GEOTECHNICAL SOIL INVESTIGATION REPORT

OF

HOSPITAL BUILDING

GHYANGLEKH RURAL MUNICIPALITY, SINDHULI, NEPAL

PREPARED FOR: EMPIRICAL ENGINEERING CONSULTANCY PVT. LTD. SUKEDHARA, KATHMANDU

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EXECUTIVE SUMMARY

Traceable Measurement Pvt. Ltd. (hereon "Traceable Measurement") was retained by Empirical Engineering Consultancy Pvt. Ltd. (hereon "Empirical Engineering"), to carry out a geotechnical investigation and subsequent interpretative reporting in relation to the proposed building construction for Ghyanglekh Hospital in Ghyanglekh Rural Municipality, Sindhuli.

The purpose of investigation, conducted on March 3-4, 2021 was to provide geotechnical recommendation related to the design and construction of a proposed hospital building. A general description of the soils encountered, the soil properties, anticipated behavior of soils during construction and measured groundwater levels are provided in this report. General geotechnical recommendations for shallow and deep foundations are provided in this report. In addition, soil modulus and liquefaction potential were estimated and presented in this report. The foundation design parameters were derived from calculations based on the Indian standards (IS Standards) and other relevant geotechnical references.

A total number of two field standard penetration tests (SPT) were conducted in the boreholes and samples were collected during drilling. Geotechnical laboratory tests on collected soil samples were conducted at Traceable Measurements Pvt. Ltd., Sanepa, Lalitpur. These tests included water contents, grain size distributions, specific gravity, and direct shear test. As the soil was cohesionless, Atterberg limit tests are not applicable. The geotechnical investigation revealed a general soil profile consisting of fine sand and gravel. Bore hole 1 (BH-01) and bore hole 2 (BH-02) consist of silty sand (SM) and poorly graded gravel (GP), respectively, from ground surface to a depth of 12.0 m. The soil profiles at BH-01 showed a poorly graded sand with 3-5% fines. Though BH-01 consists of fine sand, the probability of liquefaction is less as the density of sand is very high (SPT -N value >80). The soil profiles at BH-02 consists of poorly graded gravel (GP). Overall, the soil at the proposed building site is good for building construction.

The strength parameters, cohesion (c) and friction angle (ϕ) range from 3 kPa to 9 kPa and 29° to 34°, respectively. Allowable bearing pressure was calculated based the angle of friction and cohesion values from direct shear test results. A typical allowable bearing capacity of a foundation of 2mx2m with depth 2.0 is found about 165 kPa. Similar thumb rule was used to calculate allow bearing pressure form SPT-N values. The bearing capacity using SPT-N value was foundation very high. Allowing bearing pressure for different foundation sizes and depths are reported. The value of liquefaction potential index is zero which indicates no liquefaction.

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1. INTRODUCTION

1.1 Background

Traceable Measurement was retained by was retained by Empirical Engineering Consultancy Pvt. Ltd. (hereon “Empirical Engineering”), to provide geotechnical services in support of the design and construction of the hospital buildings in for Ghyanglekh Hospital in Ghyanglekh Rural Municipality, Sindhuli. The work presents in this report is for the geotechnical recommendation for the proposed buildings. The approximate site location is shown in Figure 1.1.

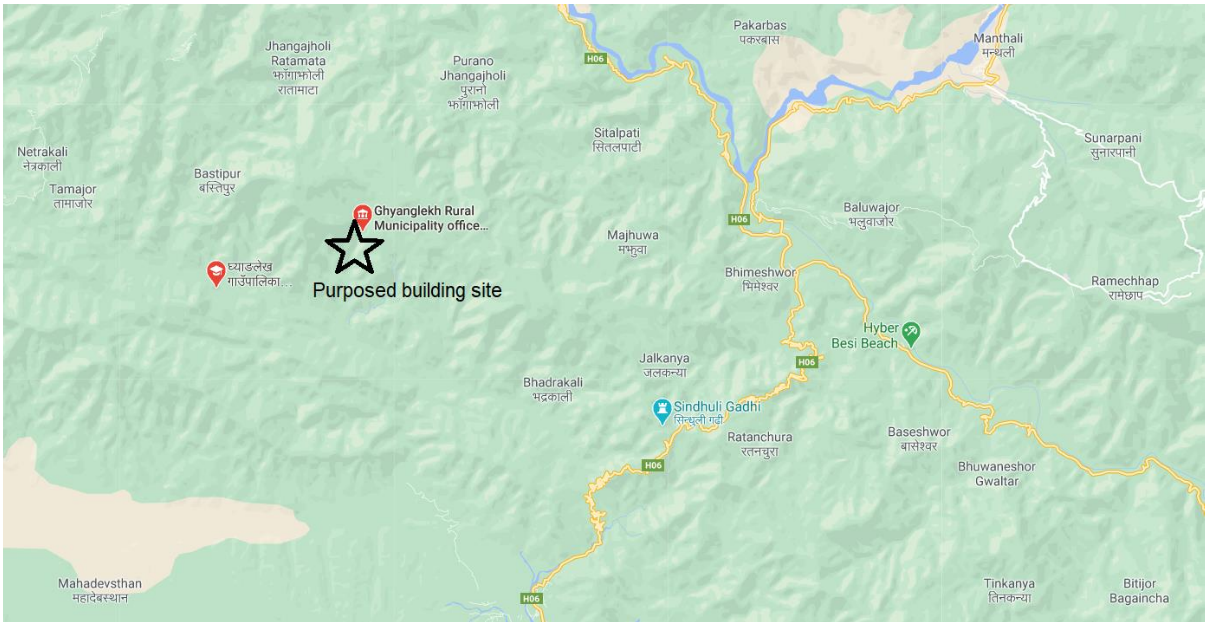


Figure 1.1 Tentative location of the proposed building site location

The field tests were conducted by drilling boreholes and collected samples during drilling. Laboratory tests (moisture content, particle size distribution, specific gravity, and direct shear) were performed using samples from BH-01, and BH-02. The borehole logs, BH-01, and BH-02, provide SPT-N values and description of the soil. The soil investigation comprises of Standard Penetration Test (SPT), Laboratory tests and prediction of the allowable bearing capacity of the site under consideration. The details of test and findings are summarized in the respective sections and paragraphs.

Equipment were mobilized and drilling works for three bore holes were carried out as per the contract agreement. The SPT were carried out along with drawing out of both disturbed and un-disturbed soil samples at locations and depth as shown in the relevant sections. The samples so drawn at site were immediately taken to the laboratory and appropriate tests were performed.

1.2 Objective

1. The objectives of this geotechnical investigation were to explore and evaluate subsurface conditions of the site and develop geotechnical recommendation for design and construction of the proposed improvements.

2. Site investigation. A detailed mapping of the site with location of all the borehole and SPT will be provided.
3. In-situ testing. With borehole logs and SPT data, the soil profile and in-situ properties can be determined.
4. Lab testing. Samples were sent to Traceable Measurement, Lalitpur, Nepal for laboratory test. Several soil indexes and properties were determined in the laboratory.
5. The foundations will be designed based on the soil parameter obtained from the laboratory and in-situ testing.
6. Bearing capacity. For each soil profile and structure type, the bearing capacity for shallow will be evaluated and a recommendation for the foundation design will be summarized.
7. Soil improvement. Soil improvement techniques will be recommended based on soil strata and soil properties if needed.

1.3 Scope of work and investigation

For the purpose of the foundation design and construction of the proposed building, the following data are to be provided:

The scope of soil investigation is as follows for borehole advancement to 15.0m at three locations:

- Standard penetration tests (SPT) at 1.5m interval
- Collection of disturbed and undisturbed samples at regular interval or as and when required
- Ground water table observation
- Laboratory test and analysis of data to determine the engineering properties
- Seismic analysis
- Technical report of the investigation work
- Allowable bearing pressure at the foundation level
- Design parameters of sub-soil strata (sub-soil profile and engineering properties of the soil strata)

2. METHODOLOGY

2.1 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 (arkose and subarkose) 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 2.1.

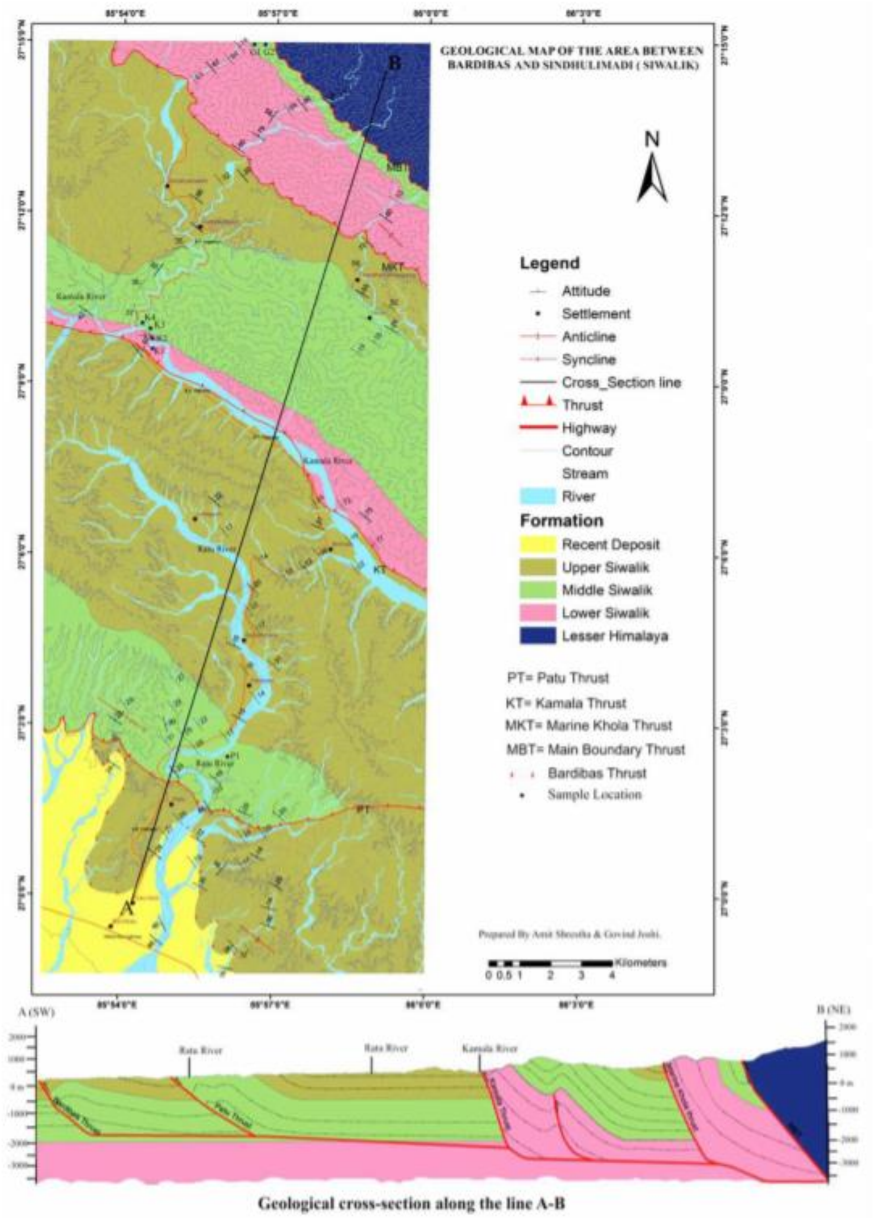


Figure 2.1 Regional geology of the study area (Shrestha et al. 2019)

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 (Figure 2.2)

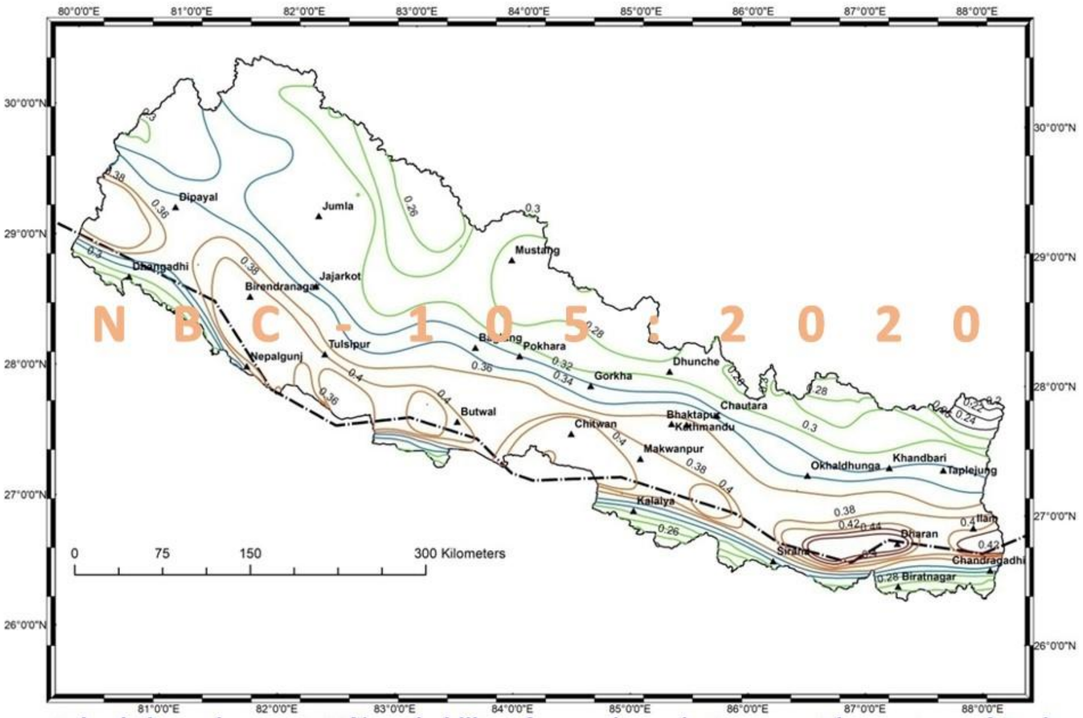


Figure 2.3 Seismic hazard map at 10% probability of exceedance in 50 years (NBC-105 2020).

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.

2.2 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 November March 2-3, 2021. Drilling works were carried out using one set of percussion drilling machine. The sides of the boreholes were lined with 150mm casing pipes.

2.2.1 Standard Penetration Test (SPT)

Standard Penetration tests (SPT) were carried out in the boreholes at average depth intervals of 1.5 m. Spilt spoon sampler of 35 mm internal diameter and 50 mm external diameter coupled with a standard cutting shoe at its lower end was driven into the ground at the base of the borehole by means of a 63.5 kg hammer falling from a height of 760 mm. After an initial 150 mm seating penetration the sampler was driven to a further depth of 150 mm twice to reach the final depth. The sum of the number of blows required to reach the two-last final 150mm depth was recorded as the N-value.

2.2.2 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.

2.3 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, and Direct Shear Tests.

2.3.1 Natural moisture content

The natural water content was determined from samples recovered from the split spoon sampler.

2.3.2 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.

2.3.3 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.

2.3.4 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 was sand and gravel.

2.3.5 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 moulds 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., 50 kPa, 100 kPa, 200 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).

3. DATA INTERPRETATION AND ANALYSIS

3.1 Analysis of allowable bearing pressure

The allowable bearing pressure (q_{all}) is the maximum pressure that can be imposed on the foundation soil taking into consideration the ultimate bearing capacity of the soil and the tolerable settlement of the structure. Analysis to determine the ultimate bearing capacity and the pressure corresponding to a specified maximum settlement were performed and the minimum pressure obtained from the two analyses were adopted as the allowable bearing pressure.

3.2 Allowable bearing pressure using strength parameter (c and ϕ)

Since the soil in the vicinity of the foundation level has been found to be grayish color very dense gravel at greater depth, grey silty clay with high plasticity at intermediate depth, the allowable bearing capacity has been analyzed using the angle of friction and cohesion values from direct shear test results. Empirical formula of Terzaghi applicable for this type of soils has been used to obtain the allowable bearing pressure with safety factor equal to 3.

a. Terzaghi's Method:

$$q_{ult} = cN_c s_c + qN_q W_q + 0.5\gamma B N_\gamma s_\gamma W\gamma \qquad (2)$$

where,

$N_q = a^2 / a \, Cos^2 (45 + \phi/2)$, $a = e^{(0.75\pi-\phi/2)\tan\phi/2}$

$N_c = (N_q - 1) \, Cot\phi$

$N_\gamma = \tan\phi / 2 * (K_{p\gamma} / \cos^2\phi - 1)$

$K_{p\gamma}$ is a factor

c. Effect of water table:

i) If water table is likely to permanently remains at or below a depth of (D_f + B) beneath the ground level surrounding the footing then Wq = 1.

ii) If the water table is located at depth D_f or likely to rise to the base of the footing or above then the value of Wq shall be taken as 0.5.

iii) If the water table is likely to permanently got located at depth $D_f<D_w<(D_f+B)$, then the value of Wq be obtained by linear interpolation.

On the basis of ultimate bearing capacity and allowable settlement, the following allowable bearing pressures for shallow foundation have been recommended. Water table is assumed at ground considering the monsoon season. As the bearing capacity of soil depends on the size of footing and depth of footing, the exact bearing capacity of soil cannot be determined without know footing size and load on footing. The reported allowable bearing pressures (Table 3.1) are for typical shallow foundation size..

Table 3.1 Allowable bearing capacity of the typical shallow footings

Bearing Capacity for typical foudation size				
BH-01; Depth = 0.0 - 12. m				
c =	3.97	kPa		
ϕ =	29.79	°		
D_w = *	0	m		
Depth of footng (m)	q_{all} (kPa)			Remarks
	Width of square footing (m)			
	2.0	3.0	4.0	
1.0	165.0	186.0	208.0	
2.0	225.0	246.0	268.0	
3.0	285.0	306.0	327.0	
* Water table is assumed at ground considering the monsoon season				
BH-02; Depth = 0.0 -12.0 m				
c =	2.13	kPa		
ϕ =	33.84	°		
D_w = *	0	m		
Depth of footng (m)	q_{all} (kPa)			Remarks
	Width of square footing (m)			
	2.0	3.0	4.0	
1.0	230.0	272.0	314.0	
2.0	328.0	370.0	412.0	
3.0	425.0	468.0	510.0	
* Water table is assumed at ground considering the				

3.3 Allowable bearing pressure using SPT-N 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) (2a)

q_{allow} = 47.8*N kPa (Terzaghi and Peck, 1967) (2b)

q_{allow} = 34*N kPa (Strounf and Butler, 1975) (2c)

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). These formula gears towards allowable stress design (ASD), for it predicts the allowable soil and rock resistances using the SPT blow count (N) alone. Allowable stress design (ASD) treats each load on a structure with equal statistical variability. Table 3.2 shows allowable bearing capacity based on SPT-N value.

Table 3.2 Allowable bearing capacity based on SPT-N value

Bearinc capacity using SPT-N			
BH-01	SPT =	80	
Depth =	3.0	m	
1. Meyerhoff (1956)			
q_{all} =	5744	kpa	
2. Terzaghi and Peck (1967)			
q_{all} =	3824	kpa	
3. Strounf and Butler (1975)			
q_{all} =	2720	kpa	
BH-02	SPT =	80	
Depth =	3.0	m	
1. Meyerhoff (1956)			
q_{all} =	5744	kpa	
2. Terzaghi and Peck (1967)			
q_{all} =	3824	kpa	
3. Strounf and Butler (1975)			
q_{all} =	2720	kpa	

3.4 Allowable bearing pressure based on tolerable 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).

$$q_{all\_net} := \frac{N_{60}}{0.08}\left(1+0.33\left(\frac{D_e}{B}\right)\right)\cdot\left(\frac{S_e}{25}\right) \quad (3)$$

Considering several size and depth of shallow footing, the allowable bearing pressure of the footing is about 1000 kPa.

a. Settlement analysis using schmertmann method:

The method proposed by Schmertmann (1970) states that the change in the Boussinesq pressure bulb was interpreted as related to strain. Since the pressure bulb changes more rapidly from about 0.4 to 0.6 B, this depth is interpreted to have the largest strains. Schmertmann then proposed using triangular relative-strain diagram to model this strain distribution with ordinates of 0, 0.6 and 0 at 0B, 0.5B and 2B respectively. The area of diagram is related to the settlement.

Settlement (δ) = $C_1C_2C_3(q-\sigma'_{zd})\Sigma I_\varepsilon H/E_s$ (4)

The Peak Value of the strain influence factor $I_{\varepsilon p}$ is

$I_{\varepsilon p} = 0.5 + 0.1\text{Sqrt}((q-\sigma'_{zd})/\sigma'_{zp})$

Square and Circular Foundation:

For z_f = 0 to B/2 $I_\varepsilon = 0.1 + (z_f/B)(2I_{\varepsilon p}-0.2)$

For z_f = B/2 to 2B $I_\varepsilon = 0.667\, I_{\varepsilon p}(2-z_f/B)$

$C_1 = 1- 0.5(\sigma'_{zd}/q - \sigma'_{zd})$

$C_2 = 1 + 0.2\log(t/0.1)$

$C_3 = 1.03 – 0.003\, L/B >= 0.73$

Settlement analysis for clay layer

$$s_e = \frac{H}{1+e_0} C_c \log_{10}\left(\frac{(P_o+\Delta P)}{P_o}\right)$$

s_e = consolidation settlement (m)

H = thickness of soil (m)

e_o = initial void ratio

C_c = compression index, obtained from consolidation test results

For preliminary analysis, *IS:8009 (Part I)-1976, clause 9.2.2* recommends,

$$C_c = 0.009(Liquid\ Limit - 10)$$

$$C_c = 0.30(e_o - 10)$$

P_o = effective pressure at mid height of layer (kN/m^2)

ΔP = pressure increment (kN/m^2)

Table 3.3 Typical pile capacity based lowest c and ϕ values

Depth, m	Pile diamter, m		
	0.5	0.7	0.9
8	508	856	1286
10	714	1180	1749
12	952	1549	2269
14	1220	1961	2846
16	1521	2417	3479

3.5 Calculation of pile capacity

There are different methods available for designing piles. In all the methods, skin friction and end bearing calculations are done in the design of piles. Calculation of negative skin friction and normal skin friction of soil is not considered in this post. However, the effect of the soil skin friction can be considered when the pile capacity is evaluated. Especially, when there is negative skin friction, which reduces the pile capacity, it should be considered in the calculation.

End Bearing Capacity = (net allowable end bearing) x (cross-sectional area of pile base

Skin Friction Capacity = (allowable skin friction) x (surface area of pile in socket length)

Pile capacity = End Bearing Capacity + Skin Friction Capacity

3.6 Liquefaction:

In Nepal, most of the geotechnical investigations are limited to standard penetration tests to a depth of 15 to 20 m, because other in-situ geotechnical investigations such as cone penetration test and shear wave velocity test have been sparsely used.
A simplified method using SPT-N value suggested by Idriss and Boulanger (2008) was adopted to perform an analysis of the factor of safety (FS) with respect to liquefaction on each layer considering the earthquake scenario of M_w 8.0 with PGA of 0.380g. The scenario earthquake of M_w 8.0 with PGA of 0.38g was chosen based on the probabilistic seismic hazard studies that have been conducted for Kathmandu Valley considering seismic source zone models based on improved earthquake catalogs and modern ground-motion models (soil (Nepal National Building Code: 105:2020 (NBC-105 2020). Additionally, the Iwasaki et al. (1982) method was adopted to calculate Liquefaction Potential Index (LPI) of the sites using FS against liquefaction on each layer.

In this method, the FS with respect to liquefaction can be calculated using Equation 5. The property of the soils to resist liquefaction is defined as the cyclic resistance ratio (CRR), and the stress (loading) that results in liquefaction is termed as the cyclic stress ratio (CSR).

$$FS = \frac{CRR_{7.5}}{CSR} MSF \qquad (6)$$

Where $CRR_{7.5}$ is the cyclic resistance ratio calibrated for the earthquake of magnitude 7.5. The $CRR_{7.5}$ can be modified using the magnitude scaling factor (*MSF)* for an earthquake having different magnitudes; MSF that accounts for the effects of the number of cycles during the earthquake or earthquake duration. The value of MSF for the considered scenario earthquake was calculated using Equation 6 (Idriss and Boulanger 2008):

$$MSF = 6.9e^{-\frac{M_W}{4}} - 0.058 \ (\leq 1.8) \qquad (7)$$

Equation 8 was used for determining the CRR for a cohesionless soil with any fines content.

$$CRR_{7.5} = \exp\left(\frac{(N_1)_{60cs}}{14.1} + \left(\frac{(N_1)_{60cs}}{126}\right)^2 - \left(\frac{(N_1)_{60cs}}{23.6}\right)^3 + \left(\frac{(N_1)_{60cs}}{25.4}\right)^4 - 2.8\right) \qquad (8)$$

where $(N_1)_{60cs}$ is an equivalent clean-sand *SPT* blow count. Following equations (Equations 9 and 10) are used to calculate $(N_1)_{60cs}$:

$$(N_1)_{60cs} = (N_1)_{60} + \Delta(N_1)_{60} \tag{9}$$

$$\Delta(N_1)_{60} = \exp\left(1.63 + \frac{9.7}{FC+0.01} - \left(\frac{15.7}{FC+0.01}\right)^2\right) \tag{10}$$

where $(N_1)_{60}$ is the corrected SPT-N value; *FC* is the fines content in the soils.

The measured *SPT-N* value was corrected using Equation 10:

$$(N_1)_{60} = NC_N C_E C_B C_R C_S \tag{11}$$

where $(N_1)_{60}$ is the *SPT* blow count normalized to the atmospheric pressure of 100 kPa, and a hammer efficiency of 60%, *N* is the measured *SPT* blow count, and C_N, C_E, C_B, C_R, and C_S are the correction factors for the overburden stress, hammer energy ratio, borehole diameter, rod length and samplers with or without liners, respectively.

The *CSR* is calculated by Equation 12:

$$CSR = 0.65\frac{\tau_{max}}{\sigma'_{vc}} = 0.65\frac{\sigma_{vc}}{\sigma'_{vc}}\frac{a_{max}}{g}r_d \tag{12}$$

where: τ_{max} is the earthquake-induced maximum shear stress, a_{max} is the peak horizontal acceleration at the ground surface, *g* is the gravitational acceleration, σ_{vc} and σ'_{vc} are the total overburden stress and effective overburden stress respectively, and r_d is the stress reduction coefficient given by Equation 13:

$$r_d = exp\left[-1.012 - 1.126sin\left(\frac{z}{11.73} + 5.133\right) + M_w\left(0.106 + 0.118sin\left(\frac{z}{11.28} + 5.142\right)\right)\right] \tag{13}$$

where: *z* is the depth of the soil layer in meter.

Liquefaction potential index (LPI)

The factor of safety against liquefaction at a given depth does not provide clear information on the severity of the potential ground deformation. For predicting the severity of liquefaction at a site through considering the soil profile in the top 20 m, the LPI was calculated using Equation 14 (Iwasaki *et al.* 1982):

$$LPI = \int_0^z F(z)W(z)dz \tag{14a}$$

$$F(z) = 1 - FS \quad \text{For FS} < 1 \tag{14b}$$

$$F(z) = 0 \quad \text{For FS} \geq 1 \tag{14c}$$

$$W(z) = 10 - 0.5z \quad \text{For z} < 20 \tag{14d}$$

$$W(z) = 0 \quad \text{For z} \geq 20 \tag{14e}$$

Based on the *LPI* value, liquefaction susceptibility of the site can be classified into four categories as (Table 3.1): Very Low, Low, High, and Very High (Iwasaki et al. 1982).

Table 3.3 Liquefaction potential classification (Iwasaki et al. 1982)

LPI	Susceptibility
0	Very low
0<LPI≤5	Low
5<LPI≤15	High
LPI > 15	Very high

In this case, as SPT-N value of soil is very high (>50), the liquefaction analysis for this site is not necessary.

4. CONCLUSIONS

1. Soil investigation work has been carried out for the construction of the proposed hospital building in Ghyanglekh Hospital in Ghyanglekh Rural Municipality, Sindhuli.

2. Moisture content, grain size analysis, specific gravity, and direct shear tests were carried out in the laboratory to characterize the soil collected during field investigation.

3. Bore hole 1 (BH-01) and bore hole 2 (BH-02) consist of silty sand (SM) and poorly graded gravel (GP), respectively, from ground surface to a depth of 12.0 m.

4. The strength parameters, cohesion (c) and friction angle (ϕ) range from 3 kPa to 9 kPa and 29° to 34°, respectively. The moisture content of the soil ranges from 19% to 21%.

5. The site investigation and liquefaction analysis reveal that there is a very low probability of liquefaction at shallow depth. The LPI value at all two bore holes are zero.

6. On the basis of ultimate bearing capacity and allowable settlement, allowable bearing pressures for shallow foundation have been recommended. The bearing capacity of the footing based on cohesion and friction angle ranges from about 165 kPa -510 kPa. The bearing capacity of footing based on SPT-N value was observed very high as compared to the bearing capacity of the footing based on c and ϕ.

7. Based on field investigation, no ground improvement is required for building construction.

REFERENCES

Bowles, J.E. (1982). Foundation Analysis and Design. McGraw-Hill, New York.

Idriss, I. M., and Boulanger, R. W. (2008). Soil liquefaction during earthquakes. Earthquake Engineering Research Institute, CA.

Iwasaki, T., Tokida, K. I., Tatsuoka, F., Watanabe, S., Yasuda, S., and Sato, H. (1982). Microzonation for soil liquefaction potential using simplified methods. In Proceedings of the 3rd international conference on microzonation, Seattle, 3, 1310-1330.

Japan International Cooperation Agency (JICA), (2002). The study of earthquake disaster mitigation in the Kathmandu Valley, Kingdom of Nepal. Final Report, I-IV.

Meyerhof, G. G. (1956). Penetration tests and bearing capacity of piles, ASCE, Journal of the Soil Mechanics and Foundation Division, 82(1), paper 886, 19 pp.

NBC-105 (2020): National Building Code Nepal: Seismic Design of Building in Nepal (NBC-105).

Schmertmann, J. H. (1979). Statics of SPT. J. Geotech. Engng Diu. Am. Soc. Civ. Engrs, 105, GT5,655-670.

Sharma, K., Deng, L., and Khadka, D. (2019). Reconnaissance of liquefaction case studies in 2015 Gorkha (Nepal) earthquake and assessment of liquefaction susceptibility. International Journal of Geotechnical Engineering, 13(4), 326-338.

Stroud, M.A. and Butler, F.G. (1975). The standard penetration test and the engineering properties of glacial materials. Proceedings of the Symposium on the Engineering Behavior of Glacial Materials, University of Birmingham, England.

Terzaghi, K. (1943). Theoretical soil mechanics. New York: Wiley.

Terzaghi, K. and Peck, R. B. (1967). Soil Mechanics in Engineering Practice, 2nd edn. Wiley International, London, New York, Sydney.

A1: PHOTOGRAPHS

A2: SUMMARY OF RESULTS

Traceable Measurement Pvt. Ltd.

Summary

Bore Hole No.	Sample	Depth (m)	Natural Moisture Content, %	Liquid Limit (LL)	Plastic Limit (LL)	Bulk Density gm/cm^3	Grain Size Distribution, %			Direct Shear Test		Specific Gravity (G_s)	Soil Modulus (Mpa)	LPI	Soil classfication
							Gravel	Sand	Fines (Silt and Clay)	c (kPa)	ϕ (degree)				
BH- 01	SPT	0.0 - 12.0	19.76	NA	NA	-	0.00	94.00	6.00	3.97	29.79	2.52	-	NA	Silty SAND (SM)
BH- 02	SPT	0.0 - 12.0	20.50	NA	NA	-	73-94	0-26	1-6	2.1-8.3	33.23	2.62	-	NA	Poorly Graded GRAVEL (GP)

A3: PILE CAPACITY CALCULATION

Sample calculation for pile load capacity.

Pile Design					
Diameter, Dp	0.9	m			
Length, Lp	8	m			
Perimeter, Pp	2.8274334	m			
Area, Ap	0.6361725				
Unit weight, g_{sat}	18	kN/m^3			
Friction Angle	29.79	Degree			
Cohesion					
Kp	2.9747405		Adhesion factor, α		
Ks	1.4873703		undrained shear strength, Su		
Delta, d	22.3425	Degree			
σ'_v	32.76	kPa			
For cohesionless soil				For cohesive soil	
Skin friction	20.03	kPa		0	kPa
Total friction	**452.98**	**kN**		0	kN
Tip resistance					
Nt	20	Choose Nt based on ϕ value	Nt		
σ'_v	65.52	kPa			

TABLE 18.2 *Range of N_t Factors*

Soil Type	Cast-in-Place Piles	Driven Piles
Silt	10 – 30	20 – 40
Loose sand	20 – 30	30 – 80
Medium sand	30 – 60	50 – 120
Dense sand	50 – 100	100 – 120
Gravel	80 - 150	150 - 300

18.2.1.2(4) Toe Resistance

The ultimate toe resistance may be estimated from:

$$R_t = N_t s_u A_t$$

where

R_t = toe resistance
A_t = cross-sectional area of pile at toe
s_u = minimum undrained shear strength of the clay at pile toe
N_t = a bearing capacity coefficient that is a function of the pile diameter, as follows:

Pile toe diameter	N_t
smaller than 0.5m	9
0.5 m to 1 m	7
larger than 1m	6

Toal tip resistance, Qt	833.64046	kN		0
				0
Pile Capacity, Q	**1286.63**	KN		

A4: PARTICLE SIZE DISTRIBUTION

Project Information

Project Name:	Ghyanglekh Hospital
Project Number:	
Client Name:	Ghyanglekh R. Municipality, Solavanjyang, Sindhuli

Laboratory Information

Lab Name:	Traceable Measurement Pvt. Ltd.
Tested By:	
Reviewed By:	
Test Date:	
Report Date:	

Sample Information

Borehole/Test Pit:	BH-01
Sample #:	
Depth:	0.0 - 12 m
Sample type:	
Sampled by:	

Preparation Method: Oven Dry [x] Air Dry [ ]

Laboratory Comments/Observations

S.N	(mm)	Wt Ret	% Ret	Cum % Ret	% Pass
1	25.4	0.00	0.00	0.00	100.00
2	19.1	0.00	0.00	0.00	100.00
3	16	0.00	0.00	0.00	100.00
4	12.7	0.00	0.00	0.00	100.00
5	9.5	0.00	0.00	0.00	100.00
6	4.75	0.00	0.00	0.00	100.00
7	2.36	0.00	0.00	0.00	100.00
8	1.70	0.00	0.00	0.00	100.00
9	0.8	0.00	0.00	0.00	100.00
10	0.425	0.00	0.00	0.00	100.00
11	0.20	405.40	38.63	38.63	61.37
12	0.15	325.80	31.04	69.67	30.33
13	0.075	260.50	24.82	94.49	5.51
Pan		57.80	5.51	100.00	0.00
Tot Pan		1049.50	100.00		

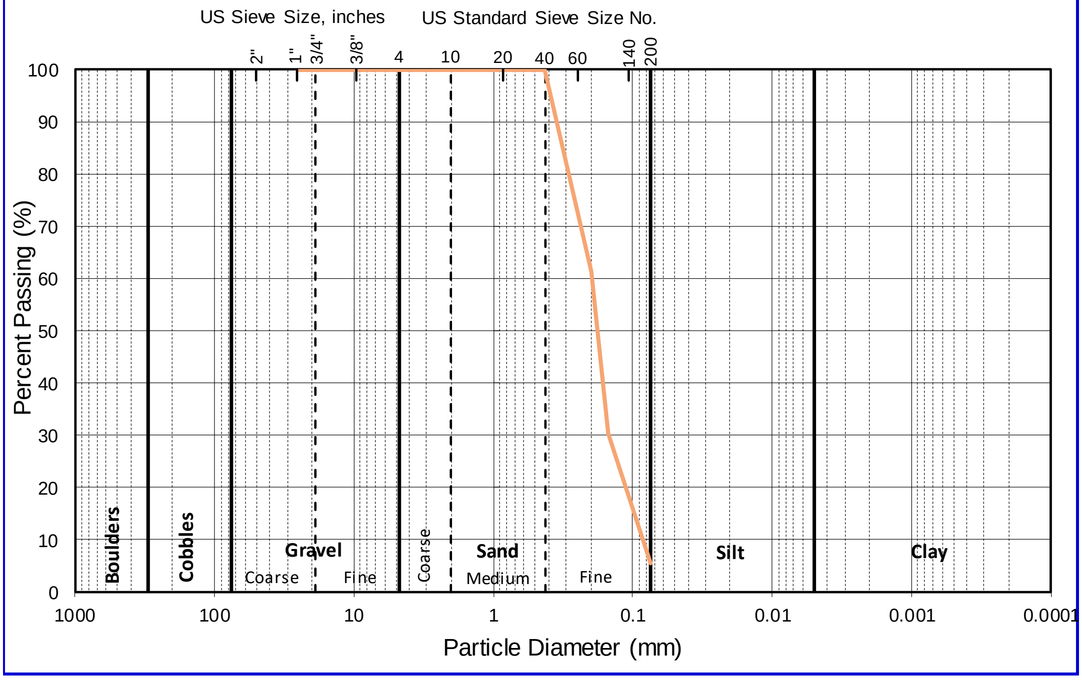
Testing Information

Pan ID	
Mass of moist soil + pan (g)	
Mass of dry soil + pan (g)	
Mass of pan (g)	
Mass of dry soil (g)	1049.50
Mass of washed soil (g)	
Mass loss in wash (g)	

Summary Parameter

Coarser than Gravel%	0
Gravel%	0
Sand%	94
Fines%	6
D60, mm:	0.20
D30, mm:	0.15
D10, mm:	0.09
Cc:	1.32
Cu:	2.32

Classification of Soils as per USCS, ASTM designation D 2487-06
Silty SAND (SM)



Project Information

Project Name:	Ghyanglekh Hospital
Project Number:	
Client Name:	Ghyanglekh R. Municipality, Solavanjyang, Sindhuli

Laboratory Information

Lab Name:	Traceable Measurement Pvt. Ltd.
Tested By:	
Reviewed By:	
Test Date:	
Report Date:	

Sample Information

Borehole/Test Pit:	BH-02
Sample #:	
Depth:	0 - 4.5 m
Sample type:	
Sampled by:	

Preparation Method: Oven Dry [x] Air Dry [ ]

Laboratory Comments/Observations

Testing Information

Pan ID	
Mass of moist soil + pan (g)	
Mass of dry soil + pan (g)	
Mass of pan (g)	
Mass of dry soil (g)	1541.50
Mass of washed soil (g)	
Mass loss in wash (g)	

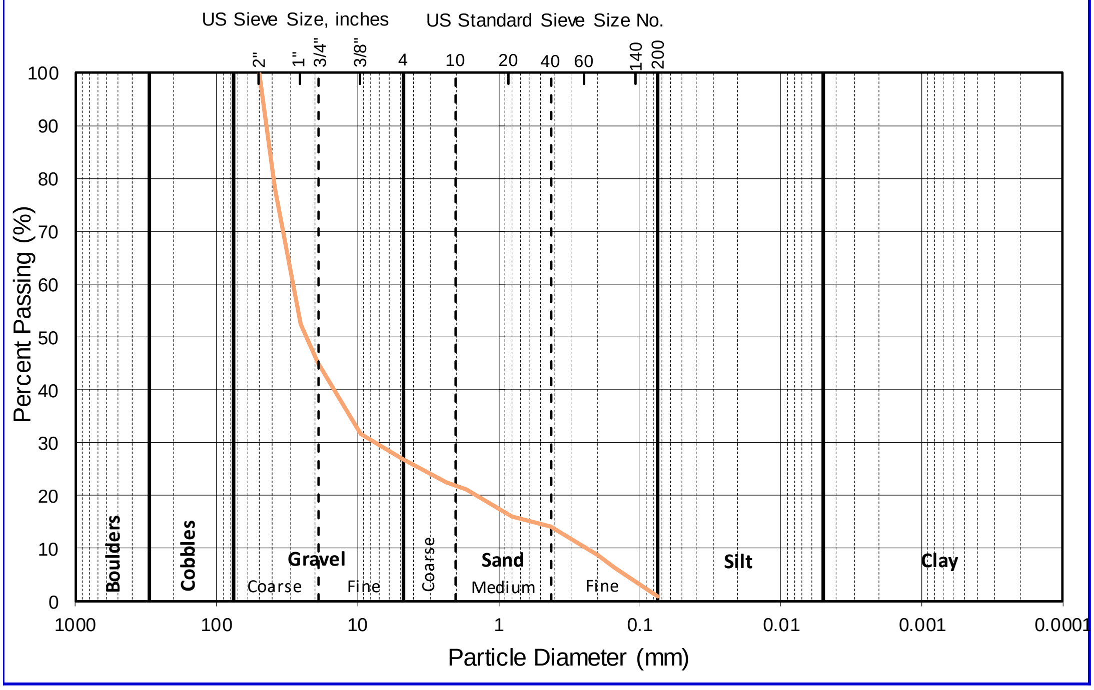
S.N	(mm)	Wt Ret	% Ret	Cum % Ret	% Pass
1	50	0.00	0.00	0.00	100.00
2	38.1	337.60	21.90	21.90	78.10
3	25.4	395.40	25.65	47.55	52.45
4	19.1	111.80	7.25	54.80	45.20
5	9.5	207.70	13.47	68.28	31.72
6	4.75	76.80	4.98	73.26	26.74
7	2.36	65.00	4.22	77.48	22.52
8	1.70	19.50	1.27	78.74	21.26
9	0.8	80.00	5.19	83.93	16.07
10	0.425	29.50	1.91	85.84	14.16
11	0.20	83.00	5.38	91.23	8.77
12	0.15	35.70	2.32	93.55	6.45
13	0.075	83.40	5.41	98.96	1.04
Pan		16.10			
Tot Pan		16.10	1.04	100.00	0.00

Summary Parameter

Coarser than Gravel%	0
Gravel%	73
Sand%	26
Fines%	1
D60, mm:	28.62
D30, mm:	7.33
D10, mm:	0.24
Cc:	7.91
Cu:	120.48

Classification of Soils as per USCS, ASTM designation D 2487-06

Poorly Graded GRAVEL (GP)



Project Information

Project Name:	Training Centre
Project Number:	
Client Name:	Ghiring Rural Municipality-5, Tanahu

Sample Information

Borehole/Test Pit:	BH-02
Sample #:	
Depth:	4.5 - 7.5 m
Sample type:	
Sampled by:	

Laboratory Comments/Observations

Testing Information

Pan ID	
Mass of moist soil + pan (g)	
Mass of dry soil + pan (g)	
Mass of pan (g)	
Mass of dry soil (g)	1334.60
Mass of washed soil (g)	
Mass loss in wash (g)	

Summary Parameter

Coarser than Gravel%	0
Gravel%	83
Sand%	16
Fines%	2
D60, mm:	42.28
D30, mm:	32.55
D10, mm:	0.15
Cc:	166.23
Cu:	280.39

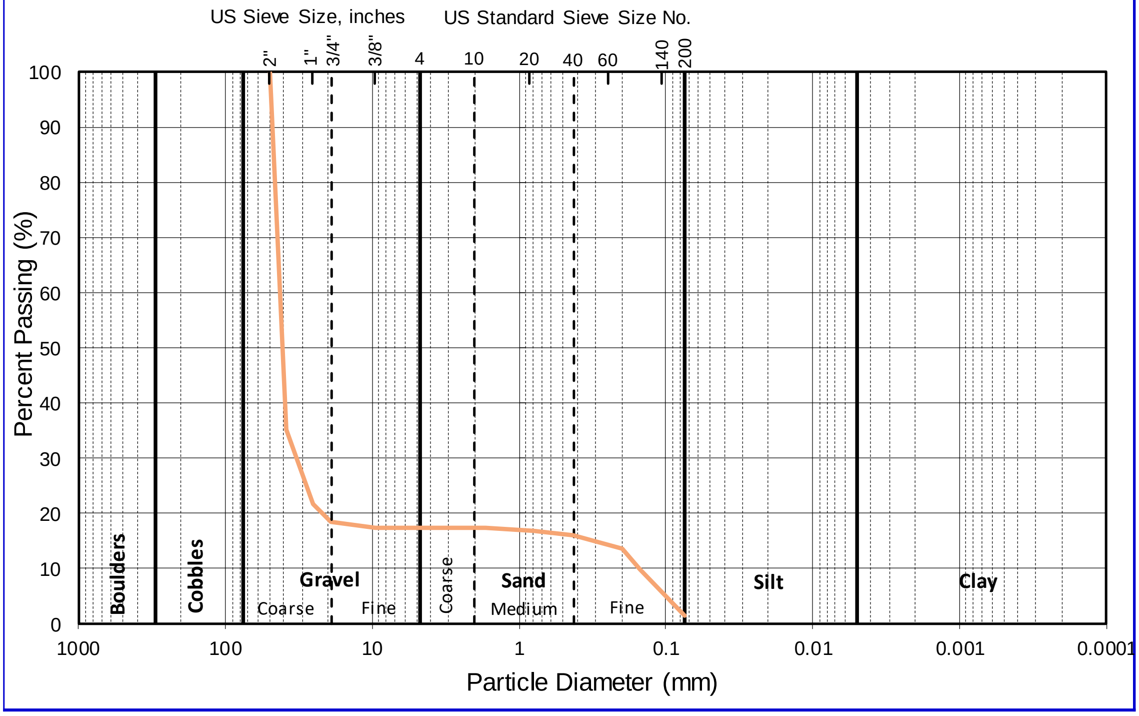
Laboratory Information

Lab Name:	Traceable Measurement Pvt. Ltd.
Tested By:	
Reviewed By:	
Test Date:	
Report Date:	

Preparation Method: Oven Dry [x] Air Dry [ ]

S.N	(mm)	Wt Ret	% Ret	Cum % Ret	% Pass
1	50	0.00	0.00	0.00	100.00
2	38.1	864.60	64.78	64.78	35.22
3	25.4	179.30	13.43	78.22	21.78
4	19.1	43.30	3.24	81.46	18.54
5	9.5	13.90	1.04	82.50	17.50
6	4.75	0.00	0.00	82.50	17.50
7	2.36	1.10	0.08	82.59	17.41
8	1.70	0.60	0.04	82.63	17.37
9	0.8	5.90	0.44	83.07	16.93
10	0.425	11.40	0.85	83.93	16.07
11	0.20	33.60	2.52	86.45	13.55
12	0.15	48.30	3.62	90.06	9.94
13	0.075	112.20	8.41	98.47	1.53
Pan		20.40			
Tot Pan		20.40	1.53	100.00	0.00

Classification of Soils as per USCS, ASTM designation D 2487-06
Poorly Graded GRAVEL (GP)



Project Information

Project Name:	Training Centre
Project Number:	
Client Name:	Ghiring Rural Municipality-5, Tanahu

Sample Information

Borehole/Test Pit:	BH-02
Sample #:	
Depth:	7.5 -9.0 m
Sample type:	
Sampled by:	

Laboratory Comments/Observations

Testing Information

Pan ID	
Mass of moist soil + pan (g)	
Mass of dry soil + pan (g)	
Mass of pan (g)	
Mass of dry soil (g)	992.70
Mass of washed soil (g)	
Mass loss in wash (g)	

Summary Parameter

Coarser than Gravel%	0
Gravel%	94
Sand%	0
Fines%	6
D60, mm:	43.20
D30, mm:	38.71
D10, mm:	21.20
Cc:	1.64
Cu:	2.04

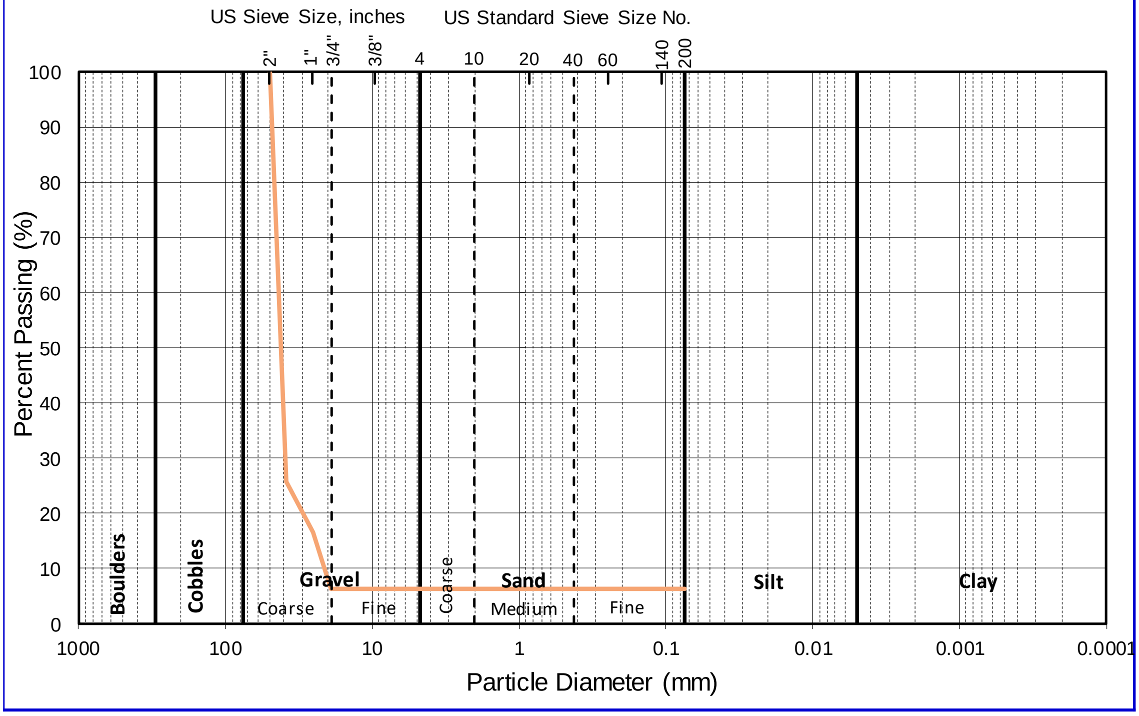
Laboratory Information

Lab Name:	Traceable Measurement Pvt. Ltd.
Tested By:	
Reviewed By:	
Test Date:	
Report Date:	

Preparation Method: Oven Dry [x] Air Dry [ ]

S.N	(mm)	Wt Ret	% Ret	Cum % Ret	% Pass
1	50	0.00	0.00	0.00	100.00
2	38.1	738.30	74.37	74.37	25.63
3	25.4	90.10	9.08	83.45	16.55
4	19.1	102.60	10.34	93.78	6.22
5	9.5	0.00	0.00	93.78	6.22
6	4.75	0.00	0.00	93.78	6.22
7	2.36	0.00	0.00	93.78	6.22
8	1.70	0.00	0.00	93.78	6.22
9	0.8	0.00	0.00	93.78	6.22
10	0.425	0.00	0.00	93.78	6.22
11	0.20	0.00	0.00	93.78	6.22
12	0.15	0.00	0.00	93.78	6.22
13	0.075	0.00	0.00	93.78	6.22
Pan		61.70			
Tot Pan		61.70	6.22	100.00	0.00

Classification of Soils as per USCS, ASTM designation D 2487-06
Poorly Graded GRAVEL (GP)



Project Information

Project Name:	Training Centre
Project Number:	
Client Name:	Ghiring Rural Municipality-5, Tanahu

Laboratory Information

Lab Name:	Traceable Measurement Pvt. Ltd.
Tested By:	
Reviewed By:	
Test Date:	
Report Date:	

Sample Information

Borehole/Test Pit:	BH-02
Sample #:	
Depth:	7.5 -9.0 m
Sample type:	
Sampled by:	

Preparation Method: Oven Dry [x] Air Dry [ ]

Laboratory Comments/Observations

Testing Information

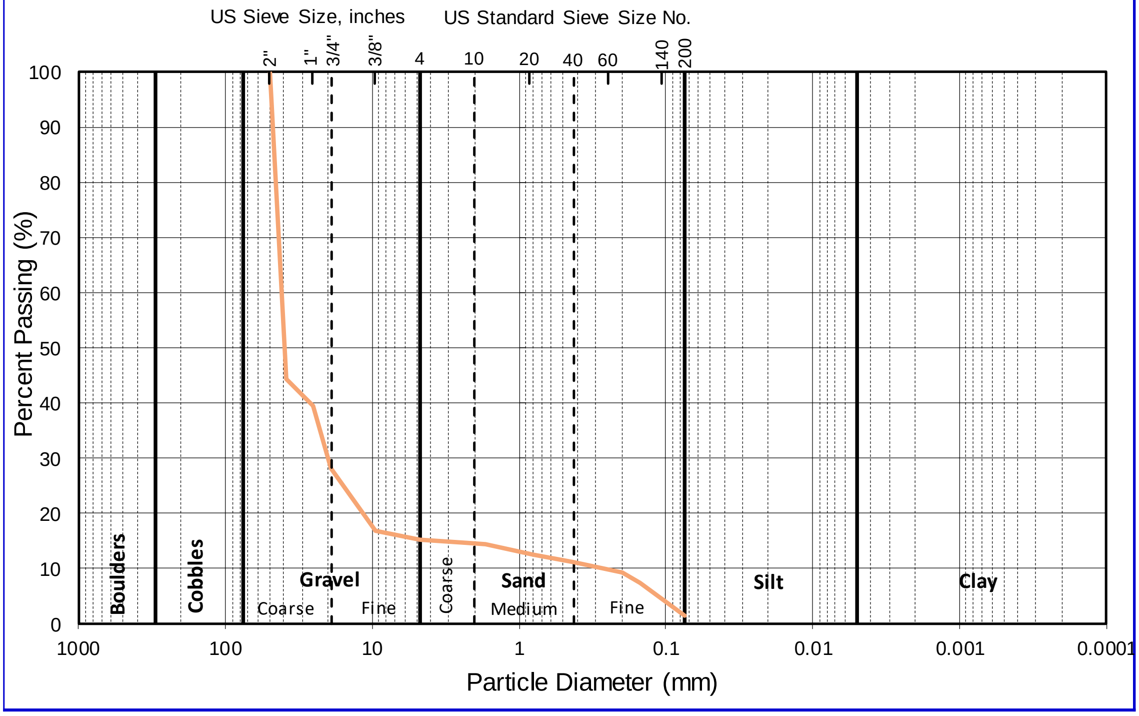
Pan ID	
Mass of moist soil + pan (g)	
Mass of dry soil + pan (g)	
Mass of pan (g)	
Mass of dry soil (g)	1357.40
Mass of washed soil (g)	
Mass loss in wash (g)	

S.N	(mm)	Wt Ret	% Ret	Cum % Ret	% Pass
1	50	0.00	0.00	0.00	100.00
2	38.1	755.80	55.68	55.68	44.32
3	25.4	64.40	4.74	60.42	39.58
4	19.1	154.20	11.36	71.78	28.22
5	9.5	153.80	11.33	83.11	16.89
6	4.75	21.40	1.58	84.69	15.31
7	2.36	9.70	0.71	85.41	14.59
8	1.70	3.00	0.22	85.63	14.37
9	0.8	25.10	1.85	87.48	12.52
10	0.425	17.30	1.27	88.75	11.25
11	0.20	26.80	1.97	90.72	9.28
12	0.15	24.70	1.82	92.54	7.46
13	0.075	82.20	6.06	98.60	1.40
Pan		19.00			
Tot Pan		19.00	1.40	100.00	0.00

Summary Parameter

Coarser than Gravel%	0
Gravel%	85
Sand%	13
Fines%	1
D60, mm:	41.13
D30, mm:	19.97
D10, mm:	0.26
Cc:	36.78
Cu:	155.93

Classification of Soils as per USCS, ASTM designation D 2487-06
Poorly Graded GRAVEL (GP)



A5: NATURAL MOISTURE CONTENT

Determination of Moisture Content

Date-2077-11-24
Project Name: Hospital Building
Location: Ghyanglekh Rural Municipality, Solavanjyang, Sindhuli
Client:
Borehole No.: BH-01
Borehole Depth: 0.0 - 12.0 m
Description if any:

S. No	Description	Sample No			Remarks
		I	II	III	
1	Container No	76	111	63	
2	Mass of Container, M_c (g)	13	12.7	12.9	
3	Mass of Container + Wet Soil, M_{cws} (g)	53.4	58.4	46.5	
4	Mass of Container + Dry Soil, M_{cds} (g)	46.8	51	40.8	
5	Mass of water, M_w=(M_{cws}-M_{cds}) (g)	6.6	7.4	5.7	
6	Mass of solid particle, M_s=(M_{cds}-M_c) (g)	33.8	38.3	27.9	
7	Water Content (w) = M_w/M_s*100%	19.53	19.32	20.43	
Average Water content %		**19.76**			

Borehole No.: BH-02
Borehole Depth: 0-4.5 m
Description if any:

S. No	Description	Sample No			Remarks
		I	II	III	
1	Container No	22	59	101	
2	Mass of Container, M_c (g)	13	12	11.9	
3	Mass of Container + Wet Soil, M_{cws} (g)	72	70.3	64.1	
4	Mass of Container + Dry Soil, M_{cds} (g)	63.2	61.2	55.7	
5	Mass of water, M_w=(M_{cws}-M_{cds}) (g)	8.8	9.1	8.4	
6	Mass of solid particle, M_s=(M_{cds}-M_c) (g)	50.2	49.2	43.8	
7	Water Content (w) = M_w/M_s*100%	17.53	18.50	19.18	
Average Water content %		**18.40**			

Borehole No.: BH-02
Borehole Depth: 4.5 - 7.5 m
Description if any:

S. No	Description	Sample No			Remarks
		I	II	III	
1	Container No	14	17	16	
2	Mass of Container, M_c (g)	13.4	17.7	17.2	
3	Mass of Container + Wet Soil, M_{cws} (g)	36.8	41	50.6	
4	Mass of Container + Dry Soil, M_{cds} (g)	32.8	37	45	
5	Mass of water, M_w=(M_{cws}-M_{cds}) (g)	4	4	5.6	
6	Mass of solid particle, M_s=(M_{cds}-M_c) (g)	19.4	19.3	27.8	
7	Water Content (w) = M_w/M_s*100%	20.62	20.73	20.14	
Average Water content %		**20.50**			

Borehole No.: BH-02
Borehole Depth: 9.0 -12m
Description if any:

S. No	Description	Sample No			Remarks
		I	II	III	
1	Container No	25	44	38	
2	Mass of Container, M_c (g)	11.6	12.8	11.6	
3	Mass of Container + Wet Soil, M_{cws} (g)	39.5	33.8	38.9	
4	Mass of Container + Dry Soil, M_{cds} (g)	35	30.3	34.5	
5	Mass of water, M_w=(M_{cws}-M_{cds}) (g)	4.5	3.5	4.4	
6	Mass of solid particle, M_s=(M_{cds}-M_c) (g)	23.4	17.5	22.9	
7	Water Content (w) = M_w/M_s*100%	19.23	20.00	19.21	
Average Water content %		**19.48**			

A6: SPECIFIC GRAVITY

Determination Of Specific Gravity of Soil

Date: 2077/06/28
Project Name: Hospital Building
Location: Ghyanglekh Rural Municipality, Solavanjyang, Sindhuli
Client:

Bore Hole No: BH-01
Bore hole Depth: 0.0 - 12 m
Description if any:

SN	Description	Sample No.			Remarks
		I	II	III	
1	Wt. of Pycnometer (gm)=A	77.4	78.2	76	
2	Wt. of Pycnometer + Dry smple= B	92.5	93.3	91.1	
3	Wt. of Pycnometer + Dry smple + water = C	197.1	197.8	195.3	
4	Wt. of Pycnometer + Water = D	188	188.5	186.4	
5	Specific Gravity = (B-A)/((D-A)-(C-B))	2.52	2.60	2.44	
6	Average Value	**2.52**			

Bore Hole No: BH-02
Bore hole Depth: 0-4.5 m
Description if any:

SN	Description	Sample No.			Remarks
		I	II	III	
1	Wt. of Pycnometer (gm)=A	77.6	78.5	76	
2	Wt. of Pycnometer + Dry smple= B	92.7	93.3	90.8	
3	Wt. of Pycnometer + Dry smple + water = C	197.1	197.6	195.5	
4	Wt. of Pycnometer + Water = D	187.6	188.4	186.3	
5	Specific Gravity = (B-A)/((D-A)-(C-B))	2.70	2.64	2.64	
6	Average Value	**2.66**			

Bore hole no.: BH-02
Bore hole Depth: 4.5m -7.5 m
Description if any:

SN	Description	Sample No.			Remarks
		I	II	III	
1	Wt. of Pycnometer (gm)=A	77.6	78.4	76	
2	Wt. of Pycnometer + Dry smple= B	92.7	93.5	91	
3	Wt. of Pycnometer + Dry smple + water = C	195.8	197.7	195.6	
4	Wt. of Pycnometer + Water = D	187.9	188.2	186.3	
5	Specific Gravity = (B-A)/((D-A)-(C-B))	2.10	2.70	2.63	
6	Average Value	**2.48**			

Bore Hole No: BH-02
Bore hole Depth: 7.5-9.0 m
Description if any:

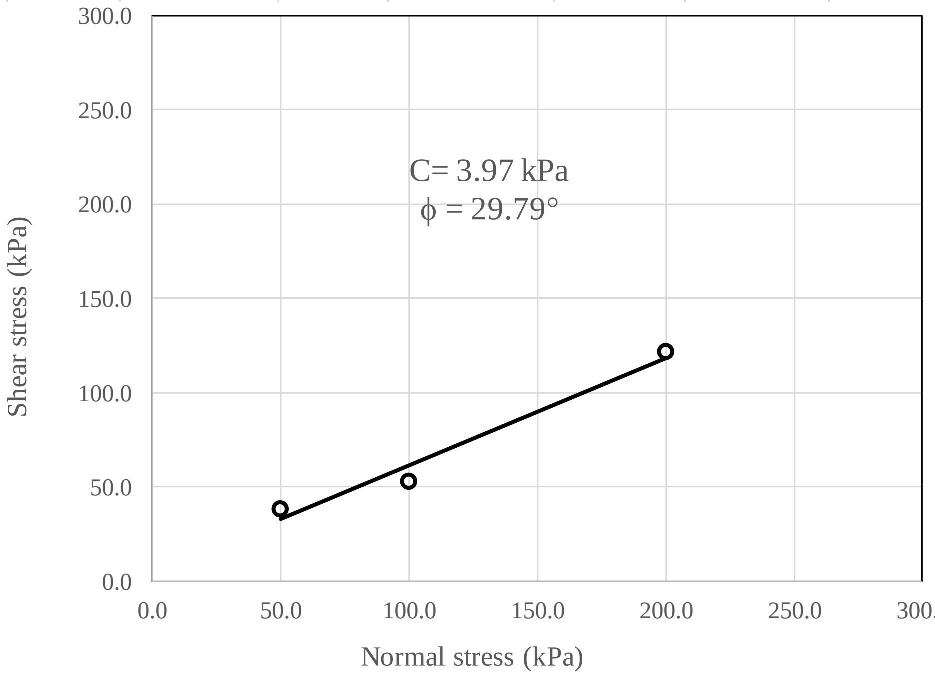
SN	Description	Sample No.			Remarks
		I	II	III	
1	Wt. of Pycnometer (gm)=A	77.6	78.5	76	
2	Wt. of Pycnometer + Dry smple= B	92.6	93.6	90.9	
3	Wt. of Pycnometer + Dry smple + water = C	197.2	198	195.6	
4	Wt. of Pycnometer + Water = D	188.1	188.2	186.3	
5	Specific Gravity = (B-A)/((D-A)-(C-B))	2.54	2.85	2.66	
6	Average Value	**2.68**			

Bore hole no.: BH-02
Bore hole Depth: 9-12.0m
Description if any:

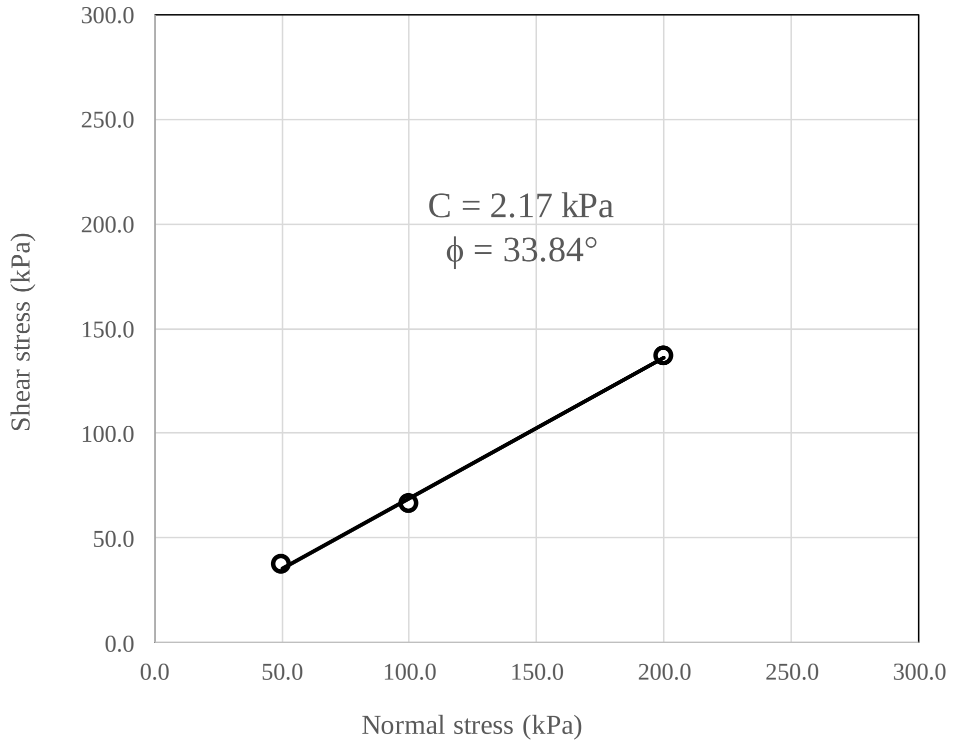
SN	Description	Sample No.			Remarks
		I	II	III	
1	Wt. of Pycnometer (gm)=A	77.7	78.6	75.9	
2	Wt. of Pycnometer + Dry smple= B	92.7	93.5	90	
3	Wt. of Pycnometer + Dry smple + water = C	197.2	197.7	195.4	
4	Wt. of Pycnometer + Water = D	188	188.5	186.4	
5	Specific Gravity = (B-A)/((D-A)-(C-B))	2.59	2.61	2.76	
6	Average Value	**2.65**			

A7: DIRECT SHEAR TEST

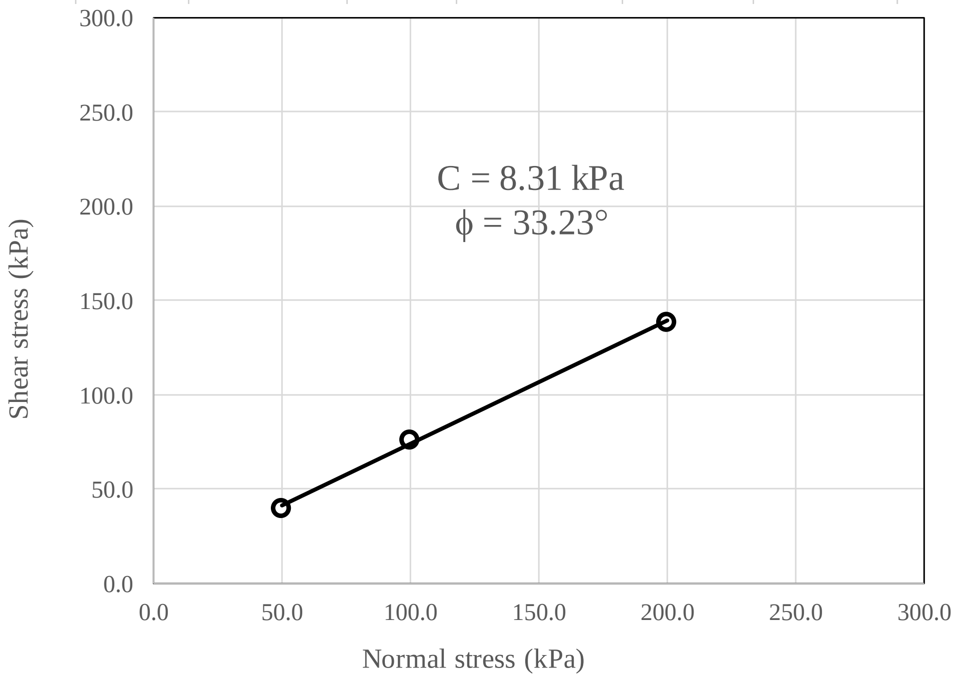
Direct Shear Test							
Project Name: Hospital Building							
Client:					Location	Ghyanglekh Rural Municipality, Solavanjyang, Sindhuli	
Bore Hole No: BH01					PRG factor	0.0026	
Bore Hole Depth: 0 - 12.0 m					Area	0.0036	
Hz Dial Gauge reading (x 0.01mm)	Normal Stress (50kN/m^2)		Normal Stress (100 kN/m^2)		Normal Stress (200 kN/m^2)		Remarks
	Load Ring Dial	Shear Stress (KN/m^2)	Load Ring Dial	Shear Stress(KN/m^2)	Load Ring Dial	Shear Stress (KN/m^2)	
0	0	0.00	0	0.00	0	0.00	
25	22	15.89	35	25.28	75	54.17	
50	27	19.50	47	33.94	90	65.00	
75	30	21.67	57	41.17	110	79.44	
100	32	23.11	58	41.89	125	90.28	
125	34	24.56	61	44.06	140	101.11	
150	35	25.28	62	44.78	146	105.44	
175	37	26.72	65	46.94	152	109.78	
200	38	27.44	65	46.94	155	111.94	
250	43	31.06	67	48.39	160	115.56	
300	46	33.22	70	50.56	164	118.44	
350	48	34.67	71	51.28	166	119.89	
400	50	36.11	73	52.72	167	120.61	
450	53	38.28	73	52.72	168	121.33	
500	55	39.72			170	122.78	
550	56	40.44			173	124.94	
600	56	40.44			174	125.67	
650					174	125.67	

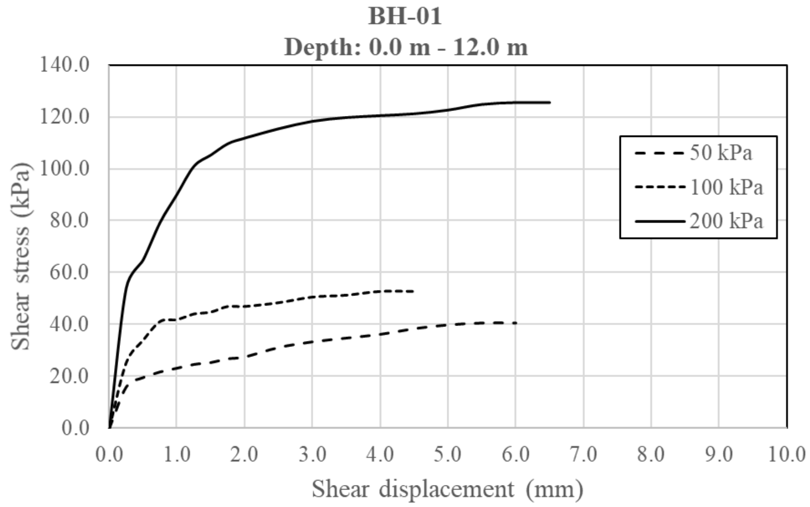


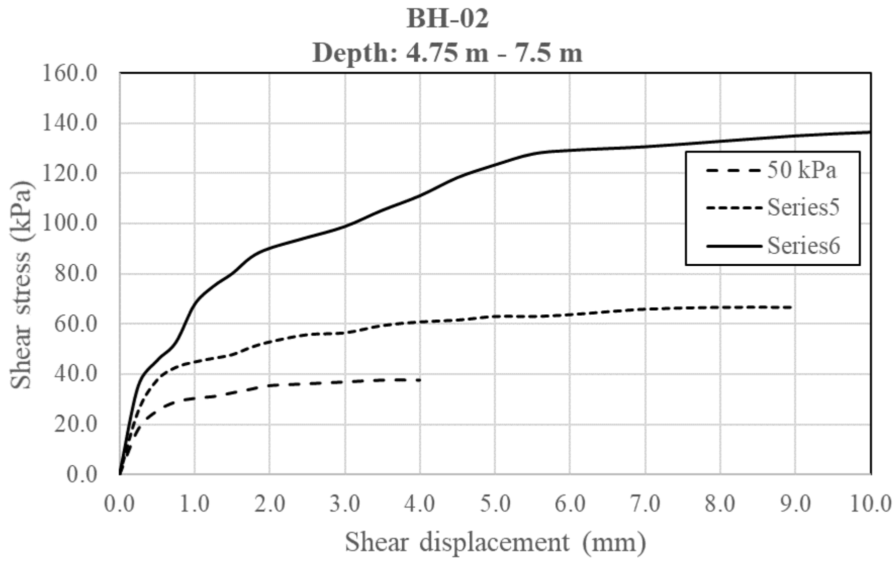
Direct Shear Test							
Project Name: Hospital Building							
Client:					Location	Ghyanglekh Rural Municipality, Solavanjyang, Sindhuli	
Bore hole no: BH-02					PRG factor	0.0026	
Bore hole Depth: 4.75m - 7.5m					Area	0.0036	
Hz Dial Gauge reading(x 0.01mm)	Normal Stress (50kN/m²)		Normal Stress (100 kN/m²)		Normal Stress (200kN/m²)		Remarks
	Load Ring Dial	Shear Stress (KN/m²)	Load Ring Dial	Shear Stress (KN/m²)	Load Ring Dial	Shear Stress (KN/m²)	
0	0	0.00	0	0.00	0	0.00	
25	25	18.06	35	25.28	49	35.39	
50	35	25.28	52	37.56	63	45.50	
75	40	28.89	59	42.61	73	52.72	
100	42	30.33	62	44.78	94	67.89	
125	43	31.06	64	46.22	104	75.11	
150	45	32.50	66	47.67	111	80.17	
175	47	33.94	70	50.56	120	86.67	
200	49	35.39	73	52.72	125	90.28	
250	50	36.11	77	55.61	131	94.61	
300	51	36.83	78	56.33	137	98.94	
350	52	37.56	82	59.22	146	105.44	
400	52	37.56	84	60.67	154	111.22	
450			85	61.39	164	118.44	
500			87	62.83	171	123.50	
550			87	62.83	177	127.83	
600			88	63.56	179	129.28	
700			91	65.72	181	130.72	
800			92	66.44	184	132.89	
900			92	66.44	187	135.06	
1000					189	136.50	
1100					190	137.22	
1200					190	137.22	

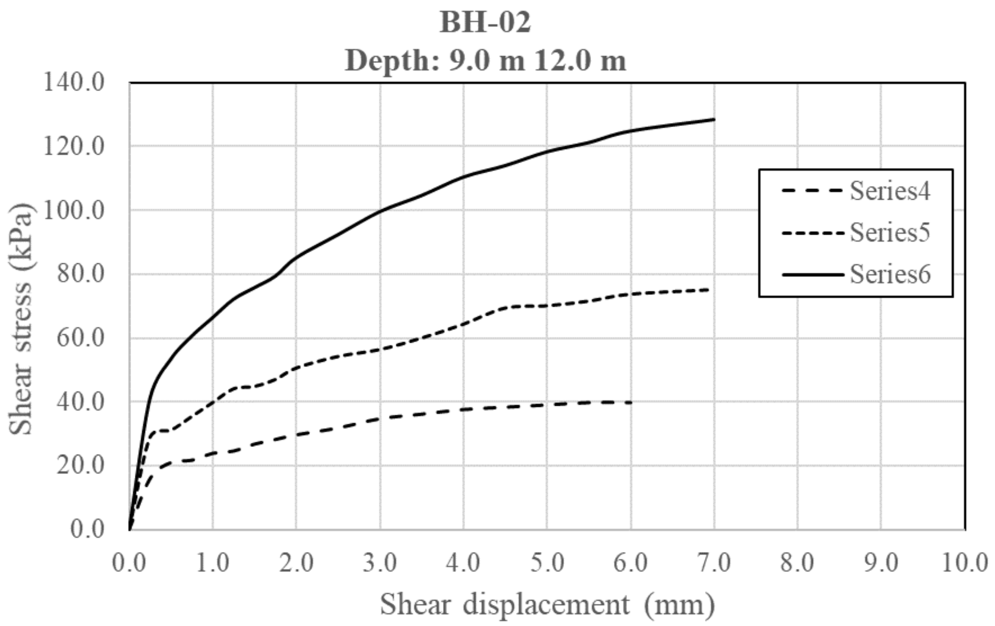


Direct Shear Test							
Project Name: Hospital Building							
Client:					Location	Ghyanglekh Rural Municipality, Solavar	
Bore hole no: BH-02					PRG factor	0.0026	
Bore hole Depth: 9.0 - 12.0 m					Area	0.0036	
Hz Dial Gauge reading(x 0.01mm)	Normal Stress (50kN/m^2)		Normal Stress (100 kN/m^2)		Normal Stress (200 kN/m^2)		Remarks
	Load Ring Dial	Shear Stress (KN/m^2)	Load Ring Dial	Shear Stress(KN/m^2)	Load Ring Dial	Shear Stress (KN/m^2)	
0	0	0.00	0	0.00	0	0.00	
25	22	15.89	40	28.89	57	41.17	
50	29	20.94	43	31.06	74	53.44	
75	30	21.67	49	35.39	84	60.67	
100	33	23.83	55	39.72	92	66.44	
125	34	24.56	61	44.06	100	72.22	
150	37	26.72	62	44.78	105	75.83	
175	39	28.17	65	46.94	110	79.44	
200	41	29.61	70	50.56	118	85.22	
250	44	31.78	75	54.17	128	92.44	
300	48	34.67	78	56.33	138	99.67	
350	50	36.11	83	59.94	145	104.72	
400	52	37.56	89	64.28	153	110.50	
450	53	38.28	96	69.33	158	114.11	
500	54	39.00	97	70.06	164	118.44	
550	55	39.72	99	71.50	168	121.33	
600	55	39.72	102	73.67	173	124.94	
700			104	75.11	178	128.56	
800			105	75.83	183	132.17	
900			105	75.83	186	134.33	
1000					190	137.22	
1100					191	137.94	
1200					192	138.67	
1300					192	138.67	




BH-01
Depth: 0.0 m - 12.0 m
Shear stress (kPa)
Shear displacement (mm)
50 kPa
100 kPa
200 kPa
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0


BH-02
Depth: 4.75 m - 7.5 m
Shear stress (kPa)
Shear displacement (mm)
50 kPa
Series5
Series6
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0


BH-02
Depth: 9.0 m 12.0 m
Shear stress (kPa)
Shear displacement (mm)
Series4
Series5
Series6
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0

A8: SETTLEMENT CALCULATION

Calculation of footing Settlment

Calculation of settlement

Total settlement given by $\delta_t = \delta_d + \psi \cdot \delta_c$ (Skempton and Bjerrum, 1957)

δ_t = Total settlement

δ_d = Distortion settlement

ψ = Three dimensional adjustment factor

δ_c = Consolidation settlement

Distortion settlement by elastic theory

$$\delta_d = \frac{(q - \sigma'_{zD}) \cdot B \cdot I_1 \cdot I_2}{E_u}$$

Length of footing, L	2	m	
Width of footing, B	2	m	
Unit weight of soil, g	19		
Bearing pressure	165	Kpa	
Depth for sett.	2		
σ'_v	38		
Influences Factor			
I1	0.5		
I2	0.5		
Young's modulus	10000	Mpa	
Distortion settlement	6.35	mm	**<25 mm okay**

Conslidation Settlement

$$\delta_c := av \cdot H_s \cdot \log\left(\frac{\Delta\sigma'_V + \sigma'_V}{\sigma'_V}\right) =$$

$$\frac{C_c}{1 + e_0} = av$$

Cc	-	
e0	-	
Hs		
σ'_v		
$\Delta\sigma'_v$		
Cons. Settlement	0	for sand
Total settlment	6.4	mm

A9: BORE HOLE LOG SHEET

Traceable Measurements Pvt. Ltd.

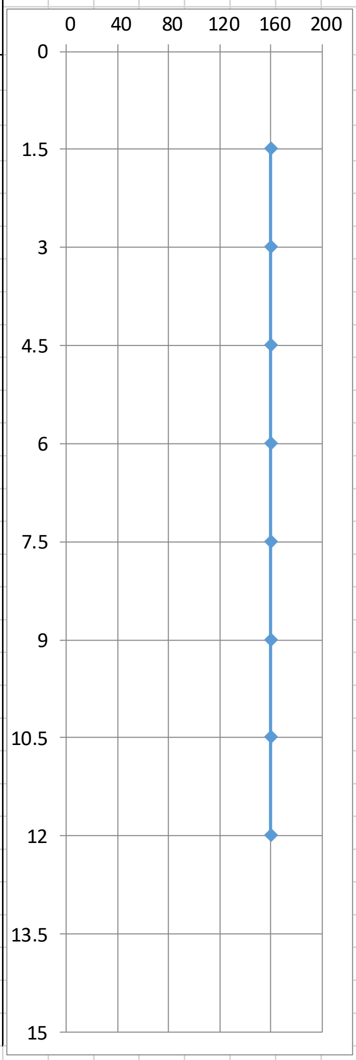
Drilling Log

Project: Ghylanglekh Hospital, Sindhuli
Location: Solavanjyang, Sindhul
Client:
Date: 2021-03-03
Borehole No: **BH-01**

Ground water: m

Soil Description	Symbol	Depth, m	Sample No. &Type	Water return (%)	No. of blows 10/15 cm	No. of blows 10/15 cm	No. of blows 10/15 cm	Nc-Value	N-Value
		- 1		-					
Fine Sand		- 2	SPT	-	6	80	80	166	160
Fine Sand		- 3 - 4	SPT	-	80	80	80	240	160
Fine Sand		- 5	SPT	-	80	80	80	240	160
Fine Sand		- 6 - 7	SPT	-	80	80	80	240	160
Fine Sand		- 8	SPT	-	80	80	80	240	160
Fine Sand		- 9 - 10	SPT	-	80	80	80	240	160
Fine Sand		- 11	SPT	-	80	80	80	240	160
Fine Sand		- 12 - 13	SPT	-	80	80	80	240	160
				-	80	80	80	240	160

N-Value SPT DCPT



End Depth	*** Completed at 15.00m**			**Ground: Dry**		
Types of Soil		**N Value**				
Granular Soil	Compactness	**0 to 4**	**4 to 10**	**10 to 30**	**30 to 50**	**> 50**
		Very Loose	Loose	Med. Dense	Dense	Very Dense
Cohesive Soil	Consistency	**0 to 2**	**2 to 4**	**4 to 8**	**8 to 16**	**16 to 32**	**> 32**
		Very Soft	Soft	Med. Soft	Stiff	Very Stiff	Hard

Traceable Measurements Pvt. Ltd.

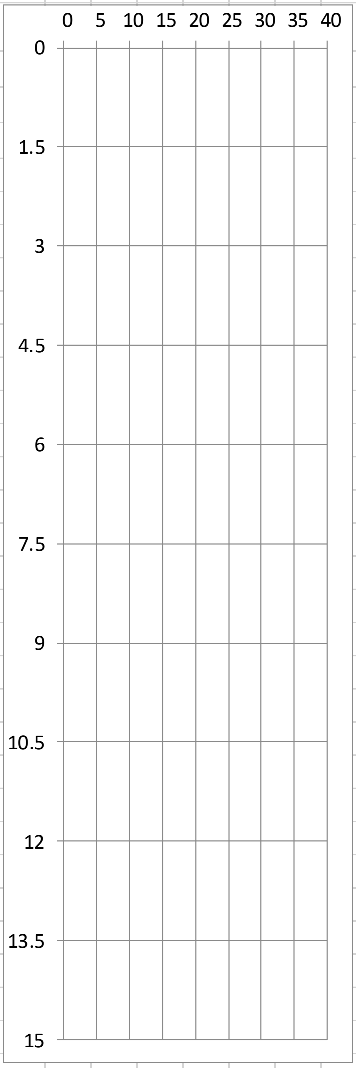
Drilling Log

Project:	Ghylanglekh Hospital, Sindhuli
Location:	Solavanjyang, Sindhul
Client:	
Date:	2021-03-04
Borehole No:	**BH-02**

Ground water: m

Soil Description	Symbol	Depth, m	Sample No. &Type		Water return (%)	No. of blows 10/15 cm	10/15 cm	10/15 cm	Nc-Value	N-Value
		- 1								
Gravel		- 2		SPT	-					
Gravel		- 3, - 4		SPT	-					
Gravel		- 5		SPT	-					
Gravel		- 6, - 7		SPT	-					
Gravel		- 8		SPT	-					
Gravel		- 9, - 10		SPT	-					
Gravel		- 11		SPT	-					
Gravel		- 12, - 13		SPT	-					

N-Value: SPT, DCPT



End Depth *** Completed at 15.00m** **Ground: Dry**

Types of Soil		**N Value**					
Granular Soil	Compactness	**0 to 4**	**4 to 10**	**10 to 30**	**30 to 50**	**> 50**	
		Very Loose	Loose	Med. Dense	Dense	Very Dense	
Cohesive Soil	Consistency	**0 to 2**	**2 to 4**	**4 to 8**	**8 to 16**	**16 to 32**	**> 32**
		Very Soft	Soft	Med. Soft	Stiff	Very Stiff	Hard