	1.2	0.6	1.1	1.1	1.07	1	1	1	0.5	3649.41	1216.47	1339.44	204.73	506.73
		12	16.41	1.4	32.24	0	23.1	18.15	131.32	37	25	33.9	18	8.88	8.58	1.2	1.2	0.6	1.2	1.1	1.08	1	1	1	0.5	6932.47	2310.82	2442.14	225.47	558.06
		13	13.10	4.21	6.596	82.7	22.4	16.89	138.4	7.1	1.9	0.7	6.3	1.51	0.4	1.2	1.2	0.6	1.1	1	1	1	1	1	0.5	265.64	88.55	226.94	179.88	445.23
		14	13.10	4.21	6.596	82.7	22.4	16.89	145.48	7.1	1.9	0.7	6.3	1.51	0.4	1.2	1.2	0.6	1.1	1	1	1	1	1	0.5	283.25	94.42	239.90	179.88	445.23
		15	13.04	7.99	28.51	82.3	22.4	16.68	152.35	27	16	19	15	6.4	5.39	1.2	1.2	0.6	1.2	1.1	1.1	1	1	1	0.5	5308.73	1769.58	1921.93	179.13	443.36
		16	12.40	7.64	18.77	78.2	22.3	17.54	160.08	14	5.8	4.72	9.8	3.3	2.03	1.2	1.2	0.6	1.2	1.1	1.08	1	1	1	0.5	1906.97	635.66	795.73	170.33	421.59
		17	12.40	7.64	18.77	78.2	22.3	17.54	167.81	14	5.8	4.72	9.8	3.3	2.03	1.2	1.2	0.6	1.2	1.1	1.09	1	1	1	0.5	2026.93	675.64	843.45	170.33	421.59
		18	9.61	8.06	11.87	60.1	21.7	18.57	176.57	9.3	3	1.76	7.6	2.11	0.91	1.2	1.2	0.6	1.2	1.1	1.08	1	1	1	0.5	979.87	326.62	503.19	131.97	326.63
		19	16.09	5.4	3.409	102	23	18.87	185.63	6.1	1.4	0.31	5.8	1.26	0.21	1.2	1.2	0.6	1.1	1	1	1	1	1	0.5	210.75	70.25	255.88	221.01	547.02

Tested By:
Er. Deepak Kumar Mahaseth

Approved By:
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Annex 5: Settlement Calculation for Shallow Foundation

EXPERT TESTING LABORATORY PVT. LTD.

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Shettlement Calculation

Project:Chovar-Patan-Chapagaun under ground 132 kV transmission line

Location: Patan Sub-station, lagankhel

Ground Water Level(m) 4

Size of Footing : 3mX3m

Depth of foundation (m)= 4

Stress from foundation for settlement calculation(qu) kN/m^2= 150

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	3.0-4.0	1	SW-SM	28.8	18.37	150.00	73.47	0.41	0.52	6.20	17517.55	43793.88	0.11	0.000003	43793.88
2	4.0-5.0	1	SW-SM	21.5	18.37	150.00	91.84	0.41	0.54	6.30	13317.61	33294.02	0.15	0.000005	33294.02
3	5.0-6.0	1	SW-SM	14.3	18.37	150.00	110.21	0.46	0.40	5.80	8133.92	20334.80	0.25	0.000012	20334.80
4	6.0-7.0	1	SW	8.5	17.84	150.00	128.05	0.76	0.53	6.20	5171.89	12929.73	0.38	0.000029	12929.73
5	7.0-8.0	1	SC	8.9	17.07	150.00	145.12	0.77	0.49	6.10	5326.25	13315.62	0.48	0.000036	13315.62
6	8.0-9.0	1	SC	12.7	16.79	150.00	161.90	0.77	0.48	6.00	7465.92	18664.80	0.48	0.000025	18664.80
7	9.0-10.0	1	SP	16.5	16.50	150.00	178.40	0.51	0.54	6.30	10177.55	25443.88	0.30	0.000012	25443.88
8	10.0-11.0	1	SP	15.0	18.13	150.00	196.53	0.51	0.58	6.40	9422.39	23555.98	0.28	0.000012	23555.98
9	11.0-12.0	1	SP	15.0	18.13	150.00	214.66	0.60	0.37	5.60	8244.59	20611.49	0.25	0.000012	20611.49
10	12.0-13.0	1	SP	16.4	17.65	150.00	232.30	0.60	0.37	5.60	8993.12	22482.81	0.23	0.000010	22482.81
11	13.0-14.0	1	SP	13.1	17.27	150.00	249.57	0.92	0.37	5.60	7205.96	18014.90	0.20	0.000011	18014.90
12	14.0-15.0	1	SP	13.1	17.27	150.00	266.84	0.67	0.14	4.60	5919.18	14797.96	0.18	0.000012	14797.96
13	15.0-16.0	1	SP-SC	13.3	16.54	150.00	283.38	0.92	0.14	4.60	5995.52	14988.79	0.15	0.000010	14988.79
14	16.0-17.0	1	SP-SC	12.45	15.9	150	299.2832	0.923	0.13	4.5	5494.33385	13735.835	0.15	0.000011	13735.835
15	17.0-18.0	1	SP	12.4	15.90	150.00	315.18	0.65	0.11	4.10	5005.95	12514.87	0.11	0.000009	12514.87
														0.000208	17137.74

Tested By:

Er. Deepak Kumar Mahaseth

Approved By:

GeoTech Er. Aanand Mishra

Nec No: 6933"CIVIL"

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Shettlement Calculation

Elastic settlement from Schmertmann et. al 1978			
Correction factor for emdement of foundation (C1)=		0.210	
Correction factor to account for creep in soil (C2)=		1.540	
Elastic settlement	**Se=**	**5.150**	mm
Elastic Settlement in saturated clay from Janbu et al. 1956			
Elastic settlement	**Se=**	**30.578**	mm
Consolidation Settlement inclay layer			
Thickness of clay layer (m)		75.000	
initial void ratio		0.900	
Compression index		0.225	
Eff. pressure at mid of clay layer before construction		911.46	
Eff. pressure at mid of clay layer after construction		1061.46	
Consolidation Settlement	S_c	**12.270**	mm
Total Settlement	S_t	**42.848**	mm

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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 4m from ground

S.N.	Depth(m)	Corrected SPT(N60)	Soil Type		% of Fine (FC)	Unit weight of Soil(kN/m2)	Total vertical stress(σ_v) kN/m2	Effective vertical stress(σ_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	40.333	SW	33.715	2.46	19.33	19.331	19.331	33.72	33.715	0.9992	1.000	0.2338	293.82	0	0
2	2	40.333	SW	33.715	4.2	19.331	38.662	38.662	33.72	33.716	0.991	1.000	0.2319	293.83	1267.2	0
3	3	42.167	SW-SM	28.801	5.94	18.368	93.767	83.957	28.80	28.826	0.9819	1.000	0.2566	16.085	62.692	0
4	4	14.667	SW-SM	14.296	1.06	18.368	167.24	147.62	14.30	14.296	0.9718	1.000	0.2576	0.2344	0.9101	0
5	5	14.667	SW-SM	14.296	10.26	18.368	185.61	156.18	14.30	15.564	0.9608	1.000	0.2672	0.2856	1.069	0
6	6	8.25	SW	8.5033	20.26	17.839	203.45	164.21	8.50	13.024	0.9491	1.000	0.2752	0.1962	0.713	2.0093
7	7	9.1667	SC	8.9007	1.77	17.068	220.51	171.46	8.90	8.9007	0.9367	1.000	0.2819	0.1231	0.4366	3.6619
8	8	21.083	SC	16.468	1.77	16.785	237.3	178.44	16.47	16.468	0.9237	1.000	0.2874	0.3334	1.1599	0
9	9	21.083	SP	16.468	3.27	16.502	253.8	185.13	16.47	16.468	0.9101	1.000	0.2919	0.3334	1.1419	0
10	10	17.417	SP	15.008	2.79	18.127	271.93	193.45	15.01	15.008	0.8961	1.000	0.2947	0.2612	0.8863	0.5683
11	11	17.417	SP	15.008	2.8	18.127	290.06	201.77	15.01	15.008	0.8817	1.000	0.2966	0.2612	0.8808	0.5364
12	12	22	SP	16.37	2.9	17.646	307.7	209.6	16.37	16.37	0.8671	1.000	0.2978	0.3276	1.1001	0
13	13	16.5	SP	13.117	10.87	17.267	324.97	217.06	13.12	14.669	0.8523	1.000	0.2985	0.2479	0.8303	0.5938
14	14	16.5	SP	13.117	10.87	17.267	342.24	224.52	13.12	14.669	0.8374	1.000	0.2986	0.2479	0.83	0.5099
15	15	17.417	SP-SC	13.286	3.65	16.545	358.78	231.25	13.29	13.286	0.8225	1.000	0.2985	0.2033	0.6808	0.798
16	16	17.417	SP	12.446	3.58	15.901	374.68	237.34	12.45	12.446	0.8076	1.000	0.2983	0.1821	0.6105	0.779
17	17	17.417	SP	12.446	3.58	15.901	390.58	243.43	12.45	12.446	0.7928	1.000	0.2976	0.1821	0.6118	0.5823
18	18	13.75	SP	9.7411	5.88	18.206	408.79	251.83	9.74	9.7629	0.7783	1.000	0.2956	0.1341	0.4537	0.5463
19	19	26.583	SP-SC	16.108	13.1	17.471	426.26	259.49	16.11	18.657	0.7641	1.000	0.2937	0.5119	1.743	0
20	20	26.583	SP-SC	16.108	13.1	17.471	443.73	267.15	16.11	18.657	0.7502	1.000	0.2915	0.5119	1.7558	0
																10.585

As liquefaction potential Index is greater than 5 so there is medium possibility of liquefaction.

Tested By:
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Annex 7: Bearing Capacity Calculation for Bored Cast In-situ Piles

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Bearinng Capacity of Cast In-situ Bored Pile

Material in Pile :	Concrete	
Diameter of pile:	0.5	m
Length of Pile:	10	m
Depth of excavation :	3.5	m
Water table depth:	4	m
Bearing capcity factor Nc:	9	
Area of Pile :	0.19625	m^2
Factor of Saftey:	2	

Depth(m)	Thickness of layer(m)	Design cohesion 'c' kPa	Design internal frictional resistance 'φ'	Field SPT value 'N'	Effective surge charge pressure kPa	Effective unit weight of soil kN/m^3	Bearing capacity factor N_γ	Bearing capacity factor N_q	Coefficient of earth pressure K_i	Angle of wall friction between pile and soil δ_i	Adhesion factor α_i	Ultimate load carrying capcacity from static formula kPa	Ultimate load carrying capacity from Meyerhof's theorem kPa	Allowable load carrying capacity kPa
0														
1.5	1.5	1.12	30.78	44	0.00	19.33	26.42	20	0.32	15.39	0.3	27.840	-	13.920
3	1.5	2.52	30.49	46	0.00	18.37	24.89	20	0.33	15.24	0.3	29.478	-	14.739
4.5	1.5	0.70	30.49	16	12.84	18.37	24.89	20	0.33	15.24	0.42	80.057	116.2389	40.029
6	1.5	0.98	31.95	9	24.88	17.84	32.42	20	0.31	15.98	0.85	138.254	140.7826	69.127
7.5	1.5	1.05	36.74	10	35.77	17.07	69.36	46	0.25	18.37	0.75	397.455	190.4591	198.728
9	1.5	3.01	33.93	23	45.81	16.50	42.56	23	0.28	16.97	0.35	265.627	332.0271	132.813
10.5	1.5	2.80	28.04	19	58.28	18.13	17.89	18	0.36	14.02	0.38	**250.975**	411.3523	**125.487**
12	1.5	1.40	32.24	24	70.04	17.65	33.89	20	0.30	16.12	0.3	334.410	537.2123	167.205
13.5	1.5	4.21	6.60	18	81.22	17.27	0.70	10	0.79	3.30	0.4	200.210	606.7201	100.105
15	1.5	7.99	28.51	19	91.32	16.54	18.97	12	0.35	14.25	0.38	286.701	698.808	143.351
16.5	1.5	7.64	18.77	19	100.46	15.90	4.72	10	0.51	9.39	0.38	265.104	788.3434	132.552
18	1.5	8.06	11.87	15	113.05	18.21	1.76	10	0.66	5.94	0.42	298.469	848.8191	149.235
19.5	1.5	5.40	3.41	29	124.54	17.47	0.31	10	0.89	1.70	0.38	320.569	1021.214	160.284
									Bearing capacity			250.975	411.3523	125.487

Tested By:

Er. Deepak Kumar Mahaseth

Approved By:

GeoTech Er. Anand Mishra

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Annex 8: Direct Shear Test Results

EXPERT TESTING LABORATORY PVT. LTD.

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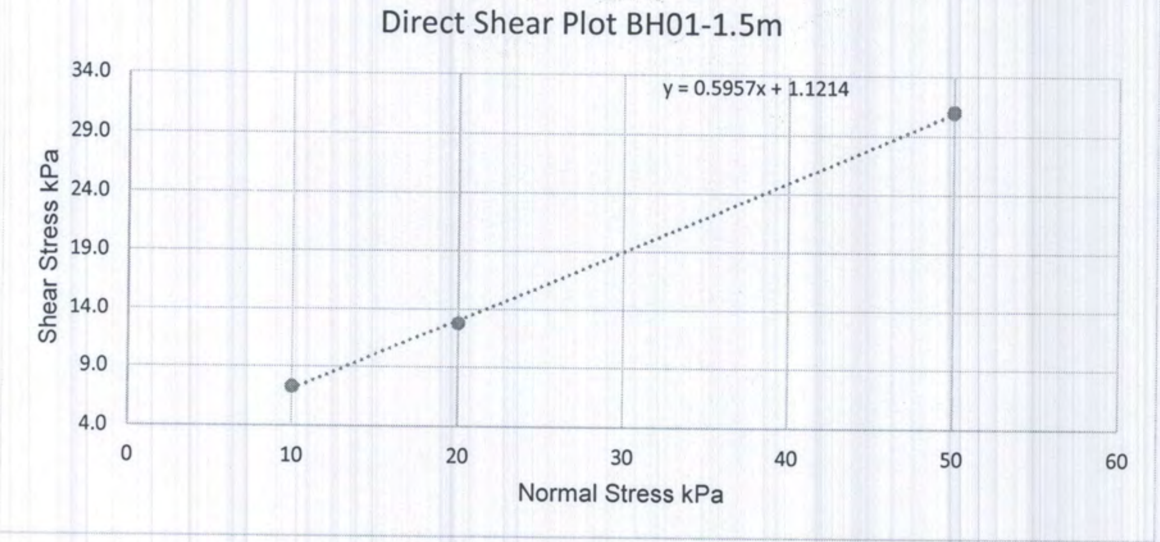
Direct shear test Results

Project:Chovar-Patan-Chapagaun under ground 132 kV transmission line	Location: Patan Sub-station, lagankhel
Test Method: IS 2720 part 13:1986	Specimen Plan dimension: 0.06m X 0.06m
Bore hole No: BH01	Thickness of specimen:
Depth(m) : 1.5m	PRG factor: 0.00328
Soil type:SW	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	10	7.3	1	1.12	30.78	
2	20	12.8	3			
3	50	31.0	5			



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Approved By:
GeoTech Er. Aanand Mishra
Nec No: 6933"CIVIL"

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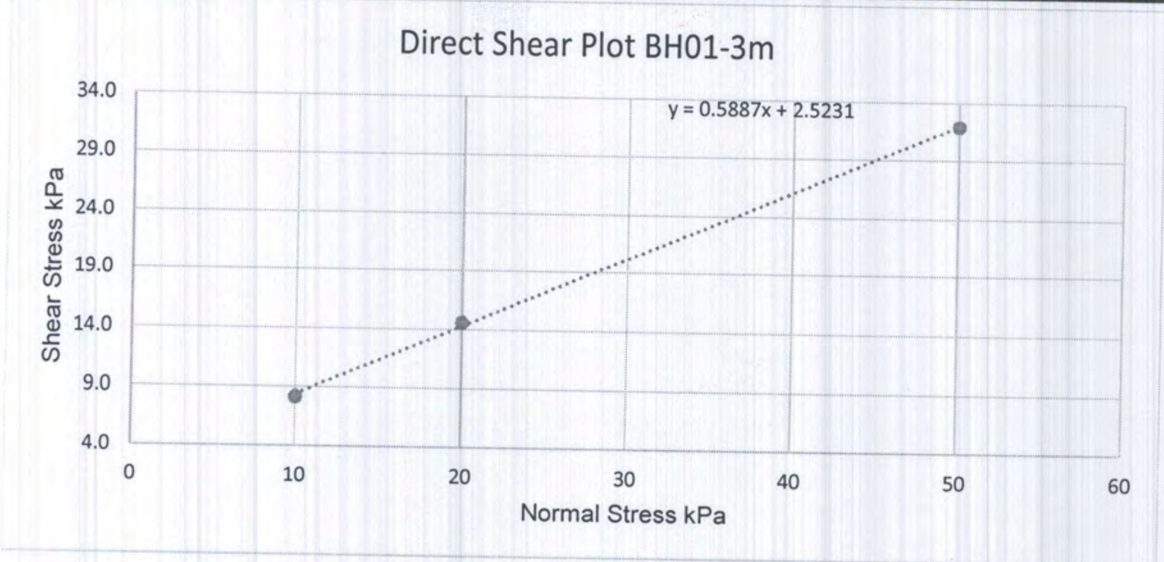
Direct shear test Results

Project:Chovar-Patan-Chapagaun under ground 132 kV transmission line	Location: Patan Sub-station, lagankhel
Test Method: IS 2720 part 13:1986	Specimen Plan dimension: 0.06m X 0.06m
Bore hole No: BH01	Thickness of specimen:
Depth(m) : 3m	PRG factor: 0.00328
Soil type:SW-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	10	8.2	2	2.52	30.49	
2	20	14.6	7			
3	50	31.9	7			



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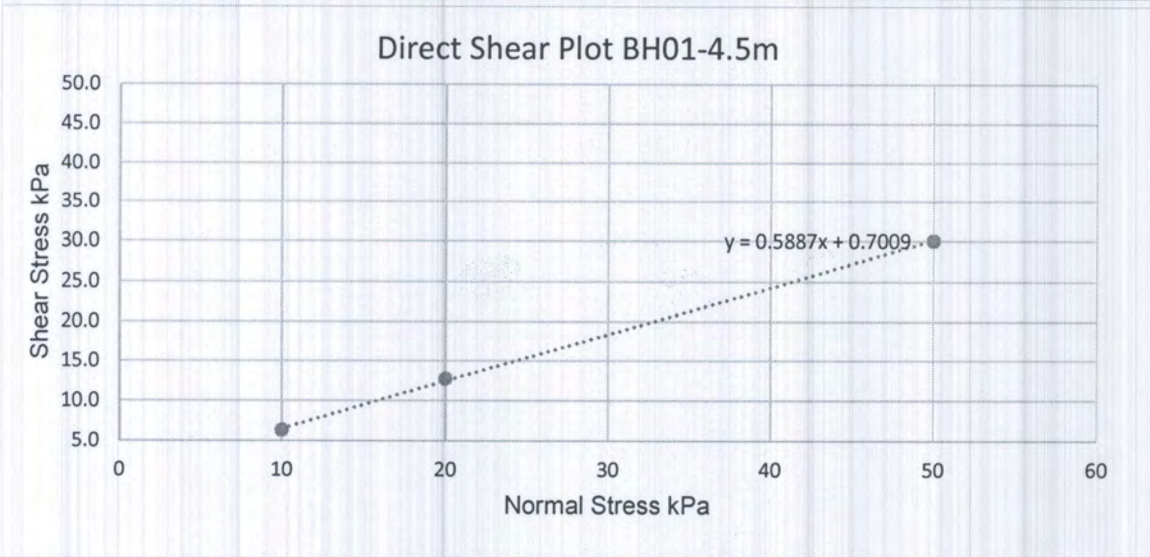
Direct shear test Results

Project:Chovar-Patan-Chapagaun under ground 132 kV transmission line	Location: Patan Sub-station, lagankhel
Test Method: IS 2720 part 13:1986	Specimen Plan dimension: 0.06m X 0.06m
Bore hole No: BH01	Thickness of specimen:
Depth(m) : 4.5m	PRG factor: 0.00328
Soil type:SW	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	10	6.4	2	0.70	30.49	
2	20	12.8	4			
3	50	30.1	5			



Tested By:
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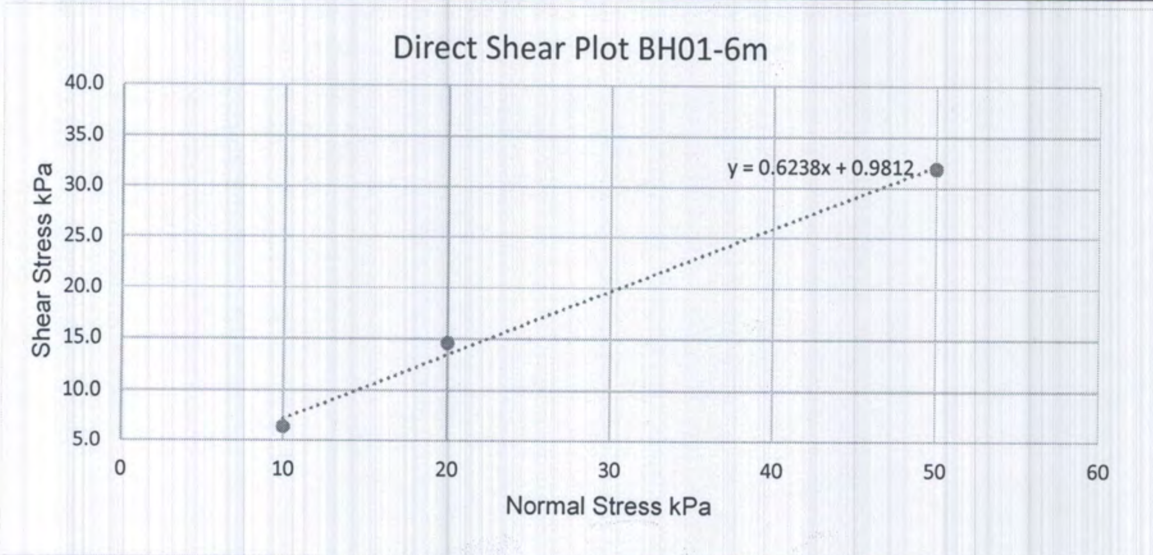
Direct shear test Results

Project:Chovar-Patan-Chapagaun under ground 132 kV transmission line	Location: Patan Sub-station, lagankhel
Test Method: IS 2720 part 13:1986	Specimen Plan dimension: 0.06m X 0.06m
Bore hole No: BH01	Thickness of specimen:
Depth(m) : 6m	PRG factor: 0.00328
Soil type:SC	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	10	6.4	1	0.98	31.95	
2	20	14.6	5			
3	50	31.9	5.5			



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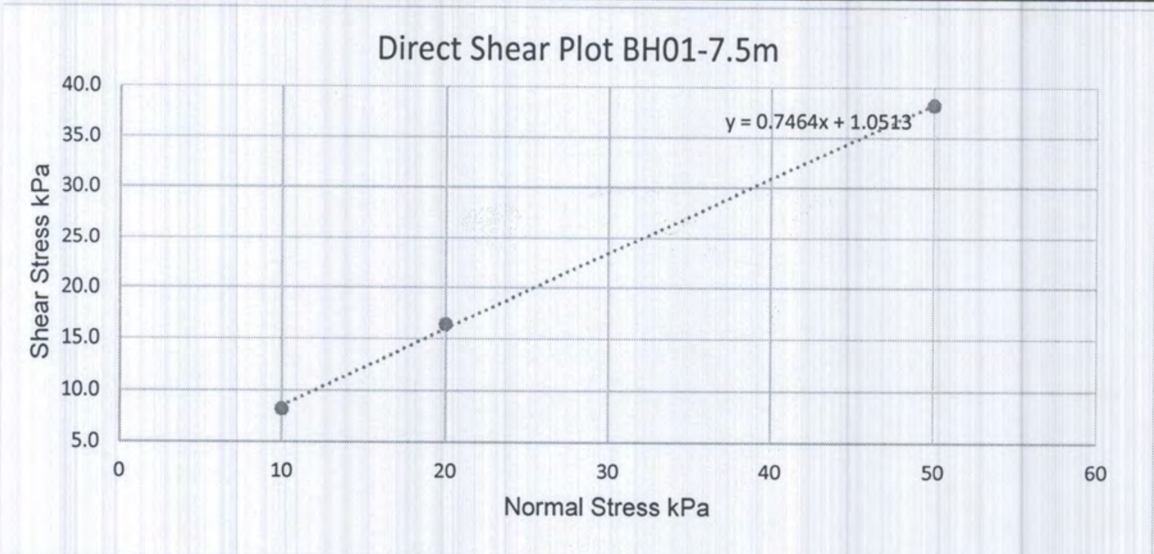
Direct shear test Results

Project:Chovar-Patan-Chapagaun under ground 132 kV transmission line	Location: Patan Sub-station, lagankhel
Test Method: IS 2720 part 13:1986	Specimen Plan dimension: 0.06m X 0.06m
Bore hole No: BH01	Thickness of specimen:
Depth(m) : 7.5m	PRG factor: 0.00328
Soil type:SP	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	10	8.2	2	1.05	36.74	
2	20	16.4	3			
3	50	38.3	3.5			



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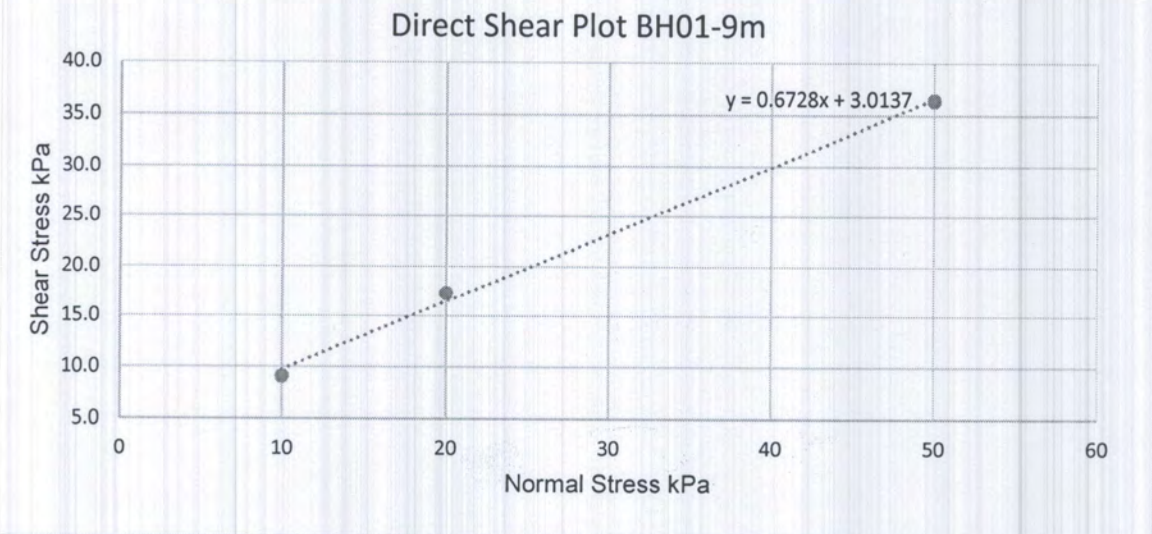
Direct shear test Results

Project:Chovar-Patan-Chapagaun under ground 132 kV transmission line	Location: Patan Sub-station, lagankhel
Test Method: IS 2720 part 13:1986	Specimen Plan dimension: 0.06m X 0.06m
Bore hole No: BH01	Thickness of specimen:
Depth(m) : 9m	PRG factor: 0.00328
Soil type:SP	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	10	9.1	4	3.01	33.93	
2	20	17.3	7			
3	50	36.4	7.5			



Tested By:
Er. Deepak Kumar Mahaseth

Approved By:
GeoTech Er. Aanand Mishra
Nec No: 6933"CIVIL"

EXPERT TESTING LABORATORY PVT. LTD.

BAFAL, LALITPUR-17

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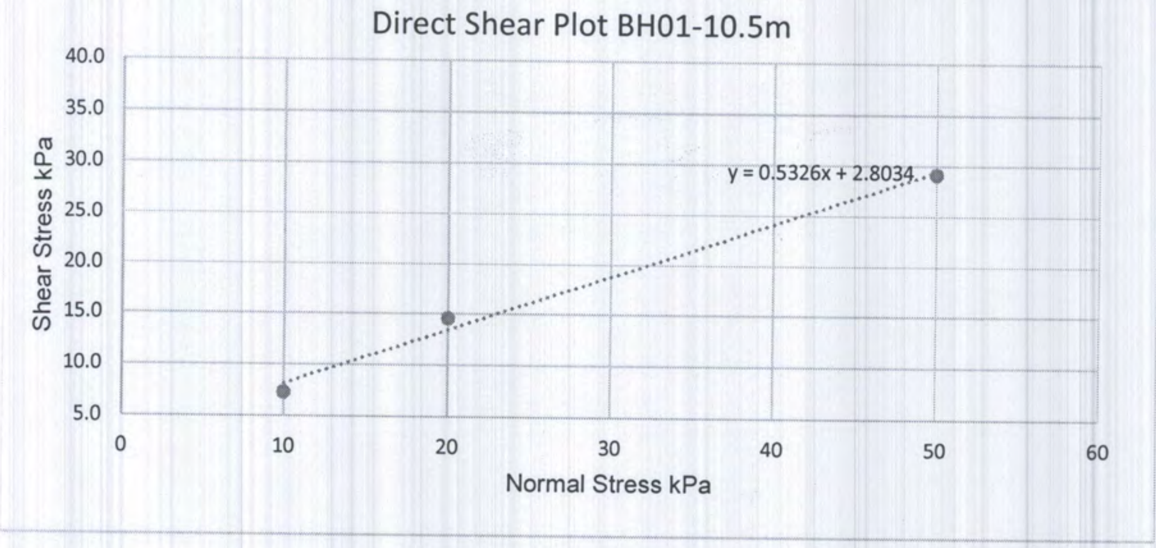
Direct shear test Results

Project:Chovar-Patan-Chapagaun under ground 132 kV transmission line	Location: Patan Sub-station, lagankhel
Test Method: IS 2720 part 13:1986	Specimen Plan dimension: 0.06m X 0.06m
Bore hole No: BH01	Thickness of specimen:
Depth(m) : 10.5m	PRG factor: 0.00328
Soil type:SP	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	10	7.3	2	2.80	28.04	
2	20	14.6	3			
3	50	29.2	4			



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Approved By:

GeoTech Er. Aanand Mishra

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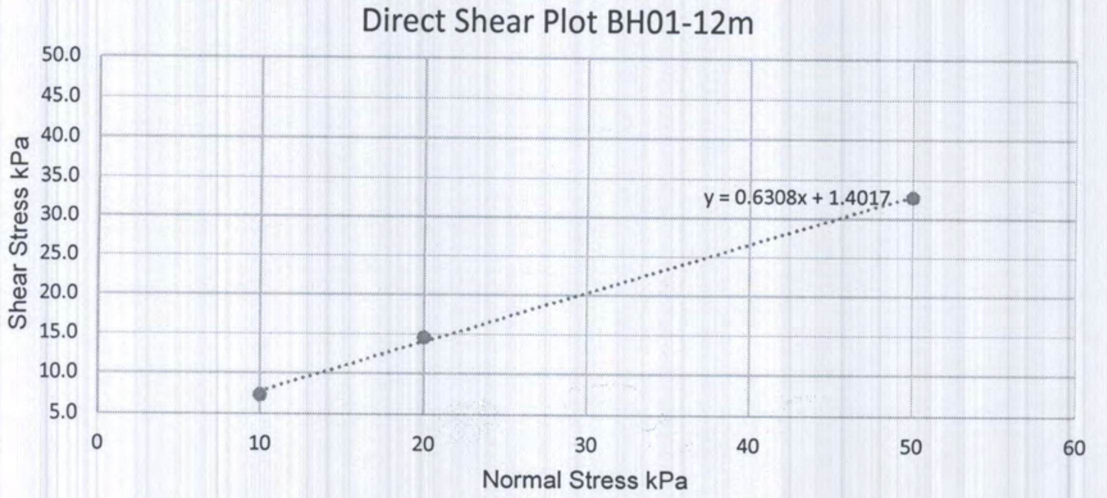
Direct shear test Results

Project:Chovar-Patan-Chapagaun under ground 132 kV transmission line	Location: Patan Sub-station, lagankhel
Test Method: IS 2720 part 13:1986	Specimen Plan dimension: 0.06m X 0.06m
Bore hole No: BH01	Thickness of specimen:
Depth(m) : 12m	PRG factor: 0.00328
Soil type:SP	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	10	7.3	1	1.40	32.24	
2	20	14.6	4			
3	50	32.8	5			



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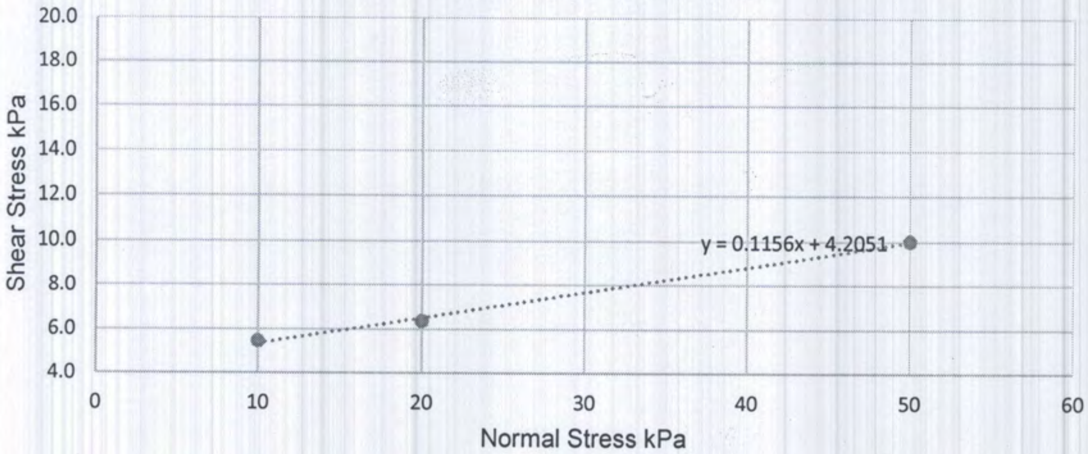
Direct shear test Results

Project:Chovar-Patan-Chapagaun under ground 132 kV transmission line	Location: Patan Sub-station, lagankhel
Test Method: IS 2720 part 13:1986	Specimen Plan dimension: 0.06m X 0.06m
Bore hole No: BH01	Thickness of specimen:
Depth(m) : 13.5m	PRG factor: 0.00328
Soil type:SP-SC	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	10	5.5	0.8	4.21	6.60	
2	20	6.4	2			
3	50	10.0	4			

Direct Shear Plot BH01-13.5m



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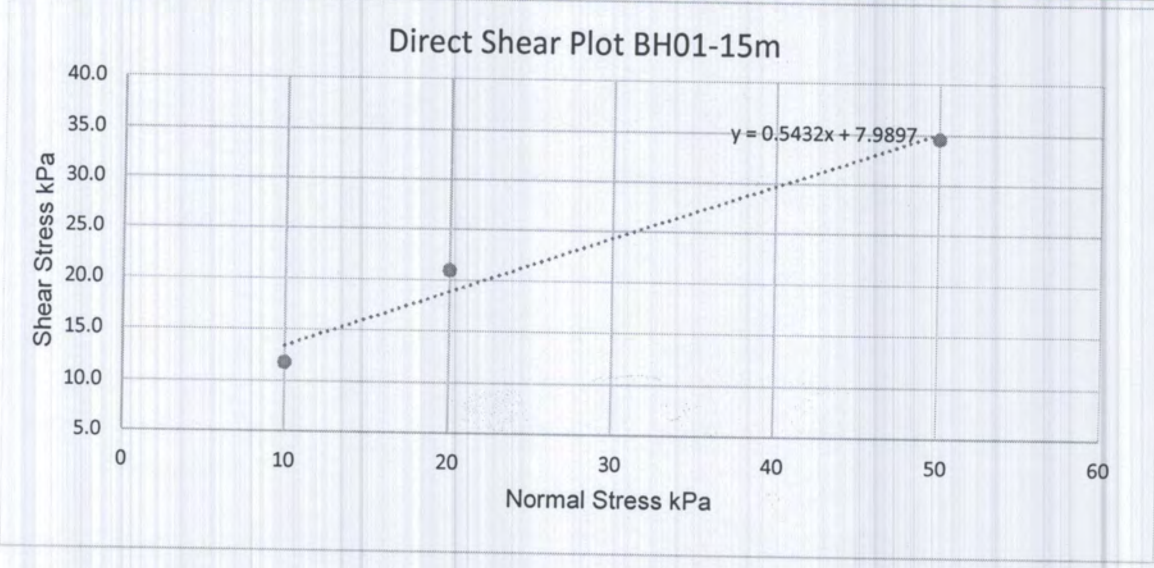
Direct shear test Results

Project:Chovar-Patan-Chapagaun under ground 132 kV transmission line	Location: Patan Sub-station, lagankhel
Test Method: IS 2720 part 13:1986	Specimen Plan dimension: 0.06m X 0.06m
Bore hole No: BH01	Thickness of specimen:
Depth(m) : 15m	PRG factor: 0.00328
Soil type:SP	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	10	11.8	0.8	7.99	28.51	
2	20	21.0	2			
3	50	34.6	4			



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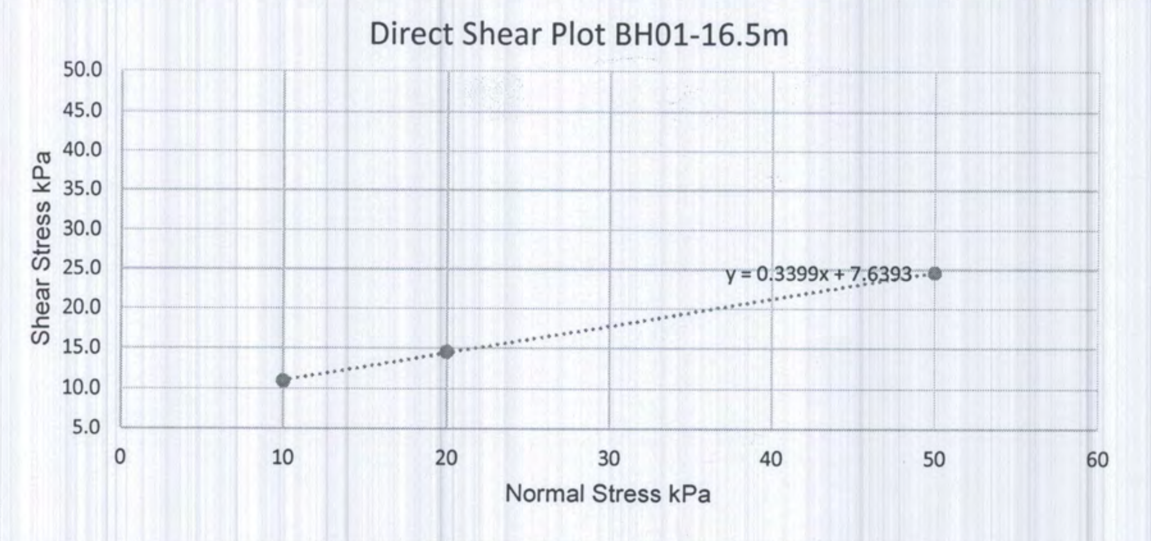
Direct shear test Results

Project:Chovar-Patan-Chapagaun under ground 132 kV transmission line	Location: Patan Sub-station, lagankhel
Test Method: IS 2720 part 13:1986	Specimen Plan dimension: 0.06m X 0.06m
Bore hole No: BH01	Thickness of specimen:
Depth(m) : 16.5m	PRG factor: 0.00328
Soil type:SP	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	10	10.9	0.8	7.64	18.77	
2	20	14.6	2			
3	50	24.6	4			



Tested By:

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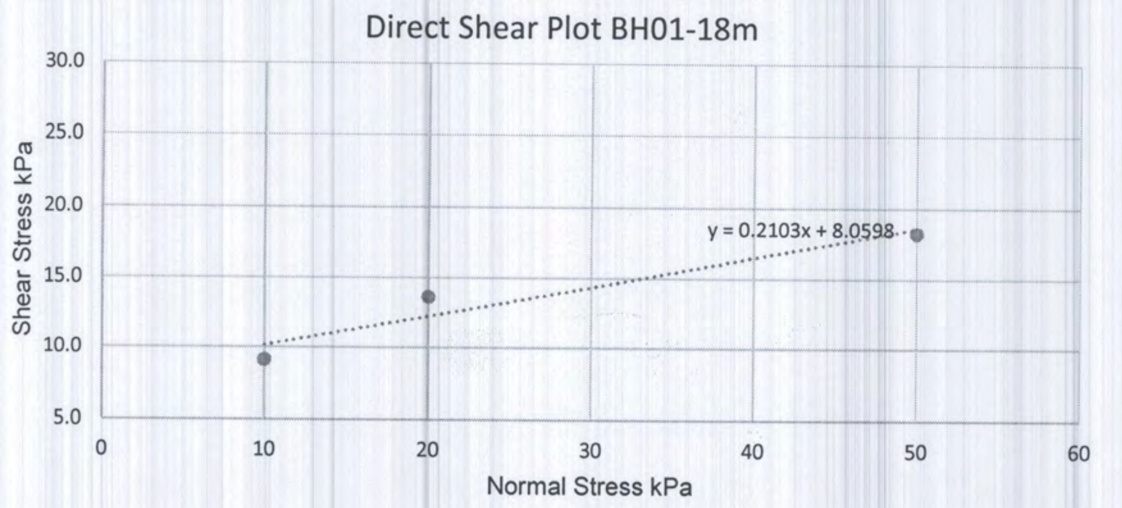
Direct shear test Results

Project:Chovar-Patan-Chapagaun under ground 132 kV transmission line	Location: Patan Sub-station, lagankhel
Test Method: IS 2720 part 13:1986	Specimen Plan dimension: 0.06m X 0.06m
Bore hole No: BH01	Thickness of specimen:
Depth(m) : 18m	PRG factor: 0.00328
Soil type: SP-SC	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	10	9.1	1.5	8.06	11.87	
2	20	13.7	2			
3	50	18.2	3.5			



Tested By:
Er. Deepak Kumar Mahaseth

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GeoTech Er. Aanand Mishra
Nec No: 6933"CIVIL"

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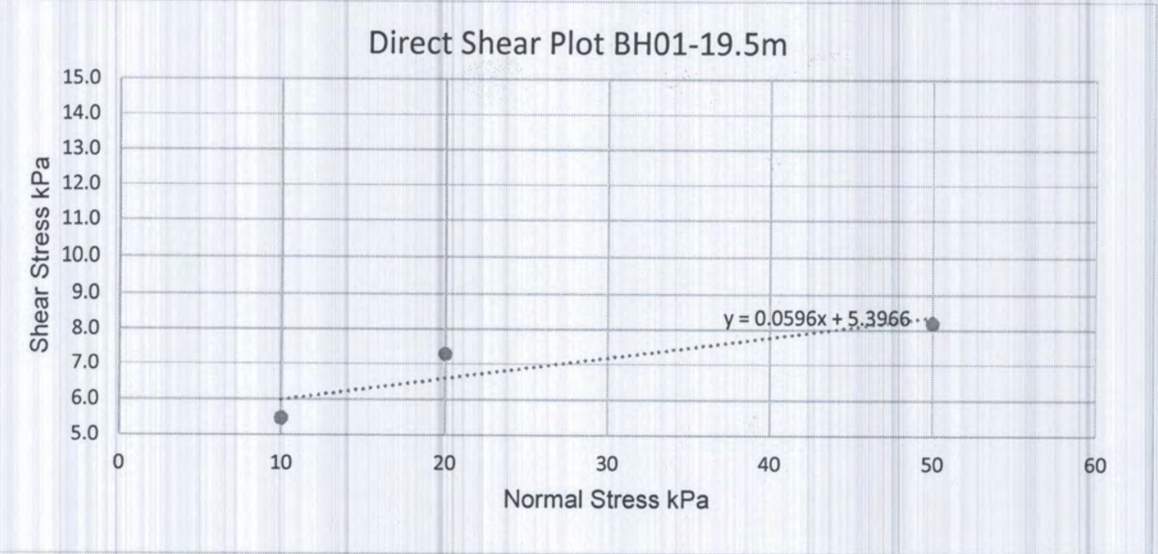
Direct shear test Results

Project:Chovar-Patan-Chapagaun under ground 132 kV transmission line	Location: Patan Sub-station, lagankhel
Test Method: IS 2720 part 13:1986	Specimen Plan dimension: 0.06m X 0.06m
Bore hole No: BH01	Thickness of specimen:
Depth(m) : 19.5m	PRG factor: 0.00328
Soil type: SC	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	10	5.5	1	5.40	3.41	
2	20	7.3	2.5			
3	50	8.2	3			



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Design Input Data (Summary)

Project:Chovar-Patan-Chapagaun under ground 132 kV transmission line

Location: Patan Sub-station, lagankhel

Ground Water Level 4m

S.N.	Bore Hole	Depth(m)	Soil Type	Field SPT	Bulk unit weight(γ)kN/m³	Specific Gravity(G)	D_{50} (mm)	Moisture Content(w)%	Liquid Limit(LL)	Initial Void Ratio(e)	Saturated unit weight(γ_{sat})kN/m³	$(N1)_{60}$	Field Based		Lab Based		Design	
													φ	C (kPa)	φ	C (kPa)	φ	C (kPa)
1	BH-01	1.5	SW	44	19.33	2.44	2.902	9.20	10	0.355	10.41	33.72	26.73	0	30.78	1.12	30.78	1.121
2	BH-01	3	SW-SM	46	18.37	2.4	0.598	10	10	0.41	10.36	28.8	25.7	0	30.49	2.52	30.49	2.523
3	BH-01	4.5	SW-SM	16	18.37	2.40	0.489	10.00	10	0.41	10.36	14.3	22.67	0	30.49	0.70	30.49	0.701
4	BH-01	6	SW	9	17.84	2.44	0.135	8.92	10	0.463	10.43	8.503	21.46	0	31.95	0.98	31.95	0.981
5	BH-01	7.5	SC	10	17.07	2.46	0.355	24.18		0.756	10.05	8.901	21.54	0	36.74	1.05	36.74	1.051
6	BH-01	9	SP	23	16.5	2.48	0.247	20.00		0.766	10.1	16.47	23.12	0	33.93	3.01	33.93	3.014
7	BH-01	10.5	SP	19	18.13	2.34	0.253	18.98		0.509	10.1	15.01	22.82	0	28.04	2.80	28.04	2.803
8	BH-01	12	SP	24	17.65	2.41	0.231	19.29		0.596	10.1	16.37	23.1	0	32.24	1.40	32.24	1.402
9	BH-01	13.5	SP	18	17.27	2.59	0.295	30.88		0.923	10	13.12	22.42	82.85	6.60	4.21	6.596	4.205
10	BH-01	15	SP-SC	19	16.54	2.25	0.199	25.00		0.666	10.02	13.29	22.46	83.94	28.51	7.99	28.51	7.99
11	BH-01	16.5	SP	19	15.9	2.48	0.202	25.71		0.923	10.03	12.45	22.28	78.5	18.77	7.64	18.77	7.639
12	BH-01	18	SP	15	18.21	2.47	0.134	24.14		0.649	10.05	9.741	21.72	60.96	11.87	8.06	11.87	8.06
13	BH-01	19.5	SP-SC	29	17.47	2.42	0.131	26.72		0.722	10.02	16.11	23.05	102.2	3.41	5.40	3.409	5.397

Tested By:
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Bearinng Capacity of Cast In-situ Bored Pile

Material in Pile :	Concrete	Water table depth:	4 m
Diameter of pile:	0.5 m	Bearing capcity factor Nc:	9
Length of Pile:	10 m	Area of Pile :	0.19625 m^2
Depth of excavation :	3.5 m	Factor of Saftey:	2

Depth(m)	Thickness of layer(m)	Design cohesion 'c' kPa	Design internal frictional resistance 'φ'	Field SPT value 'N'	Effective surge charge pressure kPa	Effective unit weight of soil kN/m^3	Bearing capacity factor N_γ	Bearing capacity factor N_q	Coefficient of earth pressure K_i	Angle of wall friction between pile and soil δ_i	Adhesion factor α_i	Ultimate load carrying capcacity from static formula kPa	Ultimate load carrying capacity from Meyerhof's theorem kPa	Allowable load carrying capacity kPa
0														
1.5	1.5	1.12	30.78	44	0.00	19.33	26.42	20	0.32	15.39	0.3	27.840	-	13.920
3	1.5	2.52	30.49	46	0.00	18.37	24.89	20	0.33	15.24	0.3	29.478	-	14.739
4.5	1.5	0.70	30.49	16	12.84	18.37	24.89	20	0.33	15.24	0.42	80.057	116.2389	40.029
6	1.5	0.98	31.95	9	24.88	17.84	32.42	20	0.31	15.98	0.85	138.254	140.7826	69.127
7.5	1.5	1.05	36.74	10	35.77	17.07	69.36	46	0.25	18.37	0.75	397.455	190.4591	198.728
9	1.5	3.01	33.93	23	45.81	16.50	42.56	23	0.28	16.97	0.35	265.627	332.0271	132.813
10.5	1.5	2.80	28.04	19	58.28	18.13	17.89	18	0.36	14.02	0.38	**250.975**	411.3523	**125.487**
12	1.5	1.40	32.24	24	70.04	17.65	33.89	20	0.30	16.12	0.3	334.410	537.2123	167.205
13.5	1.5	4.21	6.60	18	81.22	17.27	0.70	10	0.79	3.30	0.4	200.210	606.7201	100.105
15	1.5	7.99	28.51	19	91.32	16.54	18.97	12	0.35	14.25	0.38	286.701	698.808	143.351
16.5	1.5	7.64	18.77	19	100.46	15.90	4.72	10	0.51	9.39	0.38	265.104	788.3434	132.552
18	1.5	8.06	11.87	15	113.05	18.21	1.76	10	0.66	5.94	0.42	298.469	848.8191	149.235
19.5	1.5	5.40	3.41	29	124.54	17.47	0.31	10	0.89	1.70	0.38	320.569	1021.214	160.284
									Bearing capacity			250.975	411.3523	125.487

Tested By:
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EXPERT TESTING LABORATORY PVT. LTD.

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Shettlement Calculation

Project:Chovar-Patan-Chapagaun under ground 132 kV transmission line

Location: Patan Sub-station, lagankhel

Ground Water Level(m) 4

Size of Footing : 3mX3m

Depth of foundation (m)= 4

Stress from foundation for settlement calculation(qu) kN/m^2= 150

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	3.0-4.0	1	SW-SM	28.8	18.37	150.00	73.47	0.41	0.52	6.20	17517.55	43793.88	0.11	0.000003	43793.88
2	4.0-5.0	1	SW-SM	21.5	18.37	150.00	91.84	0.41	0.54	6.30	13317.61	33294.02	0.15	0.000005	33294.02
3	5.0-6.0	1	SW-SM	14.3	18.37	150.00	110.21	0.46	0.40	5.80	8133.92	20334.80	0.25	0.000012	20334.80
4	6.0-7.0	1	SW	8.5	17.84	150.00	128.05	0.76	0.53	6.20	5171.89	12929.73	0.38	0.000029	12929.73
5	7.0-8.0	1	SC	8.9	17.07	150.00	145.12	0.77	0.49	6.10	5326.25	13315.62	0.48	0.000036	13315.62
6	8.0-9.0	1	SC	12.7	16.79	150.00	161.90	0.77	0.48	6.00	7465.92	18664.80	0.48	0.000025	18664.80
7	9.0-10.0	1	SP	16.5	16.50	150.00	178.40	0.51	0.54	6.30	10177.55	25443.88	0.30	0.000012	25443.88
8	10.0-11.0	1	SP	15.0	18.13	150.00	196.53	0.51	0.58	6.40	9422.39	23555.98	0.28	0.000012	23555.98
9	11.0-12.0	1	SP	15.0	18.13	150.00	214.66	0.60	0.37	5.60	8244.59	20611.49	0.25	0.000012	20611.49
10	12.0-13.0	1	SP	16.4	17.65	150.00	232.30	0.60	0.37	5.60	8993.12	22482.81	0.23	0.000010	22482.81
11	13.0-14.0	1	SP	13.1	17.27	150.00	249.57	0.92	0.37	5.60	7205.96	18014.90	0.20	0.000011	18014.90
12	14.0-15.0	1	SP	13.1	17.27	150.00	266.84	0.67	0.14	4.60	5919.18	14797.96	0.18	0.000012	14797.96
13	15.0-16.0	1	SP-SC	13.3	16.54	150.00	283.38	0.92	0.14	4.60	5995.52	14988.79	0.15	0.000010	14988.79
14	16.0-17.0	1	SP-SC	12.45	15.9	150	299.2832	0.923	0.13	4.5	5494.33385	13735.835	0.15	0.000011	13735.835
15	17.0-18.0	1	SP	12.4	15.90	150.00	315.18	0.65	0.11	4.10	5005.95	12514.87	0.11	0.000009	12514.87
														0.000208	17137.74

Tested By:

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Approved By:

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Shettlement Calculation

Elastic settlement from Schmertmann et. al 1978			
Correction factor for emdement of foundation (C1)=		0.210	
Correction factor to account for creep in soil (C2)=		1.540	
Elastic settlement	**Se=**	**5.150**	mm
Elastic Settlement in saturated clay from Janbu et al. 1956			
Elastic settlement	**Se=**	**30.578**	mm
Consolidation Settlement inclay layer			
Thickness of clay layer (m)		75.000	
initial void ratio		0.900	
Compression index		0.225	
Eff. pressure at mid of clay layer before construction		911.46	
Eff. pressure at mid of clay layer after construction		1061.46	
Consolidation Settlement	S_c	**12.270**	mm
Total Settlement	S_t	**42.848**	mm

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Annex 9: Sieve Analysis Results

EXPERT TESTING LABORATORY PVT. LTD.
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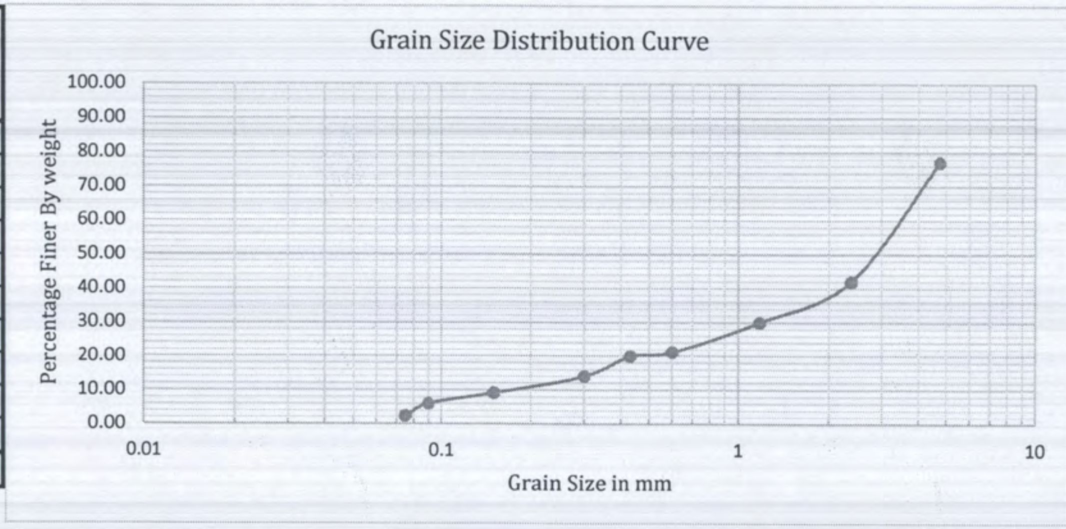
Grain Size Analysis

Test Method: IS 2720(Part-4):1985
Project:Chovar-Patan-Chapagaun under ground 132 kV transmission line
Location: Patan Sub-station, lagankhel

Bore Hole No: BH-01
Depth:1.5m
Soil type :
Checked By:Er. Aanand Kumar Mishra

Date of test:2022_3_18

S.N.	Sieve Size (mm)	Retained weight (kg)	Passing Weight (kg)	% finer by weight
1	4.75	181.86	612.65	77.11
2	2.36	278.53	334.12	42.05
3	1.18	95.3	238.82	30.06
4	0.6	70.35	168.47	21.20
5	0.43	10.19	158.28	19.92
6	0.3	46.43	111.85	14.08
7	0.15	39.33	72.52	9.13
8	0.09	24.7	47.82	6.02
9	0.075	28.3	19.52	2.46
10	0	19.52	0	0
	Total	794.51		



	Gravel % (> 4.75mm)=		22.89
	Sand % (<4.75mm & >0.075mm)=		74.65
	Silt and Clays (< 0.075mm)=		2.46

D_{10} =	0.1764	D_{30} =	1.1761	D_{60} =	3.583
Coefficient of uniformity = $C_U = D_{60} / D_{10}$ =			20.311	D_{50} =	2.902
Coefficient of curvature = C_C = = $\frac{D_{30}^2}{D_{10} D_{60}}$			2.188		

Soil Type (IS 1498:1970) :SW

SW: Well graded Sand
SM : Sandy Silts

Tested By:
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Approved By:
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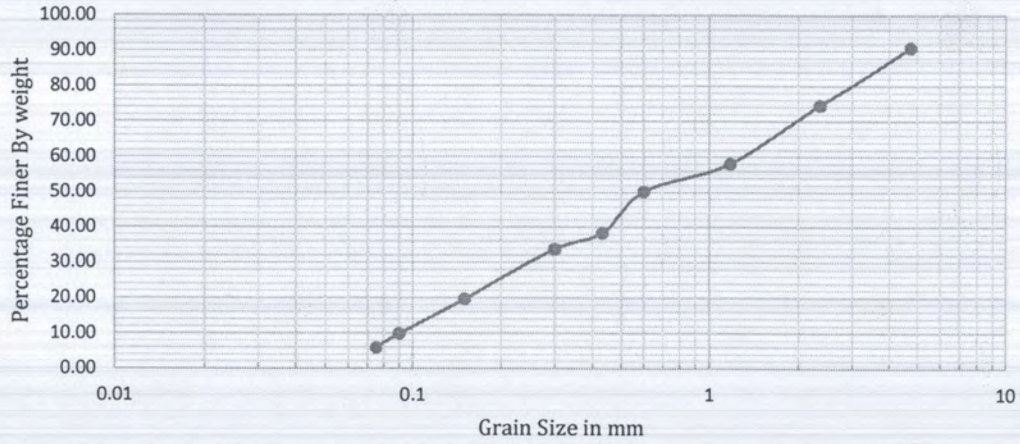
Grain Size Analysis

Grain Size Analysis

Test Method: IS 2720(Part-4):1985
Project:Chovar-Patan-Chapagaun under ground 132 kV transmission line
Location: Patan Sub-station, lagankhel
Performed By:
Date of test:2022_3_18

Bore Hole No: BH-01
Depth:3m
Soil type :
Checked By:Er. Aanand Kumar Mishra

S.N.	Sieve Size (mm)	Retained weight (kg)	Passing Weight (kg)	% finer by weight
1	4.75	48	477.88	90.87
2	2.36	85.79	392.09	74.56
3	1.18	86.5	305.59	58.11
4	0.6	41.83	263.76	50.16
5	0.43	61.98	201.78	38.37
6	0.3	24.3	177.48	33.75
7	0.15	74.06	103.42	19.67
8	0.09	51.47	51.95	9.88
9	0.075	20.71	31.24	5.94
10	0	31.24	0	0
	Total	525.88		



	Gravel % (> 4.75mm)=		9.13
	Sand % (<4.75mm & >0.075mm)=		84.93
	Silt and Clays (< 0.075mm)=		5.94

D_{10} =	0.0907	D_{30} =	0.2601	D_{60} =	1.316
Coefficient of uniformity = $C_U = D_{60} / D_{10}$ =			14.498	D_{50} =	0.598
Coefficient of curvature = C_C = = $\frac{D_{30}^2}{D_{10} D_{60}}$			0.567		

Soil Type (IS 1498:1970) :SW-SM

SW: Well graded Sand
SM : Sandy Silts

Tested By:
Er. Deepak Kumar Mahaseth

Approved By:
GeoTech Er. Aanand Mishra
Nec No: 6933"CIVIL"

EXPERT TESTING LABORATORY PVT. LTD.
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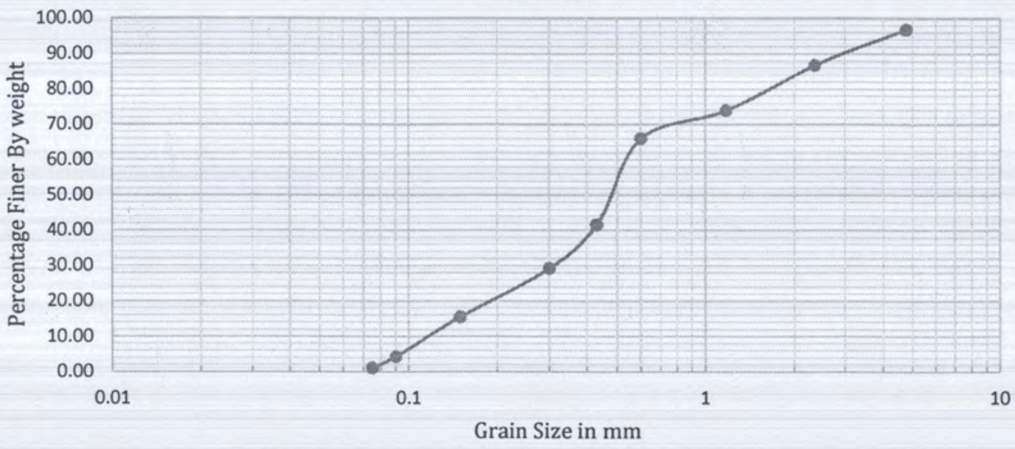
Grain Size Analysis

Grain Size Analysis

Test Method: IS 2720(Part-4):1985
Project:Chovar-Patan-Chapagaun under ground 132 kV transmission line
Location: Patan Sub-station, lagankhel
Performed By:
Date of test:2022_3_18

Bore Hole No: BH-01
Depth:4.5m
Soil type :
Checked By:Er. Aanand Kumar Mishra

S.N.	Sieve Size (mm)	Retained weight (kg)	Passing Weight (kg)	% finer by weight
1	4.75	12	364	96.81
2	2.36	38	326	86.70
3	1.18	48	278	73.94
4	0.6	30	248	65.96
5	0.43	92	156	41.49
6	0.3	46	110	29.26
7	0.15	52	58	15.43
8	0.09	42	16	4.26
9	0.075	12	4	1.06
10	0	4	0	0
	Total	376		



	Gravel % (> 4.75mm)=		3.19
	Sand % (<4.75mm & >0.075mm)=		95.74
	Silt and Clays (< 0.075mm)=		1.06

D_{10} =	0.1209	D_{30} =	0.3079	D_{60} =	0.559
Coefficient of uniformity = $C_U = D_{60} / D_{10}$ =			4.622	D_{50} =	0.489
Coefficient of curvature = C_C = = $\frac{D_{30}^2}{D_{10} D_{60}}$			1.404		

Soil Type (IS 1498:1970) :SW

SW :Well Graded Sand
SM : Sandy Silts

Tested By:
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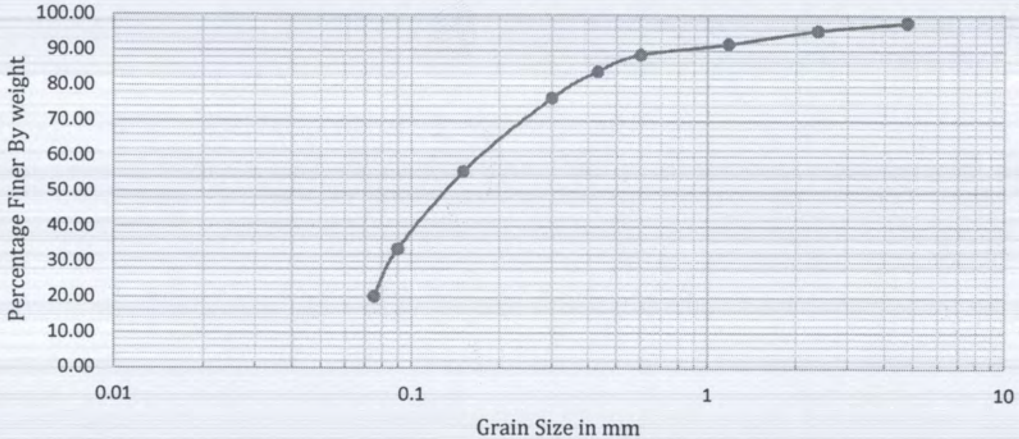
Grain Size Analysis

Grain Size Analysis

Test Method: IS 2720(Part-4):1985
Project:Chovar-Patan-Chapagaun under ground 132 kV transmission line
Location: Patan Sub-station, lagankhel
Performed By:
Date of test:2022_3_18

Bore Hole No: BH-01
Depth:6m
Soil type :
Checked By:Er. Aanand Kumar Mishra

S.N.	Sieve Size (mm)	Retained weight (kg)	Passing Weight (kg)	% finer by weight
1	4.75	6.84	317.58	97.89
2	2.36	7.35	310.23	95.63
3	1.18	12.16	298.07	91.88
4	0.6	9.98	288.09	88.80
5	0.43	15.55	272.54	84.01
6	0.3	24.5	248.04	76.46
7	0.15	67.42	180.62	55.67
8	0.09	71.46	109.16	33.65
9	0.075	43.43	65.73	20.26
10	0	65.73	0	0
	Total	324.42		



	Gravel % (> 4.75mm)=		2.11
	Sand % (<4.75mm & >0.075mm)=		77.63
	Silt and Clays (< 0.075mm)=		20.26

D_{10} =	0.0370	D_{30} =	0.0859	D_{60} =	0.181
Coefficient of uniformity = $C_U = D_{60} / D_{10}$ =			4.896	D_{50} =	0.135
Coefficient of curvature = C_C = = $\frac{D_{30}^2}{D_{10}\,D_{60}}$			1.100		

Soil Type (IS 1498:1970) :SC

SC: Clayey Sand
SM : Sandy Silts

Tested By:
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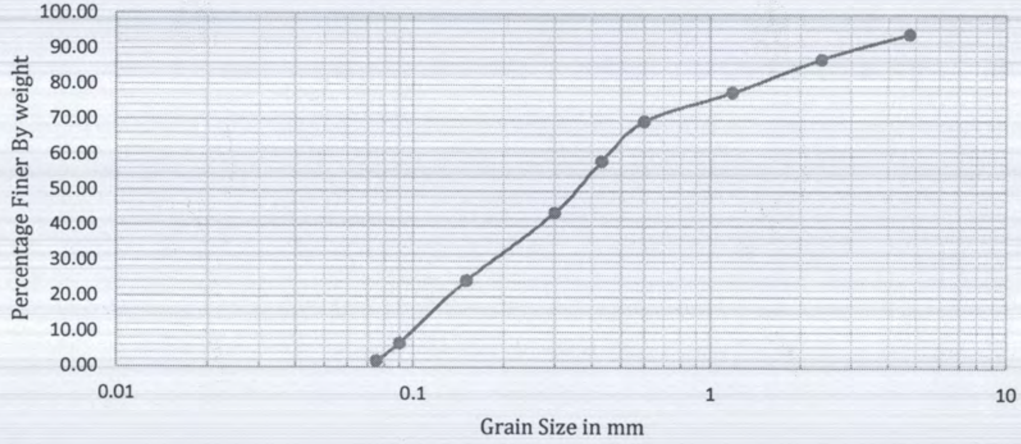
Grain Size Analysis

Grain Size Analysis

Test Method: IS 2720(Part-4):1985
Project:Chovar-Patan-Chapagaun under ground 132 kV transmission line
Location: Patan Sub-station, lagankhel
Performed By:
Date of test:2022_3_18

Bore Hole No: BH-01
Depth:7.5m
Soil type :
Checked By:Er. Aanand Kumar Mishra

S.N.	Sieve Size (mm)	Retained weight (kg)	Passing Weight (kg)	% finer by weight
1	4.75	27.74	482.4	94.56
2	2.36	36.15	446.25	87.48
3	1.18	48.89	397.36	77.89
4	0.6	41.54	355.82	69.75
5	0.43	57.51	298.31	58.48
6	0.3	74.66	223.65	43.84
7	0.15	98.45	125.2	24.54
8	0.09	90.25	34.95	6.85
9	0.075	25.9	9.05	1.77
10	0	9.05	0	0
	Total	510.14		



	Gravel % (> 4.75mm)=		5.44
	Sand % (<4.75mm & >0.075mm)=		92.79
	Silt and Clays (< 0.075mm)=		1.77

D_{10} =	0.1007	D_{30} =	0.1924	D_{60} =	0.453
Coefficient of uniformity = $C_U = D_{60} / D_{10}$ =			4.499	D_{50} =	0.355
Coefficient of curvature = C_c = $\frac{D_{30}^2}{D_{10}\,D_{60}}$			0.812		

Soil Type (IS 1498:1970) :SP

SP: Poorly graded Sand
SM : Sandy Silts

Tested By:
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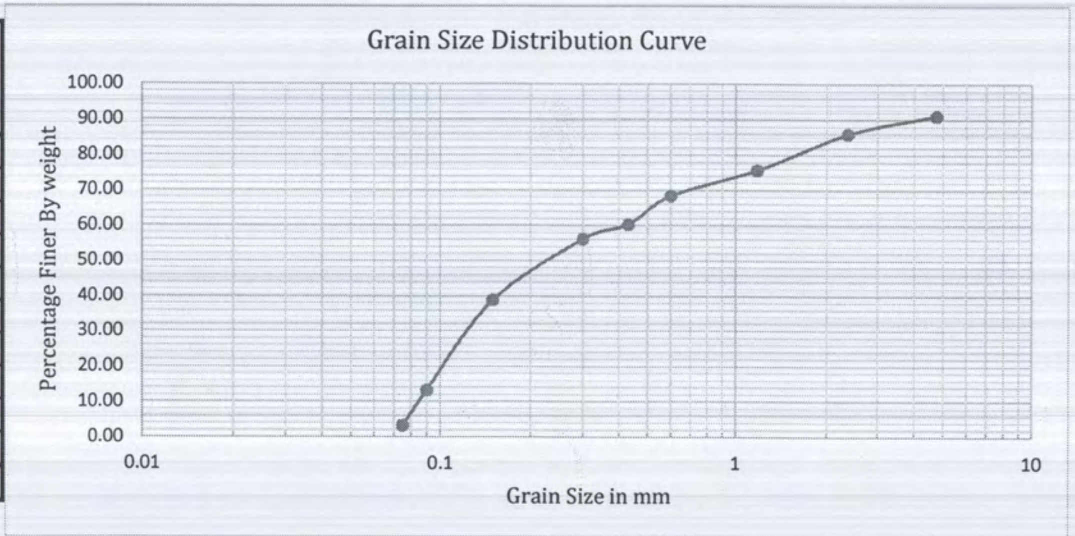
Grain Size Analysis

Grain Size Analysis

Test Method: IS 2720(Part-4):1985
Project:Chovar-Patan-Chapagaun under ground 132 kV transmission line
Location: Patan Sub-station, lagankhel
Performed By:
Date of test:2022_3_18

Bore Hole No: BH-01
Depth:9m
Soil type :
Checked By:Er. Aanand Kumar Mishra

S.N.	Sieve Size (mm)	Retained weight (kg)	Passing Weight (kg)	% finer by weight
1	4.75	31.83	324.68	91.07
2	2.36	18.45	306.23	85.90
3	1.18	36.34	269.89	75.70
4	0.6	26.25	243.64	68.34
5	0.43	28.6	215.04	60.32
6	0.3	14.73	200.31	56.19
7	0.15	61.9	138.41	38.82
8	0.09	91.07	47.34	13.28
9	0.075	35.69	11.65	3.27
10	0	11.65	0	0
	Total	356.51		



	Gravel % (> 4.75mm)=		8.93
	Sand % (<4.75mm & >0.075mm)=		87.80
	Silt and Clays (< 0.075mm)=		3.27

D_{10} =	0.0851	D_{30} =	0.1293	D_{60} =	0.420
Coefficient of uniformity = $C_U = D_{60} / D_{10}$ =			4.936	D_{50} =	0.247
Coefficient of curvature = C_C = = $\frac{D_{30}^2}{D_{10} D_{60}}$			0.468		

Soil Type (IS 1498:1970) :SP

SP: poorly graded Sand
SM : Sandy Silts

Tested By:
Er. Deepak Kumar Mahaseth

Approved By:
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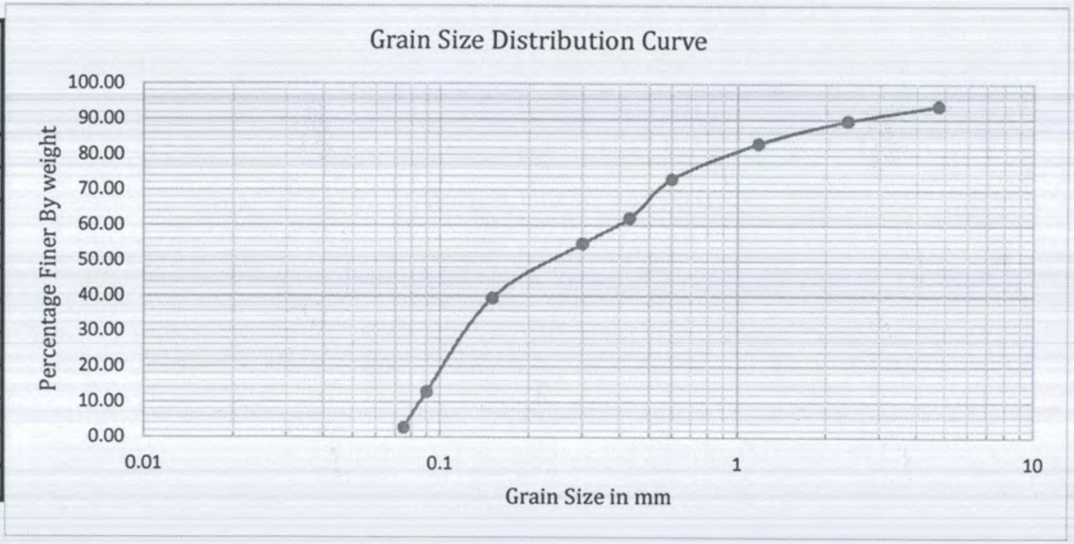
Grain Size Analysis

Grain Size Analysis

Test Method: IS 2720(Part-4):1985
Project:Chovar-Patan-Chapagaun under ground 132 kV transmission line
Location: Patan Sub-station, lagankhel
Performed By:
Date of test:2022_3_18

Bore Hole No: BH-01
Depth:10.5m
Soil type :
Checked By:Er. Aanand Kumar Mishra

S.N.	Sieve Size (mm)	Retained weight (kg)	Passing Weight (kg)	% finer by weight
1	4.75	23.4	359.59	93.89
2	2.36	16.5	343.09	89.58
3	1.18	24.32	318.77	83.23
4	0.6	38.6	280.17	73.15
5	0.43	42.3	237.87	62.11
6	0.3	27.8	210.07	54.85
7	0.15	58.7	151.37	39.52
8	0.09	102.3	49.07	12.81
9	0.075	38.4	10.67	2.79
10	0	10.67	0	0
	Total	382.99		



	Gravel % (> 4.75mm)=		6.11
	Sand % (<4.75mm & >0.075mm)=		91.10
	Silt and Clays (< 0.075mm)=		2.79

D_{10} =	0.0858	D_{30} =	0.1286	D_{60} =	0.392
Coefficient of uniformity = $C_U = D_{60} / D_{10}$ =			4.572	D_{50} =	0.253
Coefficient of curvature = C_C = = $\frac{D_{30}^2}{D_{10} D_{60}}$			0.492		

Soil Type (IS 1498:1970) :SP

SP: poorly graded Sand
SM : Sandy Silts

Tested By:
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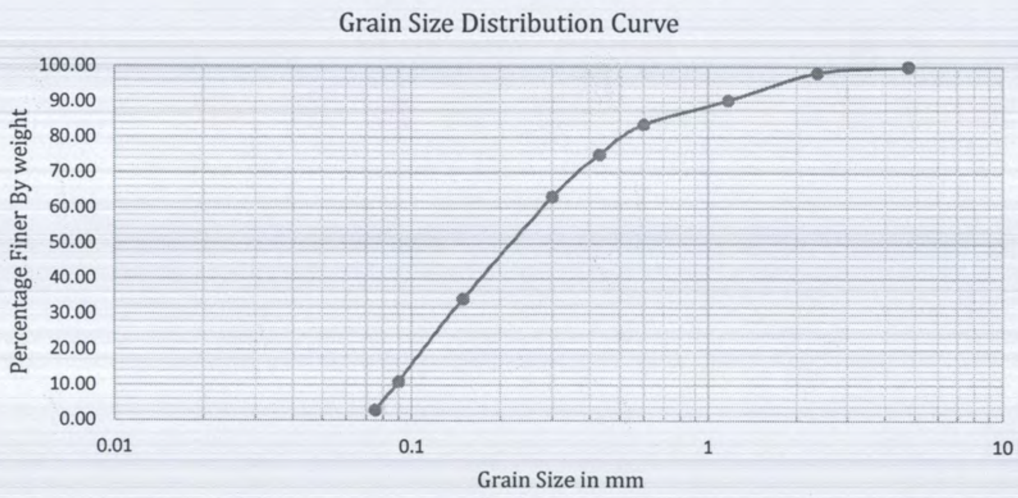
Grain Size Analysis

Grain Size Analysis

Test Method: IS 2720(Part-4):1985
Project:Chovar-Patan-Chapagaun under ground 132 kV transmission line
Location: Patan Sub-station, lagankhel
Performed By:
Date of test:2022_3_18

Bore Hole No: BH-01
Depth:12m
Soil type :
Checked By:Er. Aanand Kumar Mishra

S.N.	Sieve Size (mm)	Retained weight (kg)	Passing Weight (kg)	% finer by weight
1	4.75	0	589.7	100.00
2	2.36	9.82	579.88	98.33
3	1.18	45.9	533.98	90.55
4	0.6	40.11	493.87	83.75
5	0.43	50.4	443.47	75.20
6	0.3	70.25	373.22	63.29
7	0.15	170.5	202.72	34.38
8	0.09	137.76	64.96	11.02
9	0.075	47.84	17.12	2.90
10	0	17.12	0	0
	Total	589.7		



	Gravel % (> 4.75mm)=		0.00
	Sand % (<4.75mm & >0.075mm)=		97.10
	Silt and Clays (< 0.075mm)=		2.90

D_{10} =	0.0881	D_{30} =	0.1388	D_{60} =	0.283
Coefficient of uniformity = $C_U = D_{60} / D_{10}$ =			3.211	D_{50} =	0.231
Coefficient of curvature = C_C = = $\frac{D_{30}^2}{D_{10} D_{60}}$			0.772		

Soil Type (IS 1498:1970) :SP

SP: poorly graded Sand
SM: Sandy Silts

Tested By:
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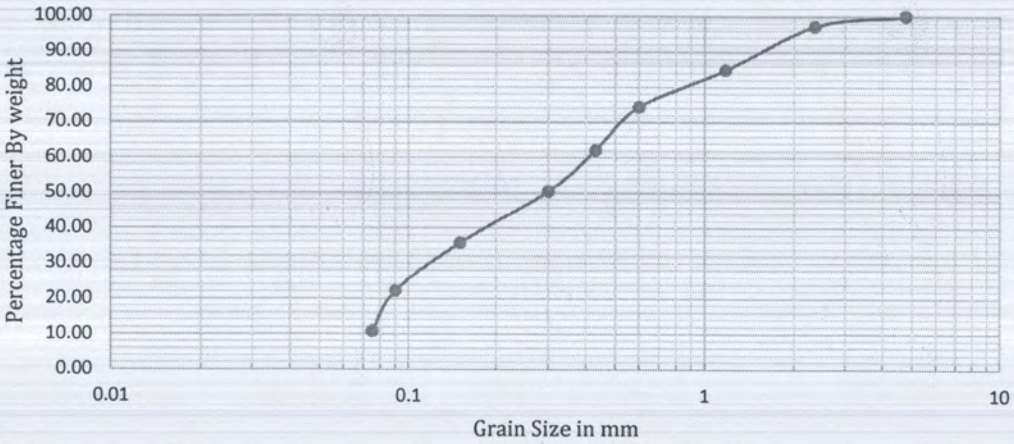
Grain Size Analysis

Grain Size Analysis

Test Method: IS 2720(Part-4):1985
Project:Chovar-Patan-Chapagaun under ground 132 kV transmission line
Location: Patan Sub-station, lagankhel
Performed By:
Date of test:2022_3_18

Bore Hole No: BH-01
Depth:13.5m
Soil type :
Checked By:Er. Aanand Kumar Mishra

S.N.	Sieve Size (mm)	Retained weight (kg)	Passing Weight (kg)	% finer by weight
1	4.75	0	419.9	100.00
2	2.36	11.86	408.04	97.18
3	1.18	51.73	356.31	84.86
4	0.6	44.14	312.17	74.34
5	0.43	51.5	260.67	62.08
6	0.3	48.86	211.81	50.44
7	0.15	61.67	150.14	35.76
8	0.09	56.69	93.45	22.26
9	0.075	47.8	45.65	10.87
10	0	45.65	0	0
	Total	419.9		



	Gravel % (> 4.75mm)=		0.00
	Sand % (<4.75mm & >0.075mm)=		89.13
	Silt and Clays (< 0.075mm)=		10.87

D_{10} =	0.0690	D_{30} =	0.1244	D_{60} =	0.407
Coefficient of uniformity = $C_U = D_{60} / D_{10}$ =			5.896	D_{50} =	0.295
Coefficient of curvature = C_C = = $\frac{D_{30}^2}{D_{10} D_{60}}$			0.552		

Soil Type (IS 1498:1970) :SP-SC

SC:Clayey Sands
SP:Poorly Graded Sand

Tested By:
Er. Deepak Kumar Mahaseth

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GeoTech Er. Aanand Mishra
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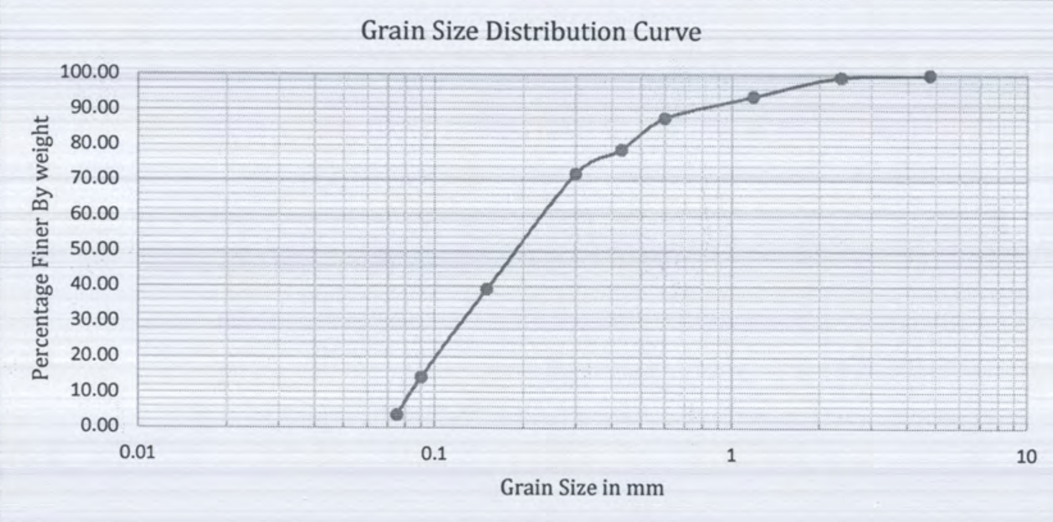
Grain Size Analysis

Grain Size Analysis

Test Method: IS 2720(Part-4):1985
Project:Chovar-Patan-Chapagaun under ground 132 kV transmission line
Location: Patan Sub-station, lagankhel
Performed By:
Date of test:2022_3_18

Bore Hole No: BH-01
Depth:15m
Soil type :
Checked By:Er. Aanand Kumar Mishra

S.N.	Sieve Size (mm)	Retained weight (kg)	Passing Weight (kg)	% finer by weight
1	4.75	0	361.422	100.00
2	2.36	2.8	358.622	99.23
3	1.18	19.442	339.18	93.85
4	0.6	22.32	316.86	87.67
5	0.43	32.34	284.52	78.72
6	0.3	24.3	260.22	72.00
7	0.15	118.4	141.82	39.24
8	0.09	90.3	51.52	14.25
9	0.075	38.32	13.2	3.65
10	0	13.2	0	0
	Total	361.422		



	Gravel % (> 4.75mm)=		0.00
	Sand % (<4.75mm & >0.075mm)=		96.35
	Silt and Clays (< 0.075mm)=		3.65

D_{10} =	0.0840	D_{30} =	0.1278	D_{60} =	0.245
Coefficient of uniformity = $C_U = D_{60} / D_{10}$ =			2.918	D_{50} =	0.199
Coefficient of curvature = C_C = = $\frac{D_{30}^2}{D_{10} D_{60}}$			0.794		

Soil Type (IS 1498:1970) :SP

SP: poorly graded Sand
SM : Sandy Silts

Tested By:
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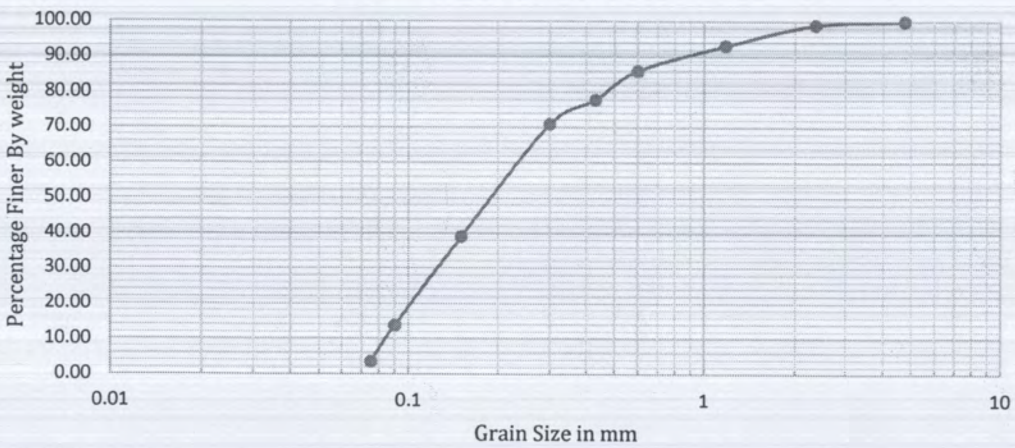
Grain Size Analysis

Grain Size Analysis

Test Method: IS 2720(Part-4):1985
Project:Chovar-Patan-Chapagaun under ground 132 kV transmission line
Location: Patan Sub-station, lagankhel
Performed By:
Date of test:2022_3_18

Bore Hole No: BH-01
Depth:16.5m
Soil type :
Checked By:Er. Aanand Kumar Mishra

S.N.	Sieve Size (mm)	Retained weight (kg)	Passing Weight (kg)	% finer by weight
1	4.75	0	346.3	100.00
2	2.36	3.5	342.8	98.99
3	1.18	20.4	322.4	93.10
4	0.6	24.34	298.06	86.07
5	0.43	28.46	269.6	77.85
6	0.3	24.1	245.5	70.89
7	0.15	110.5	135	38.98
8	0.09	87.3	47.7	13.77
9	0.075	35.3	12.4	3.58
10	0	12.4	0	0
	Total	346.3		



	Gravel % (> 4.75mm)=		0.00
	Sand % (<4.75mm & >0.075mm)=		96.42
	Silt and Clays (< 0.075mm)=		3.58

D_{10} =	0.0844	D_{30} =	0.1286	D_{60} =	0.249
Coefficient of uniformity = $C_U = D_{60} / D_{10}$ =			2.946	D_{50} =	0.202
Coefficient of curvature = C_C = = $\frac{D_{30}^2}{D_{10} D_{60}}$			0.787		

Soil Type (IS 1498:1970) :SP

SP: poorly graded Sand
SM : Sandy Silts

Tested By:
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Approved By:
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Nec No: 6933"CIVIL"

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Grain Size Analysis

Grain Size Analysis

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

Project:Chovar-Patan-Chapagaun under ground 132 kV transmission line

Location: Patan Sub-station, lagankhel

Performed By:

Date of test:2022_3_18

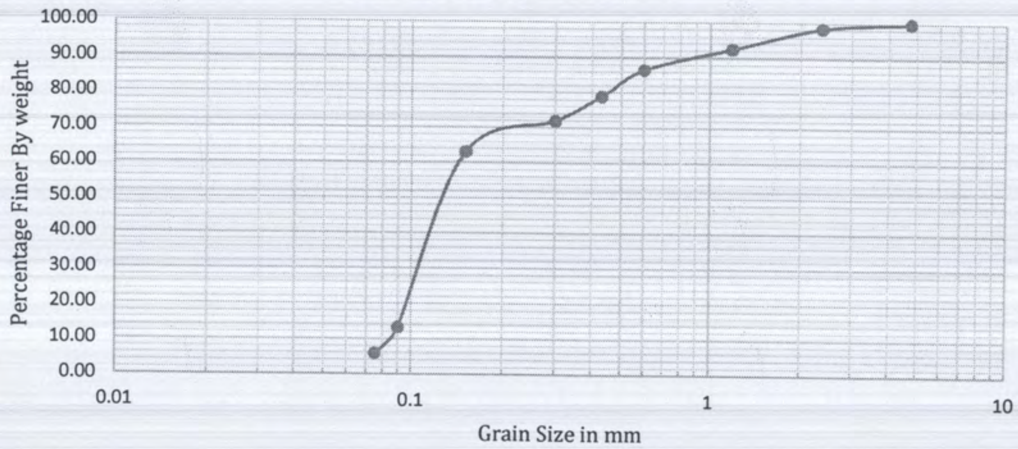
Bore Hole No: BH-01

Depth:18m

Soil type :

Checked By:Er. Aanand Kumar Mishra

S.N.	Sieve Size (mm)	Retained weight (kg)	Passing Weight (kg)	% finer by weight
1	4.75	0.59	433.97	99.86
2	2.36	6.52	427.45	98.36
3	1.18	25.5	401.95	92.50
4	0.6	26.12	375.83	86.49
5	0.425	32.8	343.03	78.94
6	0.3	30.3	312.73	71.96
7	0.15	38.44	274.29	63.12
8	0.09	216.63	57.66	13.27
9	0.075	32.1	25.56	5.88
10	0	25.56	0	0
	Total	434.56		



Gravel % (> 4.75mm)=		0.14
Sand % (<4.75mm & >0.075mm)=		93.98
Silt and Clays (< 0.075mm)=		5.88

D_{10} =	0.0834	D_{30} =	0.1101	D_{60} =	0.146
Coefficient of uniformity = $C_U = D_{60} / D_{10}$ =			1.754	D_{50} =	0.134
Coefficient of curvature = C_C = = $\frac{D_{30}^2}{D_{10}\,D_{60}}$			0.995		

Soil Type (IS 1498:1970) :SP-SC

SC:Clayey Sands

SP: Poorly Graded Sand

Tested By:

Er. Deepak Kumar Mahaseth

Approved By:

GeoTech Er. Aanand Mishra

Nec No. 6933"CIVIL"

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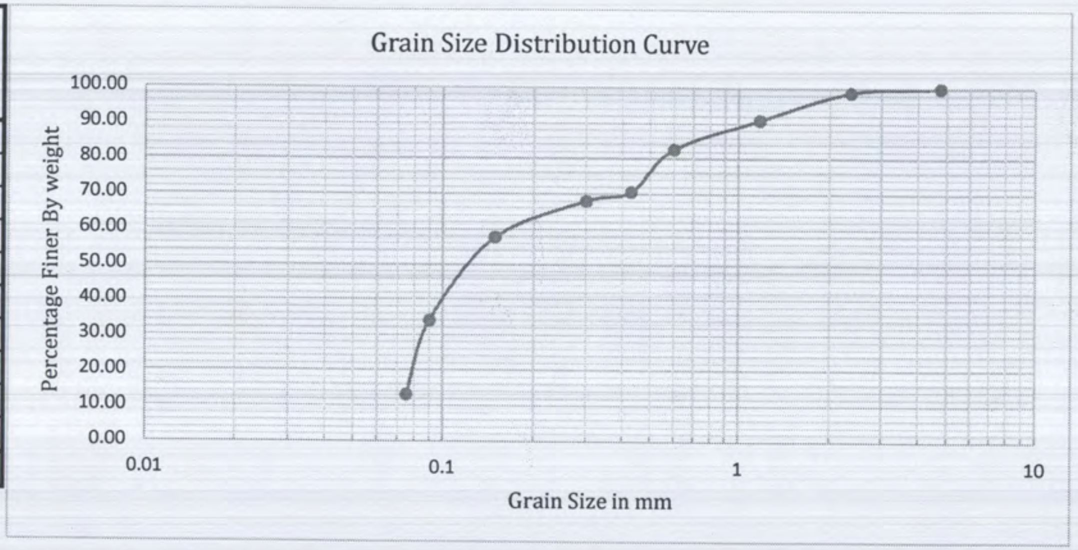
Grain Size Analysis

Grain Size Analysis

Test Method: IS 2720(Part-4):1985
Project:Chovar-Patan-Chapagaun under ground 132 kV transmission line
Location: Patan Sub-station, lagankhel
Performed By:
Date of test:2022_3_18

Bore Hole No: BH-01
Depth:19.5m
Soil type :
Checked By:

S.N.	Sieve Size (mm)	Retained weight (kg)	Passing Weight (kg)	% finer by weight
1	4.75	0	451.4	100.00
2	2.36	5.57	445.83	98.77
3	1.18	35.23	410.6	90.96
4	0.6	37.62	372.98	82.63
5	0.43	54.4	318.58	70.58
6	0.3	11.79	306.79	67.96
7	0.15	46.63	260.16	57.63
8	0.09	106.52	153.64	34.04
9	0.075	94.52	59.12	13.10
10	0	59.12	0	0
	Total	451.4		



	Gravel % (> 4.75mm)=		0.00
	Sand % (<4.75mm & >0.075mm)=		86.90
	Silt and Clays (< 0.075mm)=		13.10

D_{10} =	0.0573	D_{30} =	0.0871	D_{60} =	0.184
Coefficient of uniformity = $C_U = D_{60} / D_{10}$ =			3.219	D_{50} =	0.131
Coefficient of curvature = C_C = = $\frac{D_{30}^2}{D_{10}\,D_{60}}$			0.719		

Soil Type (IS 1498:1970) :SC

SC:Clayey Sands
SP:Poorly Graded Sand

Tested By:
Er. Deepak Kumar Mahaseth

Approved By:
GeoTech Er. Aanand Mishra
Nec No:6933"CIVIL"

Annex 10: Moisture Content Analysis Results

EXPERT TESTING LABORATORY PVT. LTD.
BAFAL, LALITPUR-17
Gmail: experttestlab078@gmail.com

Moisture Content Determination (Natural)

Project:Chovar-Patan-Chapagaun under ground 132 kV transmission line
Date :3/18/2022

Location: Patan Sub-station, lagankhel
Performed By:

Test Method: IS 2720(part II):1973
Checked By:

Sample Type (Bore hole)	Depth (m)	Soil Type	Wt. of can+wet soil(gm)	Wt. of can+dry soil(gm)	Empty can wt.(gm)	Wt. of water (gm)	Mositure content %
BH-01	1.5	SW	456.00	426.00	100.00	30.00	9.20
BH-01	3	SW-SM	422.00	392.00	92.00	30.00	10.00
BH-01	4.5	SW	444.00	416.00	102.00	28.00	8.92
BH-01	6	SC	488.00	414.00	108.00	74.00	24.18
BH-01	7.5	SP	518.00	448.00	98.00	70.00	20.00
BH-01	9	SP	434.00	382.00	108.00	52.00	18.98
BH-01	10.5	SP	442.00	388.00	108.00	54.00	19.29
BH-01	12	SP	464.00	380.00	108.00	84.00	30.88
BH-01	13.5	SP-SC	518.00	436.00	108.00	82.00	25.00
BH-01	15	SP	450.00	378.00	98.00	72.00	25.71
BH-01	16.5	SP	504.00	427.00	108.00	77.00	24.14
BH-01	18	SP-SC	432.00	362.00	100.00	70.00	26.72
BH-01	19.5	SC	418.00	356.00	106.00	62.00	24.80

Tested By:
Er. Deepak Kumar Mahaseth

Approved By:
GeoTech Er. Aanand Mishra
Nec No: 6933"CIVIL"

Annex 11: Bulk Density Results

EXPERT TESTING LABORATORY PVT. LTD.
BAFAL, LALITPUR-17
Gmail: experttestlab078@gmail.com

Bulk Density Determination

Project:Chovar-Patan-Chapagaun under ground 132 kV transmission line

Date :3/18/2022

Location: Patan Sub-station, lagankhel

Performed By:

Test Method: IS 2720(part XXVIII):1973

Checked By:Er. Aanand K. Mishra

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	1.5	SW	108.18	140.30	16.30	1.97	9.20	1.80
BH-01	3	SW-SM	108.18	138.70	16.30	1.87	10.00	1.70
BH-01	4.5	SW	108.18	137.82	16.30	1.82	8.92	1.67
BH-01	6	SC	108.18	136.54	16.30	1.74	24.18	1.40
BH-01	7.5	SP	108.18	135.60	16.30	1.68	20.00	1.40
BH-01	9	SP	108.18	138.30	16.30	1.85	18.98	1.55
BH-01	10.5	SP	108.18	137.50	16.30	1.80	19.29	1.51
BH-01	12	SP	108.18	136.87	16.30	1.76	30.88	1.34
BH-01	13.5	SP-SC	108.18	135.67	16.30	1.69	25.00	1.35
BH-01	15	SP	108.18	134.60	16.30	1.62	25.71	1.29
BH-01	16.5	SP	108.18	138.43	16.30	1.86	24.14	1.49
BH-01	18	SP-SC	108.18	137.21	16.30	1.78	26.72	1.41
BH-01	19.5	SC	108.18	134.21	16.30	1.60	24.80	1.28

Tested By:
Er. Deepak Kumar Mahaseth

Approved By:
GeoTech Er. Aanand Mishra
Nec No: 6933"CIVIL"

Annex 12: Specific Gravity Results

EXPERT TESTING LABORATORY PVT. LTD.
BAFAL, LALITPUR-17
Gmail: experttestlab078@gmail.com

Specific Gravity Determination

Project:Chovar-Patan-Chapagaun UG 132 kV transmission line **Date of test:2022_3_18**

Location: Patan Sub-station, lagankhel
Test Method: IS 2720(part III):1973

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	1.5	SW	9.20	506.00	948.00	870.00	374.00	2.44
BH-01	3	SW-SM	10.00	470.00	926.00	870.00	374.00	2.40
BH-01	4.5	SW	8.92	454.00	912.00	836.40	326.00	2.44
BH-01	6	SC	24.18	39.72	95.30	82.41	18.00	2.46
BH-01	7.5	SP	20.00	40.24	83.65	73.97	24.00	2.48
BH-01	9	SP	18.98	45.58	86.34	73.97	24.00	2.34
BH-01	10.5	SP	19.29	41.38	88.58	84.64	34.64	2.41
BH-01	12	SP	30.88	30.49	77.95	73.97	24.00	2.59
BH-01	13.5	SP-SC	25.00	37.13	81.55	74.26	24.00	2.25
BH-01	15	SP	25.71	34.14	80.21	74.16	24.00	2.48
BH-01	16.5	SP	24.14	38.30	94.30	85.80	24.00	2.47
BH-01	18	SP-SC	26.72	36.68	86.78	79.34	24.00	2.42
BH-01	19.5	SC	24.80	42.58	89.35	78.60	24.00	2.37

Tested By:
Er. Deepak Kumar Mahaseth

Approved By:
GeoTech Er. Aanand Mishra
Nec No: 6933"CIVIL"

Annex 13: Atterberg Limit Test Results

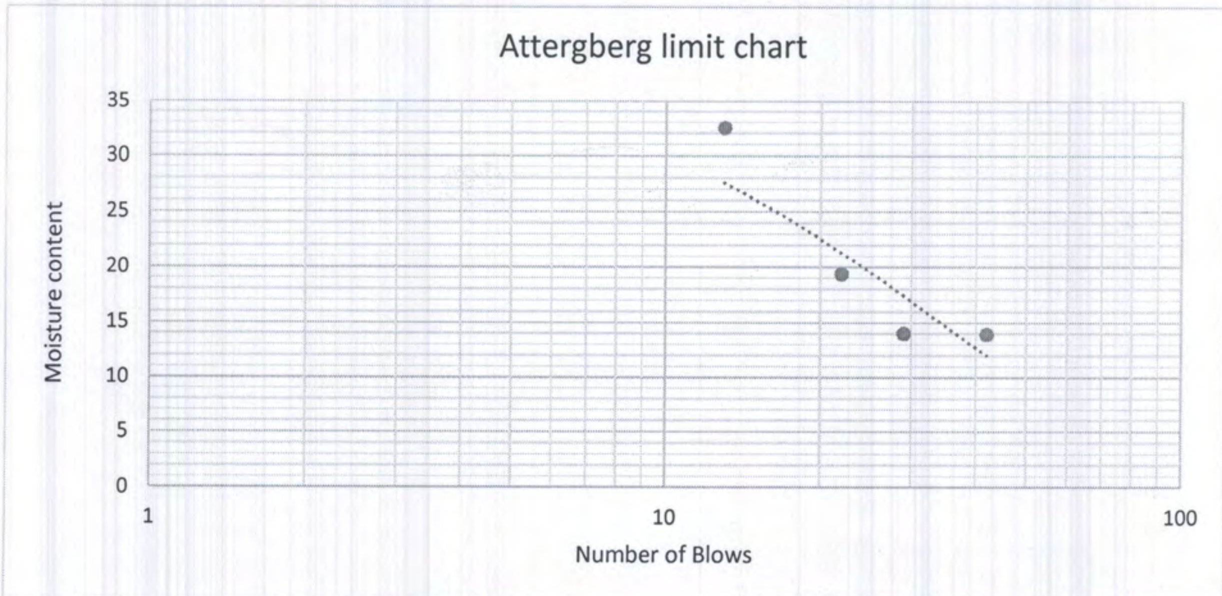
EXPERT TESTING LABORATORY PVT. LTD.
BAFAL, LALITPUR-17
Gmail: experttestlab078@gmail.com

Atterbergs Limit Test

Project:Chovar-Patan-Chapagaun under ground 132 kV transmission line
Soil type: SC
Location: Patan Sub-station, lagankhel

Period of soaking before the test:
Bore hole: BH-01
Depth:6 m

Determination No.	1	2	3	4	5
Number of blows	42	29	22	13	
Container No.	C-0	C-1	C-3	C-4	
Mass of the (container +wet soil) W_1 g	87	89	85	83	
Mass of the (container + dry soil) W_2 g	84.75	86.9	82.5	81	
Mass of water (W_1- W_2) g	2.25	2.1	2.5	2	
Mass of container W_o g	68.62	71.91	69.58	74.84	
Mass to dry soil (W_2- W_o) g	16.13	14.99	12.92	6.16	
Plastic limit test result					
Moisture content (w) %	13.94916	14.00934	19.34985	32.46753	



Liquid Limit (w_L) = 20.00
Flow index (I_f) = 44.51
Plastic Limit (w_P) = 18.00
Plasticity Index PI(%)= 2.00

Tested By:
Er. Deepak Kumar Mahaseth

Approved By:
GeoTech Er. Aanand Mishra
Nec No: 6933"CIVIL"

EXPERT TESTING LABORATORY PVT. LTD.
BAFAL, LALITPUR-17
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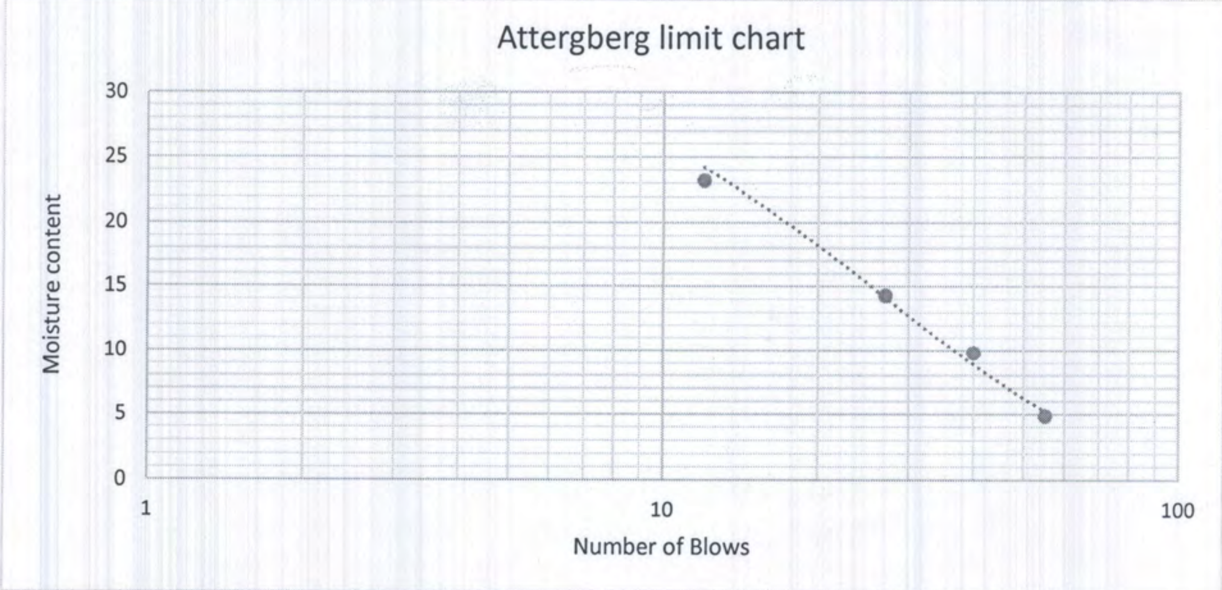
Atterbergs Limit Test

Project:Chovar-Patan-Chapagaun under ground 132 kV transmission line
Soil type: SP-SC
Location: Patan Sub-station, lagankhel

Period of soaking before the test:
Bore hole: BH-01
Depth:13.5 m

Determination No.	1	2	3	4	5
Number of blows	55	40	27	12	
Container No.	C-11	C-2	C-10	C-20	
Mass of the (container +wet soil) W_1 g	110	109.5	116	114.6	
Mass of the (container + dry soil) W_2 g	108.4	106.4	110.06	106.55	
Mass of water (W_1- W_2) g	1.6	3.1	5.94	8.05	
Mass of container W_o g	75.6	74.84	68.62	71.91	
Mass to dry soil (W_2- W_o) g	32.8	31.56	41.44	34.64	
Plastic limit test result					
Moisture content (w) %	4.878049	9.82256	14.33398	23.23903	



Liquid Limit (w_L) = 16.00
Flow index (I_f) = 26.43
Plastic Limit (w_P) = 13.00

Tested By:
Er. Deepak Kumar Mahaseth

Approved By:
GeoTech Er. Aanand Mishra
Nec No: 6933"CIVIL"

EXPERT TESTING LABORATORY PVT. LTD.
BAFAL, LALITPUR-17
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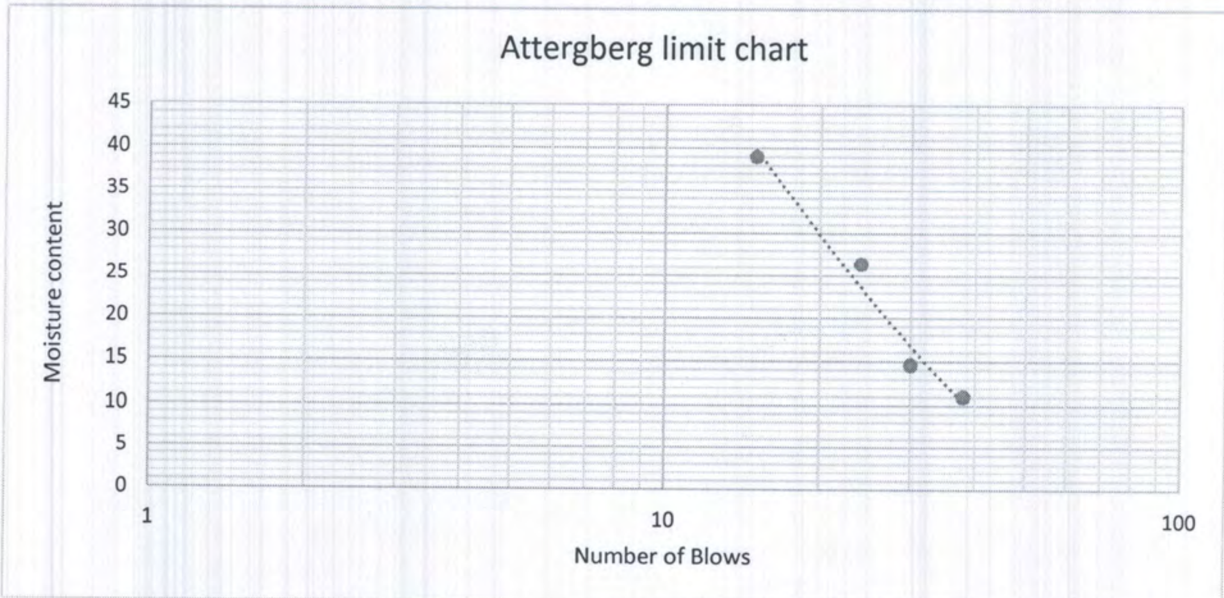
Atterbergs Limit Test

Project:Chovar-Patan-Chapagaun under ground 132 kV transmission line
Soil type: SP-SC
Location: Patan Sub-station, lagankhel

Period of soaking before the test:
Bore hole: BH-01
Depth:18 m

Determination No.	1	2	3	4	5
Number of blows	38	30	24	15	
Container No.	C-6	C-18	C-7	C-8	
Mass of the (container +wet soil) W_1 g	114	108	106	98	
Mass of the (container + dry soil) W_2 g	109.5	103.4	98.4	91.5	
Mass of water (W_1- W_2) g	4.5	4.6	7.6	6.5	
Mass of container W_o g	68.62	71.91	69.58	74.84	
Mass to dry soil (W_2- W_o) g	40.88	31.49	28.82	16.66	
Plastic limit test result					
Moisture content (w) %	11.00783	14.60781	26.37058	39.01561	



Liquid Limit (w_L) = 27.20

Flow index (I_f) = 121.38

Plastic Limit (w_P) = 19.50

Tested By:
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Approved By:
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BAFAL, LALITPUR-17
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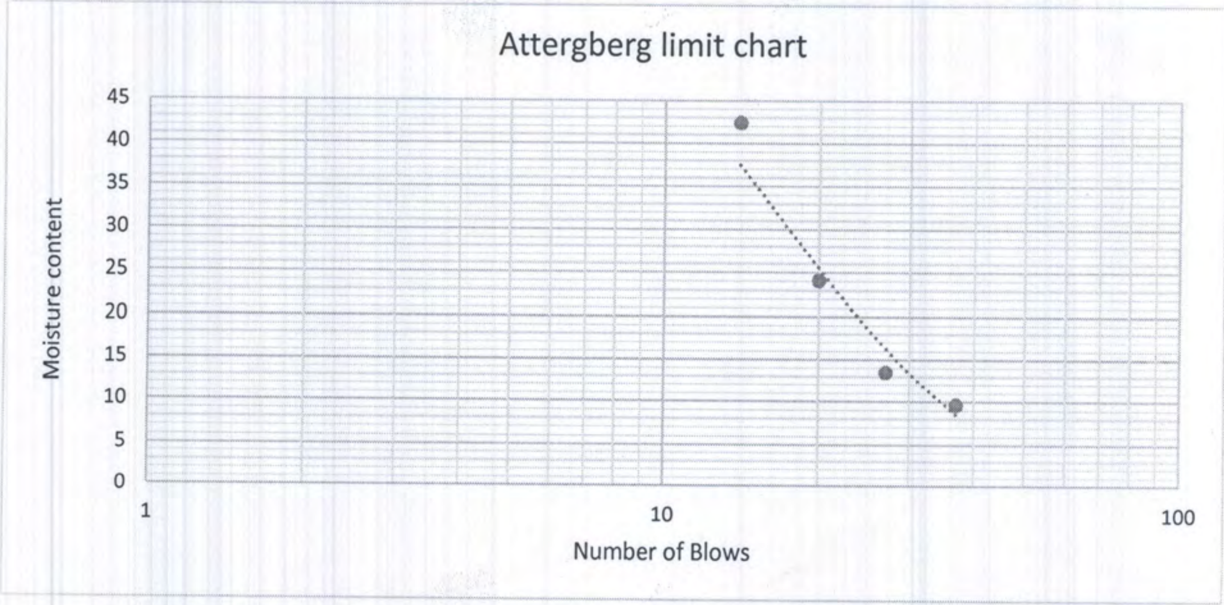
Atterbergs Limit Test

Project:Chovar-Patan-Chapagaun under ground 132 kV transmission line
Soil type: SC
Location: Patan Sub-station, lagankhel

Period of soaking before the test:

Bore hole: BH-01
Depth:19.5m

Determination No.	1	2	3	4	5
Number of blows	37	27	20	14	
Container No.	C-5	C-14	C-25	C-20	
Mass of the (container +wet soil) W_1 g	112	130	142	188	
Mass of the (container + dry soil) W_2 g	108.5	123.4	128.5	154.3	
Mass of water (W_1- W_2) g	3.5	6.6	13.5	33.7	
Mass of container W_o g	72.3	74.5	72.5	74.84	
Mass to dry soil (W_2- W_o) g	36.2	48.9	56	79.46	
Plastic limit test result					
Moisture content (w) %	9.668508	13.49693	24.10714	42.41128	



Liquid Limit (w_L) = 19.50
Flow index (I_f) = 81.41
Plastic Limit (w_P) = 18.00

Tested By:
Er. Deepak Kumar Mahaseth

Approved By:
GeoTech Er. Aanand Mishra
Nec No: 6933"CIVIL"

Annex 14: One Directional Consolidation Test Results

EXPERT TESTING LABORATORY PVT. LTD.

BAFAL, LALITPUR-17

Gmail: experttestlab078@gmail.com

Consolidation Properties Test

Project:Chovar-Patan-Chapagaun under ground 132 kV transmission line		Period of soaking before the test:	
Soil type: Sp		Bore hole: BH-01	
Location: Patan Sub-station, lagankhel		Depth:12m	
Test method: IS2720-part15 :1986		Date of test:2022_3_18	
Ring internal diameter(mm):	60	Moisture content(%):	30.88
Height of specimen(mm):	20	Weight of empty ring(gm):	184
Weight of ring(gm):	184	Specific garvity of soil (G):	2.59
Weight of soil+ring(gm):	260	Bulk density of soil(gm/cc):	1.34

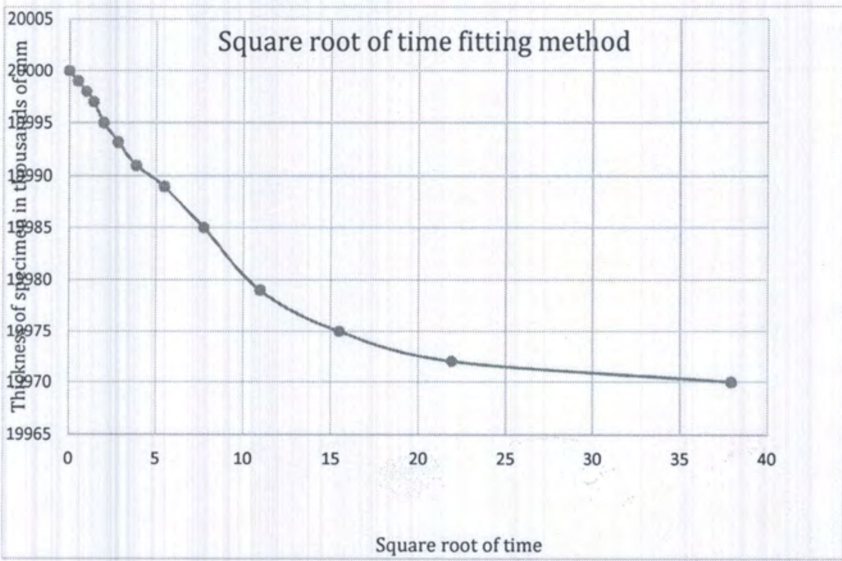
Table for dial gauge reading (settlement)

Time(min.)	Pressure Intensity (kg/cm^2)						
	0.1	0.2	0.5	1	2	4	8
0	0	0					
0.25	0.5	1					
1	1	2.5					
2	1.5	3.5					
4	2.5	5					
8	3.4	6.5					
15	4.5	8					
30	5.5	9					
60	7.5	10.5					
120	10.5	11					
240	12.5	12					
480	14	13					
1440	15	14.5					

Average specimen thickness for load increament (H_{av})= 19.93 mm

time required for 90 % consolidation from square root of time plot t_{90}= 324 minutes

Coefficient of consolidation (cv) = 0.0026 cm^2/min



Tested By:
Er. Deepak Kumar Mahaseth

Approved By:
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Nec No. 6933"CIVIL"

EXPERT TESTING LABORATORY PVT. LTD.

BAFAL, LALITPUR-17

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Consolidation Properties Test

Consolidation Properties Test

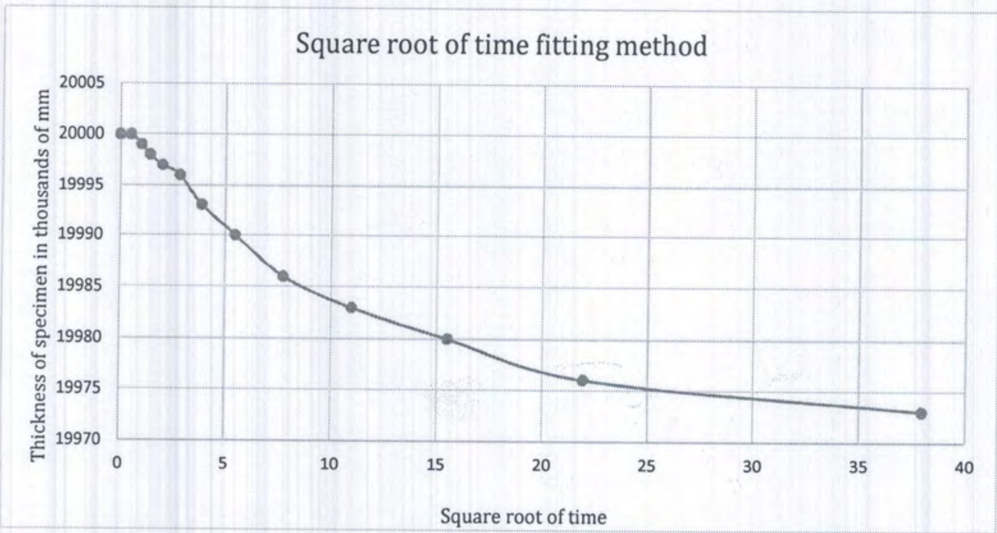
Project:Chovar-Patan-Chapagaun under ground 132 kV transmission line	Period of soaking before the test:
Soil type: SP-SC	Bore hole: BH-01
Location: Patan Sub-station, lagankhel	Depth:18m
Test method: IS2720-part15 :1986	Date of test:2022_3_18

Ring internal diameter(mm):	60	Moisture content(%):	26.72
Height of specimen(mm):	20	Weight of empty ring(gm):	184
Weight of ring(gm):	184	Specific garvity of soil (G):	2.42
Weight of soil+ring(gm):	260	Bulk density of soil(gm/cc):	1.41

Table for dial gauge reading (settlement)

Time(min.)	Pressure Intensity (kg/cm^2)						
	0.1	0.2	0.5	1	2	4	8
0	0	0					
0.25	0	0.5					
1	0.5	1.5					
2	1	2.5					
4	1.5	4					
8	2	5.5					
15	3.5	6					
30	5	7.5					
60	7	9					
120	8.5	11					
240	10	13.5					
480	12	14					
1440	13.5	14.5					

Average specimen thickness for load increament (H_{av})=	19.93 mm
time required for 90 % consolidation from square root of time plot t_{90}=	100 minutes
Coefficient of consolidation (cv) =	0.0084 cm^2/min



Tested By:

Er. Deepak Kumar Mahaseth

Approved By:

GeoTech Er. Aanand Mishra

Nec No: 6933"CIVIL"

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Consolidation Properties Test

Consolidation Properties Test

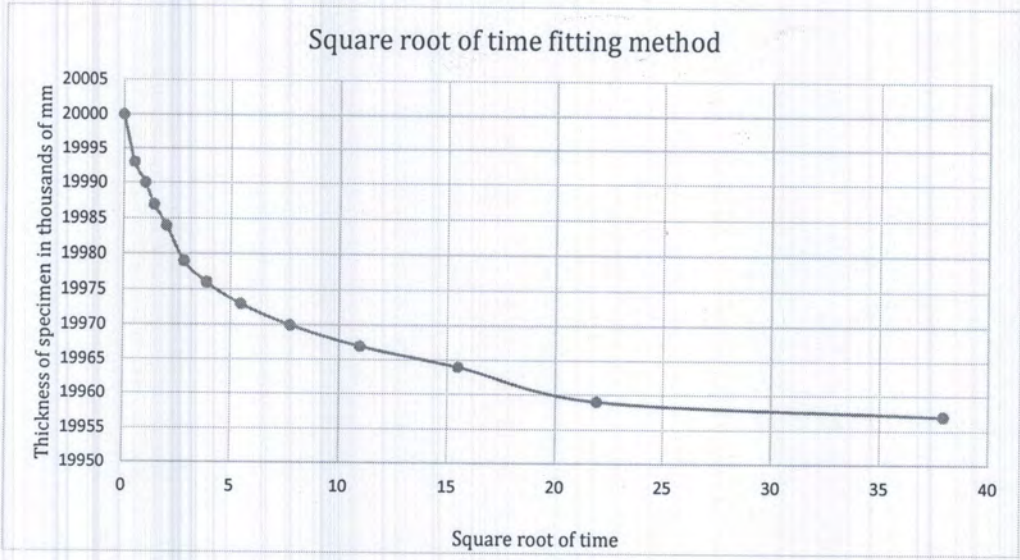
Project:Chovar-Patan-Chapagaun under ground 132 kV transmission line	Period of soaking before the test:
Soil type: SC	Bore hole: BH-01
Location: Patan Sub-station, lagankhel	Depth:20m
Test method: IS2720-part15 :1986	Date of test:2022_3_18

Ring internal diameter(mm):	60	Moisture content(%):	24.80
Height of specimen(mm):	20	Weight of empty ring(gm):	184
Weight of ring(gm):	184	Specific garvity of soil (G):	2.37
Weight of soil+ring(gm):	260	Bulk density of soil(gm/cc):	1.28

Table for dial gauge reading (settlement)

Time(min.)	Pressure Intensity (kg/cm^2)						
	0.1	0.2	0.5	1	2	4	8
0	0	0					
0.25	3.5	0.5					
1	5	1.5					
2	6.5	2.5					
4	8	4					
8	10.5	5.5					
15	12	6					
30	13.5	7.5					
60	15	9					
120	16.5	11					
240	18	13.5					
480	20.5	14					
1440	21.5	14.5					

Average specimen thickness for load increament (H_{av})= 19.89 mm
time required for 90 % consolidation from square root of time plot t_{90}= 90.25 minutes
Coefficient of consolidation (cv) = 0.0093 cm^2/min



Tested By:
Er. Deepak Kumar Mahaseth

Approved By:
GeoTech Er. Aanand Mishra
Nec No: 6933"CIVIL"

Annex 15: Free Swell Test Results

EXPERT TESTING LABORATORY PVT. LTD.

BAFAL, LALITPUR-17

Gmail: experttestlab078@gmail.com

Free Swell Index of Soil

Project:Chovar-Patan-Chapagaun under ground 132 kV transmission line	Location: Patan Sub-station, lagankhel
Test Method: IS 2720 part 40:1997	Date of experiment:2022/3/15
Bore hole No: BH01	Lab temperature: 27°C
Depth(m) : 1.5-20m	Time for swelling :24 Hrs.

Soil sample of depth in bore hole :	1.50	m
Type of soil:	SW	
Weight of soil sample in each graduated glass cylinder :	10.00	grams
Volumne of graduated glass cylinders:	100.00	ml
Volumne of soil in cylinder with distilled water (Vd):	9.50	ml
Volume of soil in cylinder with kerosseene (Vk):	9.00	ml
Free Swell Index (%)= (Vd-Vk)/Vk*100=	5.56	%

Soil sample of depth in bore hole :	3.00	m
Type of soil:	SW-SM	
Weight of soil sample in each graduated glass cylinder :	10.00	grams
Volumne of graduated glass cylinders:	100.00	ml
Volumne of soil in cylinder with distilled water (Vd):	8.00	ml
Volume of soil in cylinder with kerosseene (Vk):	7.50	ml
Free Swell Index (%)= (Vd-Vk)/Vk*100=	6.67	%

Soil sample of depth in bore hole :	4.50	m
Type of soil:	SW	
Weight of soil sample in each graduated glass cylinder :	10.00	grams
Volumne of graduated glass cylinders:	100.00	ml
Volumne of soil in cylinder with distilled water (Vd):	8.00	ml
Volume of soil in cylinder with kerosseene (Vk):	8.00	ml
Free Swell Index (%)= (Vd-Vk)/Vk*100=	-	%

Soil sample of depth in bore hole :	6.00	m
Type of soil:	SC	
Weight of soil sample in each graduated glass cylinder :	10.00	grams
Volumne of graduated glass cylinders:	100.00	ml
Volumne of soil in cylinder with distilled water (Vd):	8.00	ml
Volume of soil in cylinder with kerosseene (Vk):	7.50	ml
Free Swell Index (%)= (Vd-Vk)/Vk*100=	6.67	%

Tested By:
Er. Deepak Kumar Mahaseth

Approved By:
GeoTech Er. Aanand Mishra
Nec No: 6933"CIVIL"

EXPERT TESTING LABORATORY PVT. LTD.
BAFAL, LALITPUR-17
Gmail: experttestlab078@gmail.com

Free Swell Index of Soil

Project:Chovar-Patan-Chapagaun under ground 132 kV transmission line	Location: Patan Sub-station, lagankhel
Test Method: IS 2720 part 40:1997	Date of experiment:2022/3/15
Bore hole No: BH01	Lab temperature: 27°C
Depth(m) : 1.5-20m	Time for swelling :24 Hrs.

Soil sample of depth in bore hole :	7.50	m
Type of soil:	SP	
Weight of soil sample in each graduated glass cylinder :	10.00	grams
Volumne of graduated glass cylinders:	100.00	ml
Volumne of soil in cylinder with distilled water (Vd):	9.00	ml
Volume of soil in cylinder with kerosseene (Vk):	9.00	ml
Free Swell Index (%)= (Vd-Vk)/Vk*100=	-	%

Soil sample of depth in bore hole :	9.00	m
Type of soil:	SP	
Weight of soil sample in each graduated glass cylinder :	10.00	grams
Volumne of graduated glass cylinders:	100.00	ml
Volumne of soil in cylinder with distilled water (Vd):	8.50	ml
Volume of soil in cylinder with kerosseene (Vk):	8.00	ml
Free Swell Index (%)= (Vd-Vk)/Vk*100=	6.25	%

Soil sample of depth in bore hole :	10.50	m
Type of soil:	SP	
Weight of soil sample in each graduated glass cylinder :	10.00	grams
Volumne of graduated glass cylinders:	100.00	ml
Volumne of soil in cylinder with distilled water (Vd):	8.00	ml
Volume of soil in cylinder with kerosseene (Vk):	8.00	ml
Free Swell Index (%)= (Vd-Vk)/Vk*100=	-	%

Soil sample of depth in bore hole :	12.00	m
Type of soil:	SP	
Weight of soil sample in each graduated glass cylinder :	10.00	grams
Volumne of graduated glass cylinders:	100.00	ml
Volumne of soil in cylinder with distilled water (Vd):	8.50	ml
Volume of soil in cylinder with kerosseene (Vk):	8.00	ml
Free Swell Index (%)= (Vd-Vk)/Vk*100=	6.25	%

Expert Testing Laboratory ETL

Tested By:
Er. Deepak Kumar Mahaseth

Approved By:
GeoTech Er. Aanand Mishra
Nec No: 6933"CIVIL"

EXPERT TESTING LABORATORY PVT. LTD.
BAFAL, LALITPUR-17
Gmail: experttestlab078@gmail.com

Free Swell Index of Soil

Project:Chovar-Patan-Chapagaun under ground 132 kV transmission line	Location: Patan Sub-station, lagankhel
Test Method: IS 2720 part 40:1997	Date of experiment:2022/3/15
Bore hole No: BH01	Lab temperature: 27°C
Depth(m) : 1.5-20m	Time for swelling :24 Hrs.

Soil sample of depth in bore hole :	13.50	m
Type of soil:	SP-SC	
Weight of soil sample in each graduated glass cylinder :	10.00	grams
Volumne of graduated glass cylinders:	100.00	ml
Volumne of soil in cylinder with distilled water (Vd):	9.50	ml
Volume of soil in cylinder with kerosseene (Vk):	8.00	ml
Free Swell Index (%)= (Vd-Vk)/Vk*100=	18.75	%

Soil sample of depth in bore hole :	15.00	m
Type of soil:	SP	
Weight of soil sample in each graduated glass cylinder :	10.00	grams
Volumne of graduated glass cylinders:	100.00	ml
Volumne of soil in cylinder with distilled water (Vd):	8.00	ml
Volume of soil in cylinder with kerosseene (Vk):	7.50	ml
Free Swell Index (%)= (Vd-Vk)/Vk*100=	6.67	%

Soil sample of depth in bore hole :	16.50	m
Type of soil:	SP	
Weight of soil sample in each graduated glass cylinder :	10.00	grams
Volumne of graduated glass cylinders:	100.00	ml
Volumne of soil in cylinder with distilled water (Vd):	9.00	ml
Volume of soil in cylinder with kerosseene (Vk):	9.00	ml
Free Swell Index (%)= (Vd-Vk)/Vk*100=	-	%

Soil sample of depth in bore hole :	18.00	m
Type of soil:	SP-SC	
Weight of soil sample in each graduated glass cylinder :	10.00	grams
Volumne of graduated glass cylinders:	100.00	ml
Volumne of soil in cylinder with distilled water (Vd):	10.00	ml
Volume of soil in cylinder with kerosseene (Vk):	9.00	ml
Free Swell Index (%)= (Vd-Vk)/Vk*100=	11.11	%

Tested By:
Er. Deepak Kumar Mahaseth

Approved By:
GeoTech Er. Aanand Mishra
Nec No: 6933"CIVIL"

EXPERT TESTING LABORATORY PVT. LTD.
BAFAL, LALITPUR-17
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Free Swell Index of Soil

Project:Chovar-Patan-Chapagaun under ground 132 kV transmission line	Location: Patan Sub-station, lagankhel
Test Method: IS 2720 part 40:1997	Date of experiment:2022/3/15
Bore hole No: BH01	Lab temperature: 27°C
Depth(m) : 1.5-20m	Time for swelling :24 Hrs.

Soil sample of depth in bore hole :	19.50	m
Type of soil:	SC	
Weight of soil sample in each graduated glass cylinder :	10.00	grams
Volumne of graduated glass cylinders:	100.00	ml
Volumne of soil in cylinder with distilled water (Vd):	9.50	ml
Volume of soil in cylinder with kerosseene (Vk):	8.00	ml
Free Swell Index (%)= (Vd-Vk)/Vk*100=	18.75	%

Tested By:
Er. Deepak Kumar Mahaseth

Approved By:
GeoTech Er. Aanand Mishra
Nec No: 6933"CIVIL"

Annex 16: Laboratory CBR Test Results

EXPERT TESTING LABORATORY PVT. LTD.
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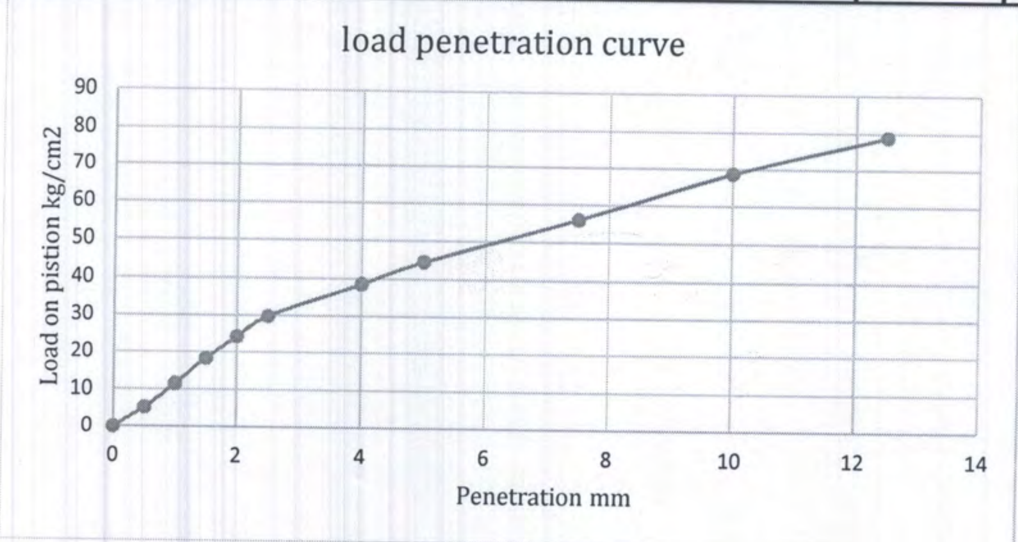
Laboratory CBR Test

Project:Chovar-Patan-Chapagaun under ground 132 kV transmission line	Period of soaking before the test:
Soil type: SP	Bore hole: BH-01
Location: Patan Sub-station, lagankhel	Depth:1.5-10m
Test method: IS2720-part16 :1987	Date of test:2022_3_18

Diameter of mould(mm):	150	Moisture content(%):	24.18
Height of mould(mm):	175	Weight of empty mould(kg):	6.4
Height of specimen(mm):	125	weight of mould with sample(kg):	12.93
Diameter of plunger(mm):	50	Bulk density of soil(gm/cc):	1.67
Rate of loading (mm/min.):	1.25	Proving ring constant:	0.0631

Dial gauge reading	Penetration (mm)	Proving ring division	Load (kN)	Presuure kgf/cm^2	CBR value %	Remarks
0	0	0	0	0		
50	0.5	16	1.01	5.24		
100	1	35	2.21	11.46		
150	1.5	56	3.53	18.34		
200	2	74	4.67	24.24		
250	2.5	91	5.74	29.81	25.376	
400	4	118	7.44	38.65		
500	5	136	8.58	44.55		
750	7.5	171	10.79	56.01		
1000	10	210	13.25	68.78		
1250	12.5	241	15.21	78.94		

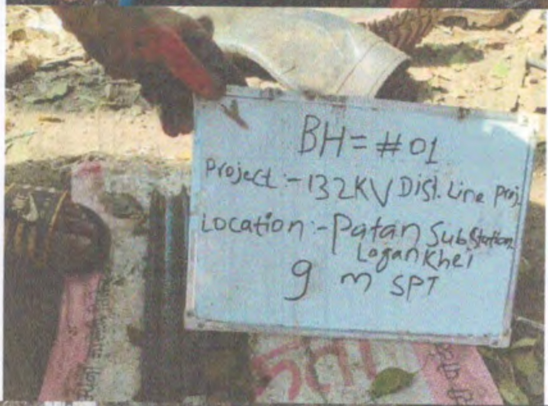


Tested By:
Er. Deepak Kumar Mahaseth

Approved By:
GeoTech Er. Aanand Mishra
Nec No: 6933"CIVIL"

Annex 17: Photographs

SITE PHOTOGRAPHS



SITE PHOTOGRAPHS

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