Procurement of Plant Design, Supply, Delivery, Installation, Testing and Commissioning of
Lot 1: Lapsiphedi-Ratmate-New Hetauda 400kV D/C Transmission Line
Lot 2: Ratmate-New Damauli 400kV D/C Transmission Line
Lot 3: New Damauli-New Butwal 400kV D/C Transmission Line (Base) And New Butwal -Nepal/India Border 400kV D/C Transmission Line (Option)

ADDENDUM #9

Issued on: 13 April 2023

This Addendum No. 9 modifies respective portions of the Bidding Document issued on 28 November 2022 and amended through Addendum No. 1 on 4 January 2023, Addendum No. 2 on 14 February 2023, Addendum No. 3 on 27 February 2023, Addendum No. 4 on 3 March 2023, Addendum No. 5 on 15 March 2023, Addendum No. 6 on 30 March 2023, Addendum No. 7 on 30 March 2023 and Addendum #8 on 10 April 2023. The changes, as indicated below, are effective on the date of issue of this Addendum.

Except as expressly amended by this Addendum, all other terms and conditions of the Bidding Document - issued on 28 November 2022 and amended through Addendum No. 1 on 4 January 2023, Addendum No. 2 on 14 February 2023, Addendum No. 3 on 27 February 2023, Addendum No. 4 on 3 March 2023, Addendum No. 5 on 15 March 2023, Addendum No. 6 on 30 March 2023, Addendum No. 7 on 30 March 2023 and Addendum #8 on 10 April 2023, remains unchanged and shall remain in full force and effect in accordance with their terms.

SN	Pages/Paragraph	Amendments
1	Part 2, B1, Annex_B1, 8. Annex F_Supporting Reports_Final Design Report-2019-11-08	**Add a new Annex "Annex F Appendix 3A - FINALR-3"** Geotechnical Investigation Report for the remaining 30km portion of Transmission Line (in different segments) as Attachment A of this Addendum 8.

ATTACHMENT A

Annex F Appendix 3A – Final R-3

Geotechnical Investigation report for the remaining 30km portion of the Transmission Line (in different segments)

Geotechnical Investigation report for remaining 30km portion of Transmission Line (in different segments)	01 MCA-N_Soil Report_Changed Port

Consulting Services for Detailed Survey and updated Line Design for 30 km of changes in 400kV Transmission Line Route Alignment

Geotechnical Investigation Report

Client: Millennium Challenger Account Nepal (MCA-N)

Consultant: Power Grid Corporation of India Ltd. (India)

and

Jade Consult Pvt. Ltd. (Nepal)

(sub-consultant)

March, 2023

Millennium Challenger Account Nepal

(MCA-N)

Geotechnical Investigation Report

Consulting Services for Detailed Survey and updated Line Design for 30 km of changes in 400kV Transmission Line Route Alignment

March, 2023

Power Grid Corporation of India Ltd. (India)

and

Jade Consult Pvt. Ltd. (Nepal)

(sub-consultant)

Date	Originator	Checker	Approver	Revision
15th Feb 2023	MR and YA	GST	PVG	R0
24th Feb 2023	MR and YA	GST	PVG	R1
14th March 2023	MR and YA	GST	PVG	R2
31st March 2023	MR and YA	GST	PVG	R3

Geotechnical Engineer, Traceable Measurements
MSc. Virginia Tech

Geotechnical Engineer, Jade Consult
MSc. NCU

LIST OF ABBREVIATIONS

AASHTO	:	American Association of State Highway Transportation Officials
ASTM	:	American Society for Testing and Materials
BS	:	British Standard
MW	:	Megawatt
DCPT	:	Dynamic Cone Penetration Test
GoN	:	Government of Nepal
IS	:	Indian Standard
MBT	:	Main Boundary Thrust
MCT	:	Main Central Thrust
OMC	:	Optimum Moisture Content
POWERGRID	:	Power Grid Corporation of India Limited
JADE	:	Jade Consult Private Limited
RMR	:	Rock Mass Rating
SPT	:	Standard Penetration Test
MCA-N	:	Millennium Challenger Account Nepal

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F : Laboratory Data and Detail Analysis of Ratamate-New Hetauda 400 kV D/C TL (T140N)

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H : Laboratory Data and Detail Analysis of New Butwal-New Damauli 400 kV D/C TL (TW198)

1 General Introduction

1.1 Background

This geotechnical report is prepared for all selected Points TW-198 (Tanahu), T238N (Nuwakot), T240N (Nuwakot), T140N (Makwanpur), T138N (Makwanpur), T17/1N (Parasi). All the field investigation works performed for the preparation of this report has been carried out with generally accepted and practiced method in geotechnical engineering.

After the agreement, the geotechnical exploration was carried out as per Terms of Reference (TOR) on the respective location of Tanahu, Nuwakot, Makwanpur and Parasi districts. The geotechnical exploration for this project includes, rotary drilling with SPT and DCPT up to approved depth and collection of undisturbed soil samples for various laboratory tests and analysis. This geotechnical report presents the finding of the geotechnical exploration, results of the lab test, regional geology of the site, bearing capacity evaluation, and settlement and liquefaction assessment based on SPT. The depth of the borings in all the location point is 12 meters.

This report contains all the findings of the geotechnical exploration, result of the lab test conducted on the thus obtained soil samples, data interpretations of the lab test result and findings of the soil exploration, and recommendations for the foundation design. Our analysis and opinions are based upon our understanding of the project, the geotechnical conditions in the area, and the data obtained from our site exploration. Natural variations will occur between exploration point locations or due to the modifying effects of construction and weather. The nature of such variations may not become evident until during or after construction. Additionally, this report must be read in its entirety. Individual sections of this report may misguide the reader to draw correct conclusions if considered in isolation from each other. Six locations were proposed for sub-soil investigation program at four districts of Nepal.

1.2 Objectives

The main objective of this report is to present the subsurface information, which will be used in the detailed design of the Civil and Electrical Structures of critical tower locations. The major objectives of this exploration are listed below:

- To conduct rotary drilling with Standard Penetration Test (SPT) or Dynamic Cone Penetration Test (DCPT) to the depth of 12 m.
- Collect the samples required as per the IS or ASTM code to conduct the soil lab test.
- Assess the suitability of the site for the project and provide geotechnical properties of the soil for foundation design as per the drilling information and results of the soil lab test.
- Recommend bearing capacity and design parameters, which will be required during design of foundation types for Civil and Electrical structures.

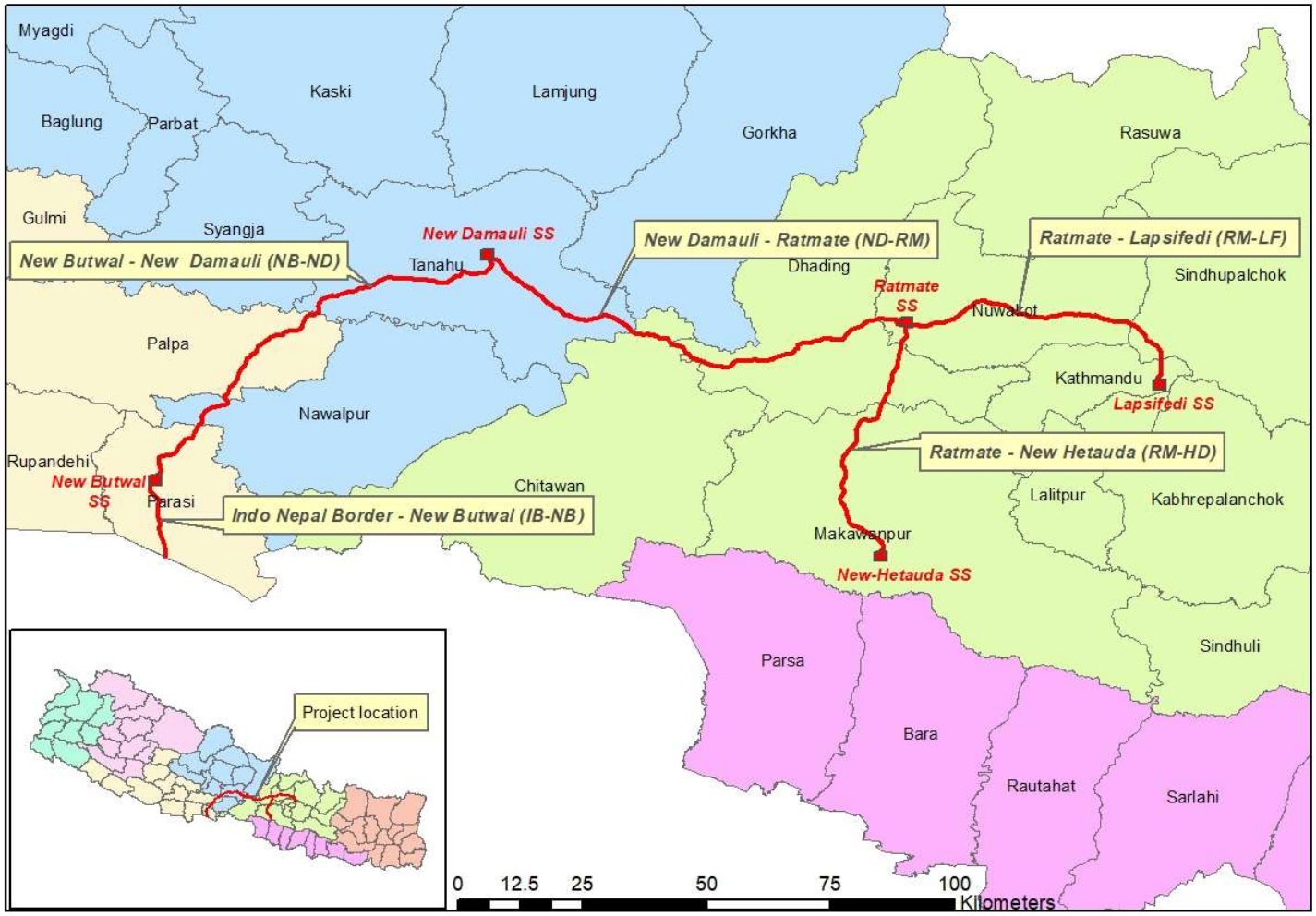

Figure 1-1: Location Map of Proposed TL Route Alignment

2 Scope of Work

The main scope of work includes the following:

- To carry out the field and laboratory tests of each bore holes.
- To find out genetic background of the sub-surface layers.
- To collect the engineering and geotechnical properties of the soil.
- Recording the depth of ground water table in all the boreholes if observed up to the depth of exploration during boring work as per specifications.
- To design the foundation types for Civil & Electrical structures.
- To preserve representative disturbed samples for conducting various index tests in the soil lab.
- Conducting the laboratory tests on selected disturbed / undisturbed soil samples collected from various boreholes.
- Preparation and submission of final detailed soil investigation reports.

3 General Geology

The great Himalayas extend for about 2400 km from the Punjab Himalaya in the west to the Arunachala Himalaya in the east along the WNW direction. Nepal occupies the north-central position in south Asia and is geographically sandwiched between China (North) and India (South). It is located in the central part of the 2400 km long Himalayan arc and covers one third of its length. Geographically, major part of Nepal (83%) falls within the mountainous region and 17% is covered by alluvial plains of the Gangetic basin.

Physiographically, Nepal can be divided into following eight distinct units (Terai, Siwalik Range, Dun Valley, Mahabharat Range, Midlands, Fore Himalaya, Higher Himalaya and Inner and Trans Himalayan Valleys (Hagen 1969). However due to the impact of continuous collision of continents has resulted in several thrust and fault in Himalaya. Based on these faults and thrust as well as rock type and ages, Nepal Himalaya can be divided into the following five major tectonics zones.

- The Terai Zone
- The Siwalik Zone
- The Lesser Himalayan Zone
- The Higher Himalayan Zone
- The Tibetan Zone

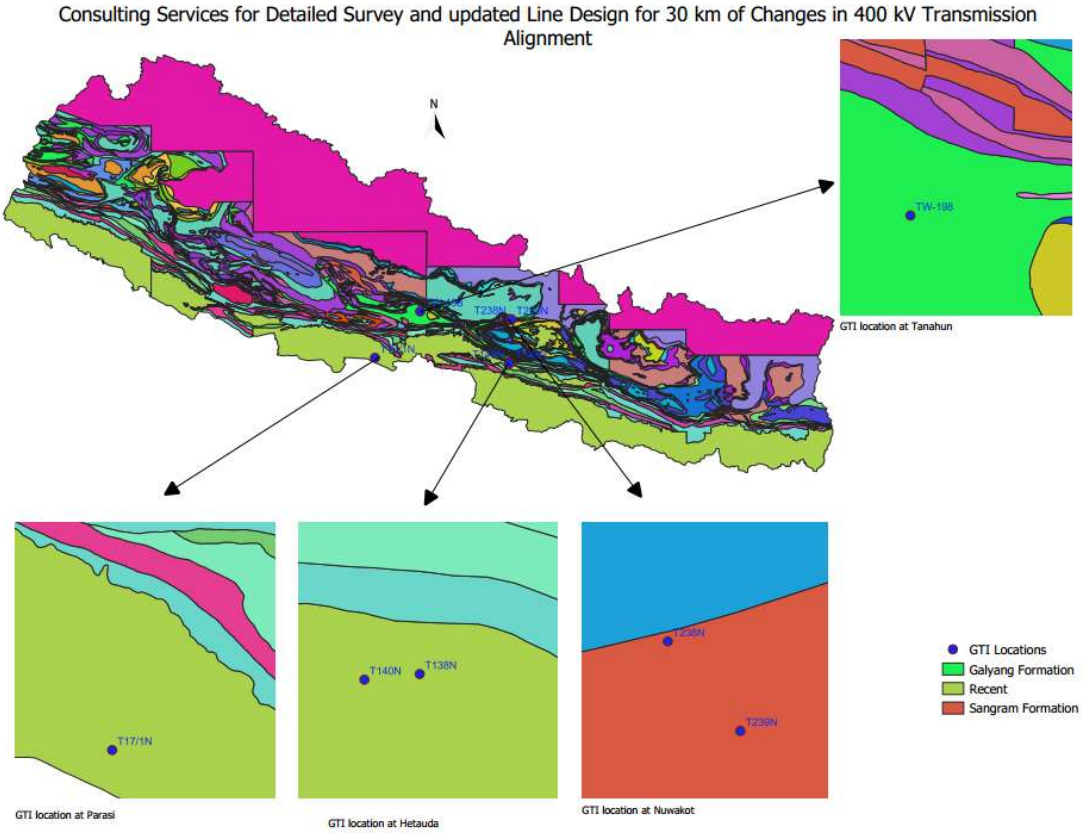

Figure 3-1: Geological Map of Project Area Showing Geological Formation

3.1 Regional Geological Setting

The project area of Detailed Survey and updated Line Design for 30 km of changes in 400 kV Transmission Line Route Alignment lies in the Indo-Gangetic Plain, Sub-Himalaya (Siwaliks or Churia Group), Lesser Himalaya and Higher Himalaya of Western and Central Nepal (Figure 3-2).

Indo-Gangetic Plain (Terai) is southernmost tectonic division of Nepal. The Terai plain is made up of alluvium of Pleistocene to recent age (1.8 million years to the present) with an average thickness of about 1500 m. This zone lies on the southern part of the Himalayas, composed of the boulders to clay. Dun Valleys (Inner Terai) are 5-30km wide valley, within the Churia hills composed of up by coarse to fine alluvial deposits.

The Sub-Himalaya (Siwaliks or Churia Group) is represented by the low hills of the Churia Range. The Siwalik Group of Nepal is composed of 5-6 km thick fluvial sediments of the middle Miocene to early Pleistocene age. The sediments are generally a layer of mudstone, sandstone, and conglomerate. The Siwalik Group is divided into the Lower, Middle (mudstone and sandstone), Middle Siwaliks (thick-bedded, coarse-grained, "pepper and salt" sandstone) and Upper Siwaliks (conglomerate with lenses of muds and sands).

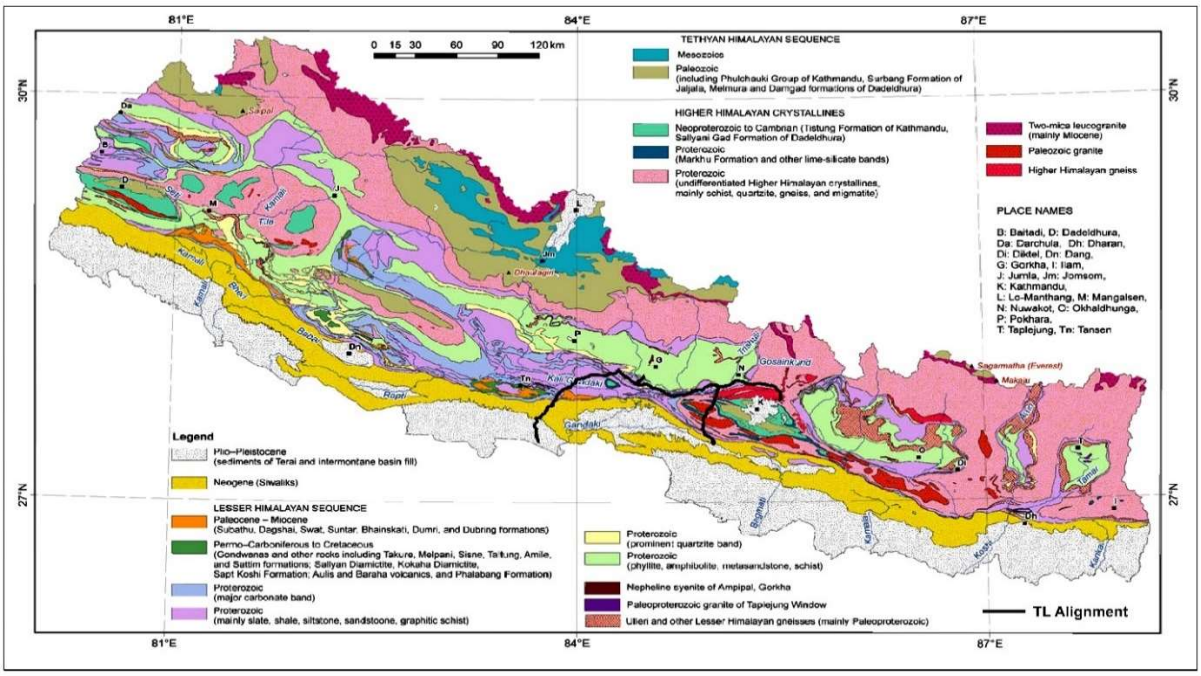

Figure 3-2: Regional geological Map of Nepal with Transmission line Alignment (Dhital, 2015)

Tectonically, the entire Lesser Himalaya consists of allochthonous and para-autochthonous rocks. Rock sequences have developed with nappes, klippes, and tectonic windows, which have complicated the geology. The Lesser Himalaya is made up of mostly the unfossiliferous sedimentary and metasedimentary rocks, consisting of quartzite, phyllite, slate, and limestone ranging in age from Pre-Cambrian to Miocene. Thrusts, the Main Boundary Thrust (MBT), and the Main Central Thrust (MCT), respectively bound the southern and northern limits of Lesser Himalayan zone.

Higher Himalaya is geologically as well as morphologically well-defined unit, and consists of a huge pile of highly metamorphosed rocks. It is situated between the fossiliferous sedimentary zone (the Tibetan-Tethys Himalaya in the north, separated by STDS and the Lesser Himalaya, separated by MCT in the south. This zone has made up of the oldest rocks of Precambrian metamorphic and granitic gneiss. This sequence can be divided into three main

units. From bottom to top, these units are Kyanite-sillimanite gneiss (Formation I), Pyroxene, marble and banded gneiss (Formation II), and Augen gneiss (Formation III).

3.2 Geomorphology

The Nepal Himalaya has eight well-defined regional geomorphologic zones in north–south direction: 1) Terai (the northern edge of the Indo-Gangetic plain), 2) Siwalik (Churia) Range, 3) Dun Valleys, 4) Mahabharat Range, 5) Midlands, 6) Fore Himalaya, 7) Higher Himalaya, and 8) Inner and Trans Himalayan Valleys [Hagen, 1969]. Each of these zones has unique altitudinal variation, slope and relief characteristics, and climatic pattern. Studied Alignment of this project will pass through Indo-Gangetic Plain, Siwalik Range, Dun valleys Mahabharat Range and Midlands Zones (Figure 3-3).

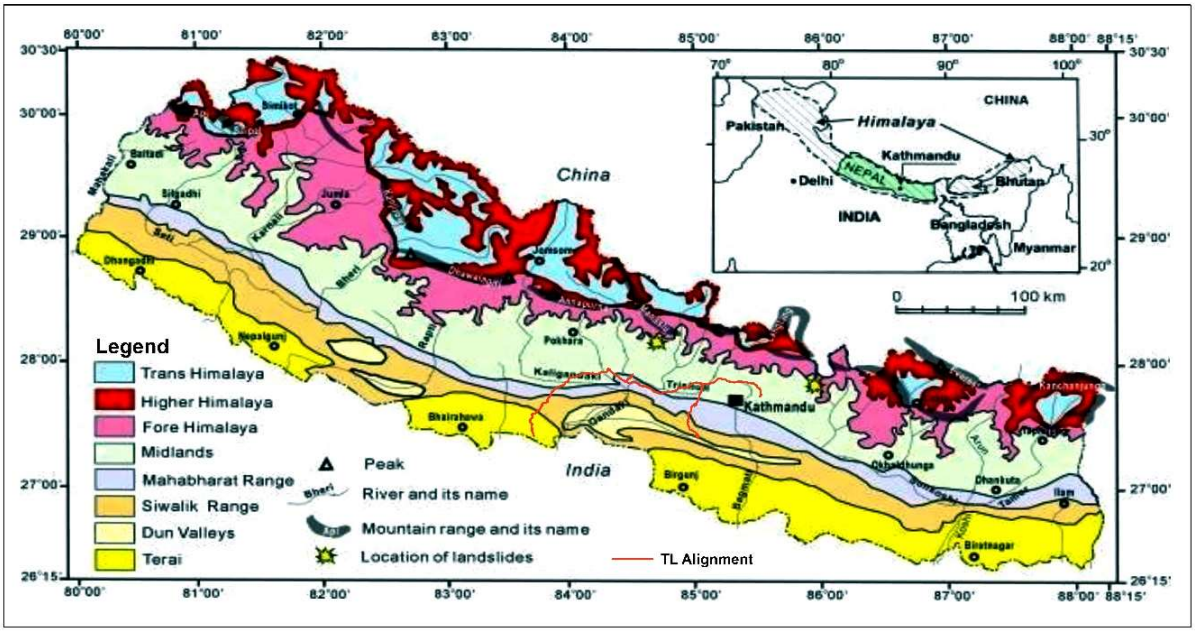

Figure 3-3: Regional geomorphological map of Nepal (modified after Dahal and Hasegawa, 2008)

Major geomorphologic agents of the alignment are controlled by the major faults, River and lithological variations. The Seti Nadi, the Marsyangdi River, the Trisuli River, the Rapti Khola and the Arun Khola and their main tributaries contribute to fluvial landforms in the area. Wide fluvial depositional features are present at Terai plain and Dun valleys and Erosional features are dominant in Sub-Himalayas and Himalayas. Similarly, hard rock and soft rock combination influences the sharp variation of elevation and slope. Major faults such as Himalayan Frontal Thrust (HFT), Central Churia Thrust (CCT), Main Boundary Thrust (MBT), and Main Central Thrust (MCT) and other local faults are responsible for tectonic landforms.

Climatic factors such as the intensity, frequency and duration of precipitation, direction of wind etc. play a major role in development of landscape. 80% of the total annual precipitation of Nepal Himalaya takes place during June to September. Topography and aspect of mountain slope also make local change in rainfall, wind and temperature. The south facing slopes of Nepal Himalaya have a higher rate of insolation and usually have higher evaporation rates [Upreti and Dhital, 1996]. As a result, such slopes always have less vegetation in comparison with north facing slopes.

3.3 Main Lithology

Residual soils are developed in situ from the decomposition of rock. They are mostly developed over colluvium deposit and weathered rock mostly in gentle slopes. The deposit consists of red, cohesive clay mixed with sand

and silt and occasional angular gravels of parent rock. The thickness of soil varies from 2-5m. Residual soils are well distributed throughout Dhading and Nuwakot districts.

Colluvial soil refers to soils transported by gravitational forces. The deposit consists of angular to sub-angular gravels and boulders (up to 3 m) with matrix of brown, clayey sandy silt with low plasticity at the ratio of 70% of fine materials and 30% of course materials. The thickness of this deposit varies depending upon inclination of slopes. This type of soil is distributed throughout the alignment. Colluvium deposits are well distributed at the hillslope of Siwalik and Lesser Himalayan region with high slope curvature and low slope angle.

In this survey, possible sites of tower location are avoided in colluvium deposits. Weathered rock product that consists of the completely weathered rock mass with the presence of the parent rock and mineralogical structures is identified at some of tower location during walkover survey. It includes the light grey colored silty soil mixed with some fines and rock fragments of the parent rock.

The alluvial deposits consist mainly of boulder and gravel with sand and silt. The boulders are mostly sub-angular to well rounded, composed mainly of granite, quartzite, gneiss, schist, dolomite and amphibolite.

Main rock types found in the project area consists of sandstone, mudstone and conglomerate of Sub-Himalaya (Siwaliks or Churia Group), quartzite, phyllite, dolomite, limestone, shale, purple and black slate and schist of the Lesser Himalaya and quartzite schist and gneiss and granite of Higher Himalaya. In general, bedding planes (or foliation planes) are north dipping with 3 sets of distinct joint planes and random fractures. Rock mass is generally fresh (W1) to moderately weathered (W3) along the alignment with majority rocks are slightly weathered (W2).

Table 3-1: Lithological Properties of Geological Formation of Proposed Locations

S.N.	Tower Location	Geological Unit	Lithological Properties
1	T238N, Nuwakot	Sangram Formation	Composed of a sequence of sandstones, shales and claystone, which were deposited in a terrestrial environment, such as river channels, floodplains and lakebeds.
2	T240N, Nuwakot	Sangram Formation	Composed of a sequence of sandstones, shales and claystone, which were deposited in a terrestrial environment, such as river channels, floodplains and lakebeds.
3	T138N, Hetauda	Recent Deposit	Quaternary Sediments of Terai Plain. Includes wide variety of materials such as sand, mud, silt and clay.
4	T140N, Hetauda	Recent Deposit	Quaternary Sediments of Terai Plain. Includes wide variety of materials such as sand, mud, silt and clay.
5	T17/1, Parasi	Recent Deposit	Quaternary Sediments of Terai Plain. Includes wide variety of materials such as sand, mud, silt and clay.
6	TW198, Tanahu	Galyang Formation	Black slates with some carbonates followed upwards by Sangram Formation

3.4 Geological Details of Proposed Location

The geological information of tower locations is tabulated below:

Table 3-2: Geological Information of Proposed Locations

S.N.	Location Name	Geological Hazard	Remarks
1	T238N, Nuwakot	No Sign of any Slope Instabilities like Landslides, Rock Falls, Mud Flows, Debris Flows etc.	

S.N.	Location Name	Geological Hazard	Remarks
2	T240N, Nuwakot	No Sign of any Slope Instabilities like Landslides, Rock Falls, Mud Flows etc. Since the point is located below road level near river, care should be taken on potential bed scouring by the river, and possible rise of ground water table during monsoon.	
3	T138N, Hetauda	No Sign of any Slope Instabilities like Landslides, Rock Falls, Mud Flows, Debris Flows etc. River training works were already done. Allocated points are at higher elevation than the existing highway. Note: If the existing points were shifted near to highway, then risk of flood will increase there by requiring pile foundation during construction.	
4	T140N, Hetauda	No Sign of any Slope Instabilities like Landslides, Rock Falls, Mud Flows, Debris Flows etc. River training works were already done. Allocated points are at higher elevation than the existing highway.	
5	T17/1, Parasi	No Sign of any Slope Instabilities like Landslides, Rock Falls, Mud Flows, Debris Flows etc. This point lies in alluvial deposits of terai region. GWT was encountered. Since the point is located near river, care should be taken on potential bed scouring by the river, and possible rise of ground water table during monsoon.	
6	TW198, Tanahu	No Sign of any Slope Instabilities like Landslides, Rock Falls, Mud Flows, Debris Flows, Liquefaction etc.	

4 Field Investigation

Site investigations enable vertical stratigraphy in correspondence of angle towers foundation to be drawn and soil samples to be tested, with the purpose of evaluation of foundation material strength parameters, bearing capacity, permeability, water table presence, soil type classification and other geotechnical/geological information. Such information, together with the normal topographical survey, provides the designer with complete details of the site for design and enables him to prepare economical designs for the tower foundations. Because of the complexity of natural deposits/rock, a unique method of exploration can't be suitable for all the geological conditions. The choice of the most suitable methodology varies according the nature of the geological material and the purpose of the exploratory program. According to this principle, different site investigation methodologies have been foreseen to properly investigate various foundation materials like rock, fine or coarse deposits.

4.1 Field Work Procedures

Field works involved Rotary Drilling Method for drilling and sampling of the boreholes in the marked locations which were finalized during technical discussion between MCA-N and Consultant.

The drilling was advanced up to the depth of 12.0 m from the ground levels and SPT/DCPT observations were taken at every 1.5 m intervals and are recorded for all 6 number of stations. Borehole logs were prepared at the site on the basis of the visual observation of the soil obtained from the boreholes. The dia. of the borehole is 100m and both SPT and DCPT were conducted on the same borehole. As usual practice here in Nepal, DCPT were

conducted when gravel mixed strata was encountered. The Split Spoon Sampler and DCPT Cone are attached on the same rod as per the requirement when conducting the test. The borehole logs of tower locations are attached in the Annex – A, soil description on the borehole were later verified by laboratory test results.

Figure 4-1: GTI Location at Nuwakot Section

- **Rotary Drilling Method**

Among the common methods of subsurface drilling in Nepal, Rotary drilling method is the suitable method for drilling in all types of soil. Rotary drilling is used to form a deep observation borehole or for obtaining representative samples.

Rotary Drilling Method is used by rotating the core bit fixed at the lower end of the drill rod i.e. barrel with drilling fluid; water or bentonite slurry. This method is adopted in the project area because of the presence of cohesion less soil layers having sandy gravels with pebbles, cobbles and boulders. Each borehole was drilled up to a depth of twelve meters. The soil extracted during drilling of each hole was observed carefully by the supervisor to make site borehole logs. The locations details of the borehole is given in Table *4-1*.

Table 4-1: Summary of Location of Boreholes at Respective Locations UTM 45 (Universal Transverse Mercator)

S. N	Description	Easting, m	Northing, m
1	T238N	306079	3082750
2	T240N	306228	3082309
3	T138N	304271	3035190
4	T140N	303560	3035120
5	T17/1	766267	3042105
6	TW198	218356	3092898

Figure 4-2: Rotary Drilling Method at Nuwakot Section

4.2 Field Tests/ Penetration Tests

4.2.1 Standard Penetration Test (IS 2131)

The standard Penetration Test (SPT) involves driving a standard split-spoon sampling tube (50 mm O.D. and 35 mm I.D.) 450 mm into the ground at the bottom of a borehole with 63.5 kg hammer falling freely from 750 mm. The borehole is advanced to the desired testing depth, the drilling tools are removed, the sampler is attached to a series of drill rods, and the entire assembly is lowered to the bottom of borehole. The hammer is positioned over the top of the drill rods and blows are applied.

There are commonly three types of hammers used in SPT test, donut hammer, safety hammer and automatic trip hammer. For this project donut hammer was used. The donut hammer provides approximately 45% of the maximum free-fall energy to the drill system. The most common method of raising and lowering the donut or safety hammer is the rope and cathead method. A rope wrapped around a rotating pulley (a cathead) is used to lift the hammer. The drill rods are marked in 150 mm increments. As the sampler is driven, the number of hammer blows required to drive the sampler each 150 mm increment is recorded. The blow counts for the last two 150 mm increments added together are the standard penetration resistance or N-value. Upon completion of driving, the sampler is withdrawn from the borehole. The split-spoon sampler is opened and the soil sample is removed and logged.

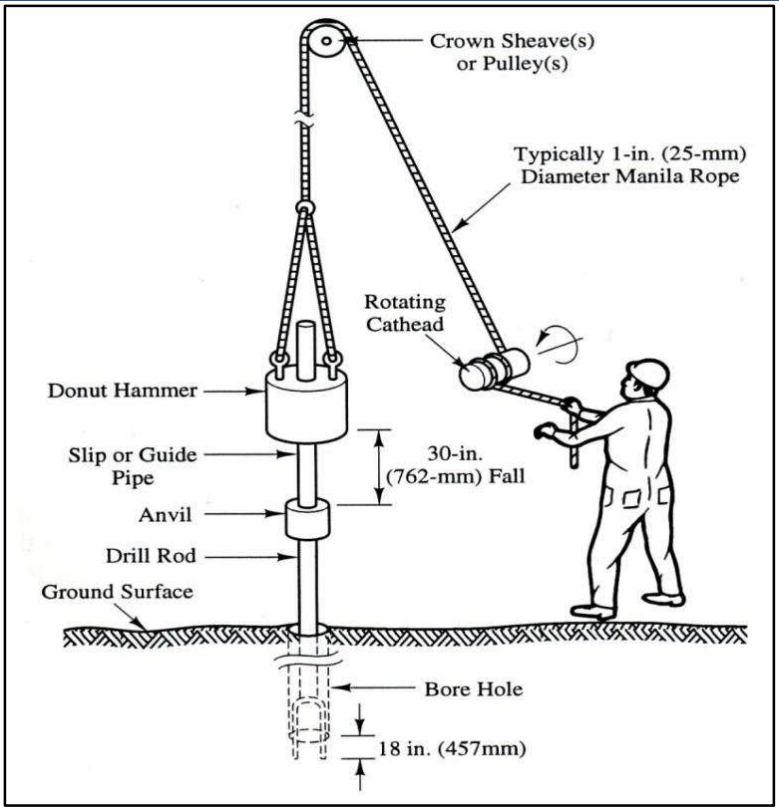

Figure 4-3: Typical Setup of Standard Penetration Test (SPT)

4.2.2 Dynamic Cone Penetration Test (IS 4968 Part I and II)

The performance of SPT in gravelly, boulder and rocky strata is found to be very poor. Therefore, another testing method called Dynamic Cone Penetration Test (DCPT) as recommended by IS-4968:1976, is used for testing in such strata. This standard covers the procedure for determining the resistance of different soil strata to dynamic penetration of a 50 mm cone. All the testing procedures are alike SPT. The DCPT value obtained is converted in SPT using the correlation given by Central Building Research Institute, Roorkee, which is adopted by IS-4968-1976.

N_{DCP}= 1.5 N_{SPT} for depths up to 4 m
N_{DCP} = 1.75 N_{SPT} for depths between 4 to 9 m
N_{DCP} = 2 N_{SPT} for depths greater than 9 m
Were,

N_{DCP}= Recorded DCPT values
N_{SPT}=SPT values

The tests are conducted at every 1.50 m interval, as far as possible, starting first at 1.50 m depth. Depending upon the soil strata encountered during subsurface drilling process, the field-tests, SPT or DCPT is adopted.

Figure 4-4: Typical DCPT Setup at Site

4.2.3 Water Table Measurements

When the drilling of the boreholes was carried out proper attention were given to notice and record any encountered ground water table. If any groundwater table was encountered after 24 hours of completion of rotary drilling, it was measured using the wetted tape.

It is anticipated that the piezometric conditions at boring will fluctuate depending on variations in weather, precipitation, surface runoff, evaporation, and other seasonal factors. Other than collection of ground water data during drilling and observations in the borings, no other measurements were obtained specific to characterization of actual groundwater conditions. Water table encountered at any borehole locations during field investigations are presented below in Table 4-2. Please refer Annex - A Borehole Logs.

Table 4-2: Groundwater Monitoring During Drilling

Tower Location	Depth of Water Encountered During Drilling
T238N	Not Encountered
T240N	4.5 m
T138N	7.3 m
T140N	Not Encountered
T17/1N	6 m
TW-198	Not Encountered

5 Laboratory Testing

Representative soil samples were selected for laboratory testing. The results of the index testing aided in the classification of materials encountered during the subsurface investigation and provided data for use engineering analysis and evaluations. Index test results, including moisture contents, fines contents, and Atterberg limits, are presented on the laboratory summary and is included in Annex

All tests were conducted confirming to the specification as per IS Codes. The following test were performed.

Table 5-1: The Laboratory Tests and their Referred Codes

S.N.	Test	IS Code
1	Bulk and dry density	By Calculation
2	Moisture Content	IS 2720 (Part 2) – 1992
3	Grain size	IS 2720 (Part 4) – 1992
4	Atterberg Limit	IS 2720 (Part 5) – 1992
5	Specific Gravity	IS 2720 (Part 3) – 1992
6	Drained Direct Shear Test	IS 2720 (Part 13) – 1986

Grain Size Analysis

The grain size analysis of soil has been performed as per IS 2720 (Part 4) – 1992 and hydrometer analysis on finer particles as per 2720 (Part 4) – 1985 as per standard practice.

Direct Shear Test

Direct shear test is the laboratory method of determining the shear strength parameter of soil. It consists of a mould to cut the soil sample to a size used in the shear box, shear box to apply loads on the soil, loading arrangements for both normal and shear force and graduated rings to measure the shear force and displacements. The shear test has been performed on remolded sample considering appropriate density and moisture as per site condition and nature of soil.

At first, the sample was prepared in a mold and then put in the shear box. Initial readings in the graduated rings were made zero. The vertical load was applied (50 kPa, 100 kPa and 200 kPa) and horizontal displacements and corresponding horizontal forces were noted in regular intervals for each load until the soil failed. These measurements were used to plot the stress strain curve of the sample during the loading for the given normal stress. Results of different tests were presented with normal stress as x- axis and shear stress as y- axis. A linear curve fitting was used. The slope of the line is the internal angle of friction of the soil and the y-ordinate of the line at zero abscissa gives the cohesion of the soil. All the shear test has been performed as per IS 2720 (Part 13) – 1986 and other IS standard practice.

5.1 Discussion on Direct Shear Test

Introduction:

The direct shear test is a common laboratory test used to determine the shear strength of soil and rock materials. In this test, a sample is placed in a shear box and subjected to a shearing force along a predetermined plane. The shear force is increased until the sample fails, and the shear strength is calculated based on the maximum force applied.

Test Results:

In this project, a direct shear test was conducted on a sample collected from different site. The test results are summarized below in **Chapter 6.**

Discussion:

Based on the direct shear test results, the shear strength parameters of the investigated samples were determined to be 0 to 33 kPa Cohesion and 14° to 34° friction angle. The displacement data also showed a typical shear behavior, with an initial elastic deformation followed by a plastic deformation phase leading to failure.

Cohesion value varies based on grain size distribution (Clay, Sand, Silt and Gravel on percentage), mineralogy and moisture content. Generally, Clay Soil have higher Cohesion value and Cohesion of Sandy soil or Gravelly soil is generally negligible.

Friction angle value varies based on grain size distribution (Clay, Sand, Silt and Gravel on percentage), mineralogy and moisture content. Generally, Clay Soil have lower friction angle than that of sandy and gravelly soil.

6 Soil Classification

Soil can be classified as gravel, sand, silt and clay according to their grain size. The proportions of these constitutions in the soil may vary and so as their characteristics. The constituents of the soil have a significant influence on its behavior. IS 2720(Part 4)-1985 has been followed for sieve analysis. Soil gradation is very important to geotechnical engineering. It is an indicator of other engineering properties such as compressibility, shear strength, and hydraulic conductivity. In a design, the gradation of the in situ or on-site soil often controls the design and ground water drainage of the site.

Most of the soil encountered in all the tower locations is coarse grained soil. In all tower locations no fill strata were encountered, i.e., all proposed tower location in on natural ground. As per the SPT and DCPT N value soil can be described as dense to very dense soil.

The Table *6-1* shows the soil composition at different bole hole locations:

Table 6-1: Soil Composition at Different Bore Hole Location

Location	Soil Composition of Different Bore Hole Location
T238N	Poorly Graded Sand with silt and fine to coarse grained sand up to depth of 1m; Gravel and Cobble
T138N	mixed soil with sand up to depth of 12 m Gravel and Boulder with sand
T140N	Gravel and boulder with sand
T17/1	Clayey sand up to depth of 1.5m; Poorly graded sand with clay and fine to coarse grained sand up
TW198	to a depth of 4.5 m; Poorly graded sand with silt up to depth of 6m; Poorly graded sand up to depth of 7 m; Clayey sand with gravel up to depth of 9m; Poorly graded sand with clay up to depth of 12m. Well graded gravel with sand up to depth of 4m; Well graded gravel with silt and sand up to depth
	of 6m; Well graded gravel with sand up to depth of 9m; Well gravel with silt and sand up to 10.5m; Well graded gravel with silt and sand up to depth of 12m

Table 6-2: Brief Summary of Soil Composition

SN	Tower Name	Depth (m)	Soil Type	SPT Value	DCPT Value	Compactness/Consistency	Sp. Gravity	Direct Shear	
								C (kPa)	Φ^0
1	T238N	1.5	Well Graded Sand with Gravel; moist, brown, fine to coarse grained sand	2	-	Very Soft	2.501	0	34
		3		20	-	Very Stiff	2.501	0	34
		4.5	Gravel and Cobble mixed Soil with Sand	-	50/15	Very Dense	-	-	-
		6		-	50/3	Very Dense	-	-	-
		7.5		-	50/9	Very Dense	-	-	-
		9		-	50/10	Very Dense	-	-	-
		10.5		-	125/30	Very Dense	-	-	-
		12		-	50/20	Very Dense	-	-	-
2	T138N	1.5	Gravel and Boulder with Sand	-	22	Very Dense	-	-	-
		3		-	50/9	Very Dense	-	-	-
		4.5		-	50/12	Very Dense	-	-	-
		6		-	50/6	Very Dense	-	-	-
		7.5		-	50/12	Very Dense	-	-	-
		9		-	50/13	Very Dense	-	-	-
		10.5		-	50/7	Very Dense	-	-	-
		12		-	50/9	Very Dense	-	-	-
3	T140N	1.5	Gravel and Boulder with Sand	-	50/12	Very Dense	-	-	-
		3		-	50/15	Very Dense	-	-	-
		4.5		-	50/10	Very Dense	-	-	-
		6		-	50/9	Very Dense	-	-	-
		7.5		-	50/13	Very Dense	-	-	-
		9		-	50/11	Very Dense	-	-	-
		10.5		-	50/14	Very Dense	-	-	-
		12		-	50/8	Very Dense	-	-	-
4	TW198	1.5	Well Graded Gravel with Sand; moist, brown, fine to coarse grained sand	33	-	Hard	2.629	-	-
		3		43	-	Hard	2.655	-	-
		4.5		50	-	Hard	2.655	-	-

SN	Tower Name	Depth (m)	Soil Type	SPT Value	DCPT Value	Compactness/Consistency	Sp. Gravity	Direct Shear	
								C (kPa)	Φ^0
		6	Well Graded Gravel with Silt and Sand; moist, brown, fine to coarse grained sand	-	50/10	Very Dense	2.617	-	-
		7.5		-	50/5	Very Dense	-	-	-
		9		-	50/8	Very Dense	-	0	33
		10.5	Well Graded Gravel with Silt and Sand; moist, brown, fine to coarse grained sand	-	50/9	Very Dense	-		
		12		-	50/7	Very Dense	2.632	0	34
5	T240N	1.5	Poorly Graded Sand with Silt; moist, dark brown, fine to coarse grained sand	21		Very Stiff	2.686	6	31
		3	Gravel and Cobble mixed Soil with Sand	-	50/10	Very Dense	-	-	-
		4.5		-	50/9	Very Dense	-	-	-
		6		-	50/8	Very Dense	-	-	-
		7.5		-	50/6	Very Dense	-	-	-
		9		-	50/9	Very Dense	-	-	-
		10.5		-	50/7	Very Dense	-	-	-
		12		-	50/5	Very Dense	-	-	-
5	T17/1N	1.5	Clayey Sand; wet, grey, fine to coarse grained sand	21	-	Very Stiff	2.516	10	14
		3	Poorly Graded Sand with Fat Clay; wet, grey, fine to coarse grained sand	25	-	Very Stiff	2.47	31	19
		4.5		28	-	Very Stiff	2.615	31	19
		6	Poorly Graded Sand with Elastic Silt; moist, brown, contains root, fine to coarse grained sand	23	-	Very Stiff	2.642	33	19
		7.5	Poorly Graded Sand; moist, brown, fine to coarse grained sand	63	-	Hard	2.678	0	34
		9	Clayey Sand with Gravel; moist, brown, fine to coarse grained sand	58		Hard	2.658	23	24
		10.5	Poorly Graded Sand with Clay; moist, brown, fine to coarse grained sand	73	-	Hard	2.658	9	31
		12		50	-	Hard	2.658	9	31

7 Bearing Capacity

A basic requirement for any foundation is that it can safely support the load that it carries, the foundation itself must not suffer structural failure, and the soil beneath it must not be loaded so heavily that its supporting capacity is exceeded. Structural failure in a foundation can be avoided by assuring that the foundation has sufficient shear and moment capacity to distribute the load it carries into the soil on which it rests. Failure of the soil beneath a foundation can be avoided by making the foundation large enough so that the stresses induced in the supporting soils are less than their shear strengths. The allowable bearing capacity for different footing size are provided for respective tower location. The total permissible settlement for the shallow and raft foundation is considered as 40 mm and 65 mm respectively. The values of net bearing pressure were computed using the SPT and DCPT value.

7.1 Shallow Foundation

Allowable bearing capacity of soil have been calculated based on the modified SPT/DCPT test result and Direct Shear Test of the disturbed sample retrieved from borehole of each site of Transmission tower location.

In conversion of DCPT to SPT IS: 4968-2 (1976), (Reaffirmed 2007) and Method described by The Central Building Research Institute, Roorkee have been adopted. They are described as given below;

N_{cbr} = 1.5 N for depth up to 3.0 m

N_{cbr} = 1.75 N for depth between 3.0 m to 6.0 m

N_{cbr} = 2.0 N for depth greater than 6.0 m

Were,

N_{cbr} is dynamic cone resistance.

The design of shallow foundation involves calculating an allowable pressure that will maintain an adequate factor of safety relative to shear failure of the bearing soil and limit the settlement of the foundation to meet serviceability requirements. The allowable bearing capacity of a shallow foundation is defined as the lesser of:

- The pressure that will result in a shear failure divided by a suitable factor of safety (FS), or
- The pressure that results in a specified limiting amount of settlement.

The allowable bearing capacity of a spread footing historically has combined the design considerations of minimizing the potential for shear failure of the soil and limiting vertical deflection (settlement). Both of these design considerations are a function of the least footing dimension, typically called the “footing width”. In general, for a footing bearing on essentially an isotropic, homogenous material, with no embedment, the factor of safety against shear failure developing beneath the footing will increase as the footing width increases. However, as a footing dimension, the stress increase felt by soil extends more deeply below the bearing elevation.

The effect of footing width on bearing and settlement is shown conceptually in Figure 7-1. Note that the allowable bearing capacity of a footing is controlled by shear failure considerations for narrow footing widths. However, as the footing width increases, the allowable bearing capacity is limited by the settlement potential of the soils supporting the footing.

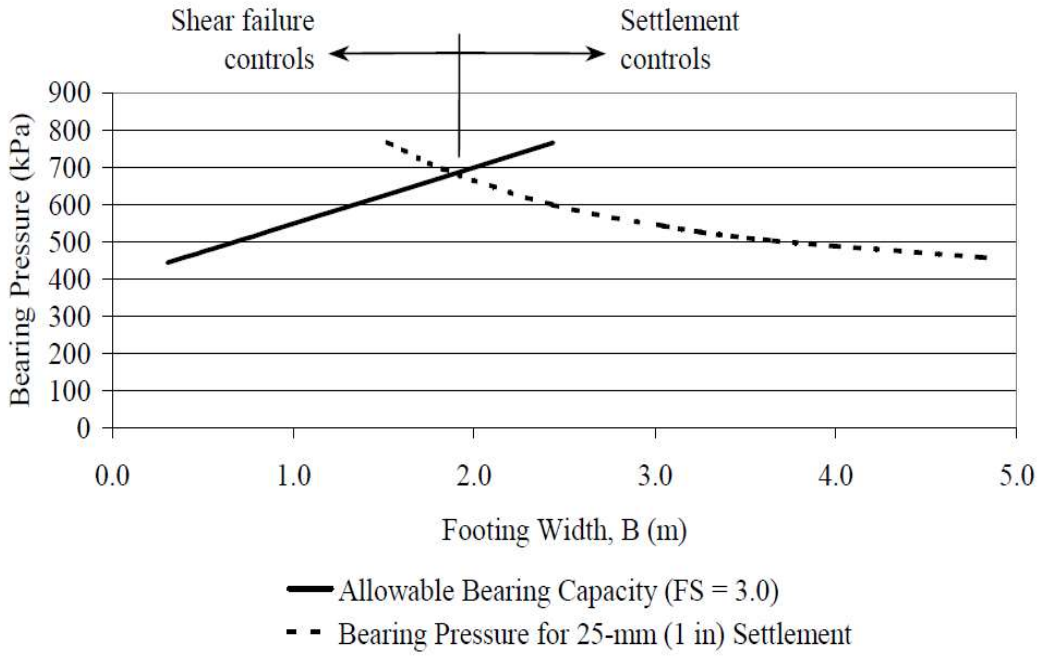

Figure 7-1: Allowable Bearing Capacity Controlled by Shear Failure Considerations Versus Settlement Considerations. (FHWA-SA-02-054, Shallow Foundation)

So, we have evaluated the bearing capacity in this report using both criterion, shear failure and settlement.

For shear failure criterion, following equation as stated by ***IS: 6403-1981*** is adopted.

The ultimate bearing capacity is given by:

$$q_{ult,net} = c'N_cS_cd_c + q(N_q - 1)S_qd_q + 0.5\gamma'B'N_\gamma S_\gamma d_\gamma$$

$$q_{allowable,net} = \frac{q'_{ult,net}}{FS}$$

Where,
N_c, N_q, N_γ are same as Vesic's Bearing capacity theory
S_c, S_q, S_γ are shape factors
d_c, d_q, d_γ are depth factors

For settlement criterion, following method is adopted as stated by ***IS: 6403-1971***. The IS code method is similar to Teng's, the equation is used to evaluate the net allowable bearing pressure for settlement of 40 mm.

$$q_{allow,net} = 55.4\,(N - 3)\left(\frac{B + 0.3}{2B}\right)^2 R_{w2} \qquad kPa$$

Where,
N = Standard Penetration Value
B = Width (m)
R_{w2} = Reduction factor for water table

As in most of the cases in substation the minimum foundation width will be approximately 2 m or greater. So, we recommend the designer to use the bearing capacity evaluated using the settlement criterion.

Table 7-1: Bearing Capacity Factors

Bearing Capacity Factors									
Φ (Deg)	(IS 6403: 1981)			Meyerhof			Hansen		
	Nc	Nq	Nγ	Nc	Nq	Nγ	Nc	Nq	Nγ
0	5.14	1	0	5.14	1	0	5.14	1	0
1	5.38	1.09	0.07	5.38	1.09	0.02	5.38	1.09	0.02
2	5.63	1.2	0.15	5.63	1.2	0.04	5.63	1.2	0.04
3	5.9	1.31	0.24	5.9	1.31	0.06	5.9	1.31	0.06
4	6.19	1.43	0.34	6.19	1.43	0.08	6.19	1.43	0.08
5	6.49	1.57	0.45	6.49	1.57	0.1	6.49	1.57	0.1
6	6.81	1.72	0.57	6.81	1.72	0.16	6.81	1.72	0.16
7	7.16	1.88	0.71	7.16	1.88	0.22	7.16	1.88	0.22
8	7.53	2.06	0.86	7.53	2.06	0.28	7.53	2.06	0.28
9	7.92	2.25	1.03	7.92	2.25	0.34	7.92	2.25	0.34
10	8.35	2.47	1.22	8.35	2.47	0.4	8.35	2.47	0.4
11	8.8	2.71	1.44	8.8	2.71	0.54	8.8	2.71	0.56
12	9.28	2.97	1.69	9.28	2.97	0.68	9.28	2.97	0.72
13	9.81	3.26	1.97	9.81	3.26	0.82	9.81	3.26	0.88
14	10.37	3.59	2.29	10.37	3.59	0.96	10.37	3.59	1.04
15	10.98	3.94	2.65	10.98	3.94	1.1	10.98	3.94	1.2
16	11.63	4.34	3.06	11.63	4.34	1.46	11.63	4.34	1.54
17	12.34	4.77	3.53	12.34	4.77	1.82	12.34	4.77	1.88
18	13.1	5.26	4.07	13.1	5.26	2.18	13.1	5.26	2.22
19	13.93	5.8	4.68	13.93	5.8	2.54	13.93	5.8	2.56
20	14.83	6.4	5.39	14.83	6.4	2.9	14.83	6.4	2.9
21	15.82	7.07	6.2	15.82	7.07	3.68	15.82	7.07	3.68
22	16.88	7.82	7.13	16.88	7.82	4.46	16.88	7.82	4.46
23	18.05	8.66	8.2	18.05	8.66	5.24	18.05	8.66	5.24
24	19.32	9.6	9.44	19.32	9.6	6.02	19.32	9.6	6.02
25	20.72	10.66	10.88	20.72	10.66	6.8	20.72	10.66	6.8
26	22.25	11.85	12.54	22.25	11.85	8	22.25	11.85	7.9
27	23.94	13.2	14.47	23.94	13.2	9.6	23.94	13.2	9.4
28	25.8	14.72	16.72	25.8	14.72	11.2	25.8	14.72	10.9
29	27.86	16.44	19.34	27.86	16.44	13.45	27.86	16.44	13
30	30.14	18.4	22.4	30.14	18.4	15.7	30.14	18.4	15.1

Bearing Capacity Factors									
Φ (Deg)	(IS 6403: 1981)			Meyerhof			Hansen		
	Nc	Nq	Nγ	Nc	Nq	Nγ	Nc	Nq	Nγ
31	32.67	20.63	25.9	32.67	20.63	18.85	32.67	20.63	17.95
32	35.49	23.18	30.22	35.49	23.18	22	35.49	23.18	20.8
33	38.64	26.09	35.19	38.64	26.09	26.55	38.64	26.09	24.75
34	42.16	29.44	41.06	42.16	29.44	31.1	42.16	29.44	28.7
35	46.12	33.3	48.03	46.12	33.3	37.75	46.12	33.3	34.35
36	50.59	37.75	56.31	50.59	37.75	44.4	50.59	37.75	40
37	55.63	42.92	66.19	55.63	42.92	54.2	55.63	42.92	48.05
38	61.35	48.93	78.03	61.35	48.93	64	61.35	48.93	56.1
39	67.87	55.96	92.25	67.87	55.96	78.8	67.87	55.96	67.75
40	75.31	64.2	109.41	75.31	64.2	93.6	75.31	64.2	79.4

Table 7-2: Shape and Depth Factors

Factor	Meyerhof	Hansen	IS Code Method
s_c	$1 + 0.2N_\phi \frac{B}{L}$	$1 + \frac{N_q}{N_c}\frac{B}{L}$	$1 + 0.2\frac{B}{L}$
s_q	$1 + 0.1N_\phi \frac{B}{L}$	$1 + \frac{B}{L}\, sin\phi$	$1 + 0.2\frac{B}{L}$
s_γ	$s_q\ for\ \phi > 10^0$	$1 - 0.4\frac{B}{L}$	$1 - 0.4\frac{B}{L}$
d_c	$1 + 0.2\sqrt{N_\phi}\frac{D_f}{B}$	$1 + 0.4\frac{D_f}{B}$	$1 + 0.2\sqrt{N_\phi}\frac{D_f}{B}$
d_q	$1 + 0.1\sqrt{N_\phi}\frac{D_f}{B}\ for\ \phi > 10^0$	$1 + 2tan\phi(1 - sin\phi)^2\frac{D_f}{B}$	$1 + 0.1\sqrt{N_\phi}\frac{D_f}{B}\ for\ \phi > 10^0$
d_γ	$d_q\ for\ \phi > 10^0$	$1\ for\ all\ values\ of\ \phi$	$d_q\ for\ \phi > 10^0$

7.2 Mat Foundation

A mat (or raft) is a thick reinforced concrete slab which supports all the load-bearing walls and column loads of a structure or a large portion of the structure, A mat foundation is more economical than individual footings when the total base area required foe the individual footings exceed about one half of the area covered by the structure. The mat foundation is also better suited when the subsurface strata have erratic properties and contains the compressible lenses. When individual footings are provided where we have erratic substrata, there is very high chance of differential settlement. So, mat foundation is opted before isolated footing.

Like shallow foundation, mat foundation should also be designed against the bearing capacity failure and settlement criterion. As the width of the mat is very large, the bearing capacity is high and therefore, the shear failure generally doesn't occur. Accordingly, the safe settlement pressure (bearing capacity evaluated based on allowable

settlement) generally governs the design, expect for very loose sand (N<5). So, we have evaluated the safe bearing pressure for the mat foundation based on ***IS:6403***, for a settlement of 65 mm.

$$q_{\text{safe bearing pressure}} = 25.4\ (N - 3)\ R_w \qquad \text{kPa}$$

Where,
N = Standard Penetration Value
R_w = Reduction factor for water table

Table 7-3: Typical Bearing Capacity Analysis Result of Mat Foundation

Bore Hole No. -T17/1N	**Safe Settlement Bearing Pressure kN/m² (IS:6403-50 mm Settlement)**							
Depth of Foundation, D_f (m)	1	3	4	6	7	9	10	12
SPT N Value	21	25	28	23	63	58	73	50
Unit wt of soil kN/m3	18	18	18	18	19	19	19	19
Water Reduction Factor Wγ	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Depth of Foundation, D_f (m)	1.0	3.0	4.0	6.0	7.0	9.0	10.0	12.0
Safe Settlement Bearing Pressure, (kN/m²)	229	279	318	254	762	699	889	597
Modulus of Subgrade Reaction, Ks (kN/m³)	18288	22352	25400	20320	60960	55880	71120	47752

The allowable bearing capacity for different footing size for all tower location are provided in Result and Recommendation section of this report.

7.3 Settlement Analysis

For cohesionless soil:

The settlement of granular soils can also be evaluated by the use of a semiempirical strain influence factor proposed by Schmertmann et al. (1978). According to this method, the settlement:

$$S = C_1 C_2 \Delta p \sum_{0}^{2B,4B} \frac{I_z}{E_s} \Delta Z$$

S = net allowable settlement
C_1 = pressure change correction factor for effective overburdern
$= = 1 - 0.5\ \frac{\sigma'_{vo}}{\Delta p}$
C_2= time influence factor = 1 + (0.2)(log(t/0.1))
t = time of interest (in years)
Δp= net foundation pressure = bearing pressure minus initial effective vertical stress
I_z= vertical strain influence factor (from figure 6-2)
E_s= soil modulus of deformation (From Schmertmann, 1970) (Es = $2q_c$, where q_c is dutch cone bearing capacity, which can be evaluated using Table 7-4)

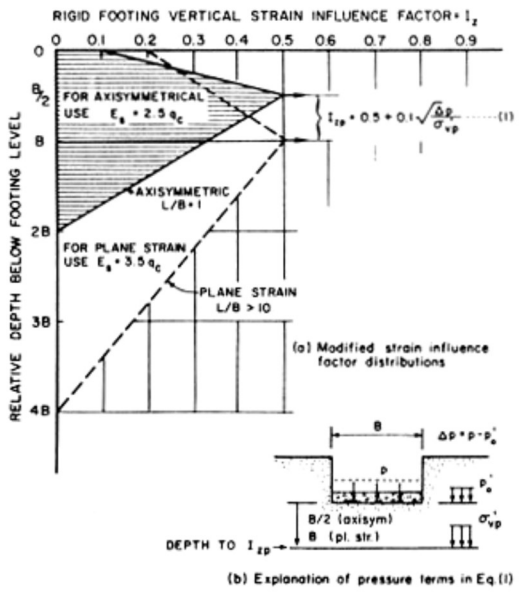

Figure 7-2: Strain Influence Factor Diagram (From Schmertmann Et Al., 1978)

Table 7-4 Correlation Between Dutch Cone Bearing Capacity and SPT N Value [Schmertmann, 1970]

Soil Type	**q_c/N**
Silts, sandy silts, slightly cohesive silt-sand mixtures	2.0
Clean, fine to med. .sands and slightly silty sands	3.5
Coarse sands and sands with little gravel	5
Sandy gravel and gravel	6

8 Regional Seismicity and Liquefaction

Nepal lies in a seismically active zone, at the interface between two of the world's major tectonic plates. All parts of Nepal are at risk from the effects of severe ground shaking due to earthquakes and there have been many remainders of this within living memory. Kathmandu experienced catastrophic damage in 1934 and an earthquake in the East of Nepal in 1988 severely damaged approximately 6,000 residential buildings. The recent earthquake of April 25, 2015 of Magnitude 7.8 and its aftershocks (reaching up to magnitude 7.3) had severe damage to structures in central and eastern Nepal and took nearly 9,000 lives.

Accordingly, the design of the Project shall also consider the possible risk of damage due to earthquake, and the earthquake loadings shall also be considered in the design of structures.

8.1 Seismic Zoning

The country is subdividing into different seismic zones based on the seismic hazard. The seismic hazard within each zone is assumed to be constant. The Seismic Zoning Factor (Z) represents the Peak Ground Acceleration (PGA) for 475 years return period. The value of Z can be obtained from the Figure 8-1. This seismic zoning map was prepared by Government of Nepal under Nepal National Building Code NBC: 105:2020. The report NBC: 105:2020 also provides the PGA (for 500 years return period) value for different cities/municipalities. The PGA recommended by the NBC: 105:2020 can be adopted for the design of the proposed structures.

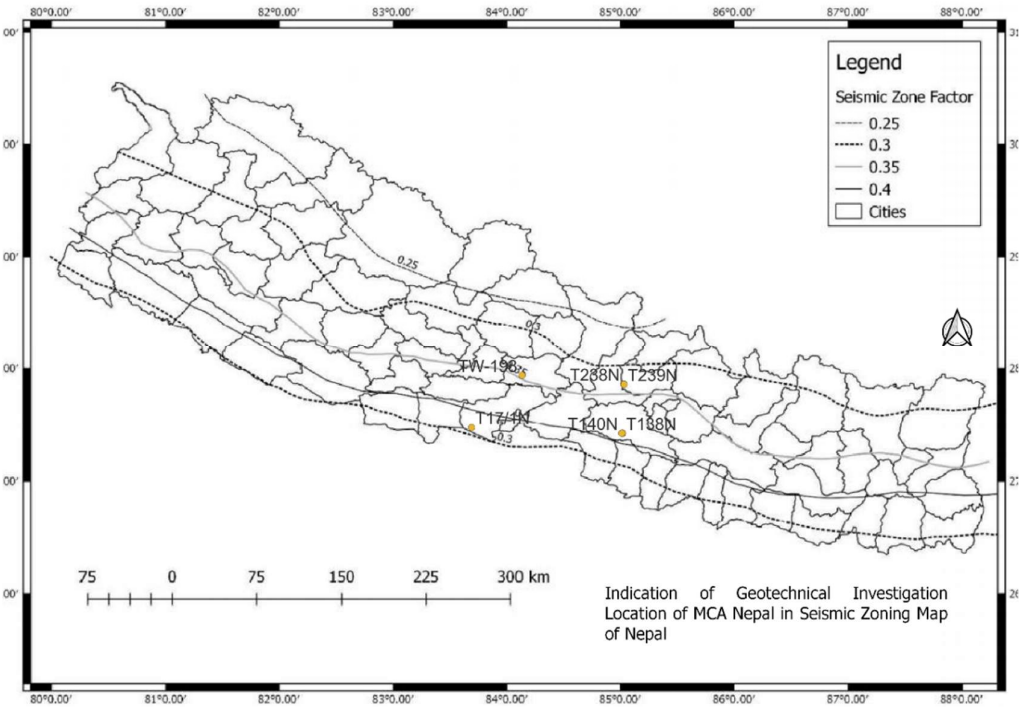

Figure 8-1: Map showing Seismic Zoning of Nepal along with GTI locations.

Table 8-1: Seismic Zoning Factors for Selected Cities and Municipalities

Cities /Municipalities	PGA	Cities /Municipalities	PGA	Cities /Municipalities	PGA	Cities /Municipalities	PGA
Baglung	0.3	Damauli	0.35	Jaleshwor	0.3	Musikot	0.3
Beni	0.3	Darchula	0.3	Janakpur	0.3	Myanglung	0.35
Besishar	0.3	Dasharathchand	0.35	Jomsom	0.25	Nepalgunj	0.4
Bharatpur	0.4	Dhading	0.3	Jumla	0.3	Okhaldhunga	0.35
Bhimdatta	0.3	Dhangadhi	0.4	Kalaiya	0.3	Phidim	0.35
Bhimeshwar	0.3	Dhankuta	0.4	Kamalamai	0.4	Pokhara	0.3
Bhojpur	0.35	Dharan	0.3	Kapilbastu	0.3	Pyuthan	0.35
Bidur	0.3	Dhulikhel	0.35	Kathmandu	0.35	Rajbiraj	0.3
Biratnagar	0.3	Dhunche	0.3	Khalanga	0.3	Ramgram	0.4
Birendranagar	0.35	Diktel	0.35	Khandbari	0.3	Salleri	0.3
Birgunj	0.3	Dipayal	0.35	Kusma	0.3	Salyan	0.35
Butwal	0.3	Dunai	0.25	Lahan	0.3	Sandhikharka	0.35
Chainpur	0.3	Gamgadhi	0.25	Libang	0.35	Simikot	0.25
Chame	0.25	Gaur	0.3	Malangwa	0.3	Tamghas	0.35
Chautara	0.3	Gorkha	0.3	Mangalsen	0.35	Tansen	0.35
Dadheldhura	0.35	Gulariya	0.4	Manma	0.3	Taplejung	0.3
Dailekh	0.35	Hetauda	0.4	Manthali	0.3	Triyuga	0.4
Damak	0.3	Ilam	0.4	Martadi	0.3	Tulsipur	0.4
						Waling	0.35

Based on the National Seismological Centre, Department of Mines and Geology (DMG) Nepal published Seismic Hazard Map of Nepal showing Bedrock Peak Ground Horizontal Acceleration Contour as shown in Figure 8-2. This figure can also be used to estimate the PGA during design of any civil structures.

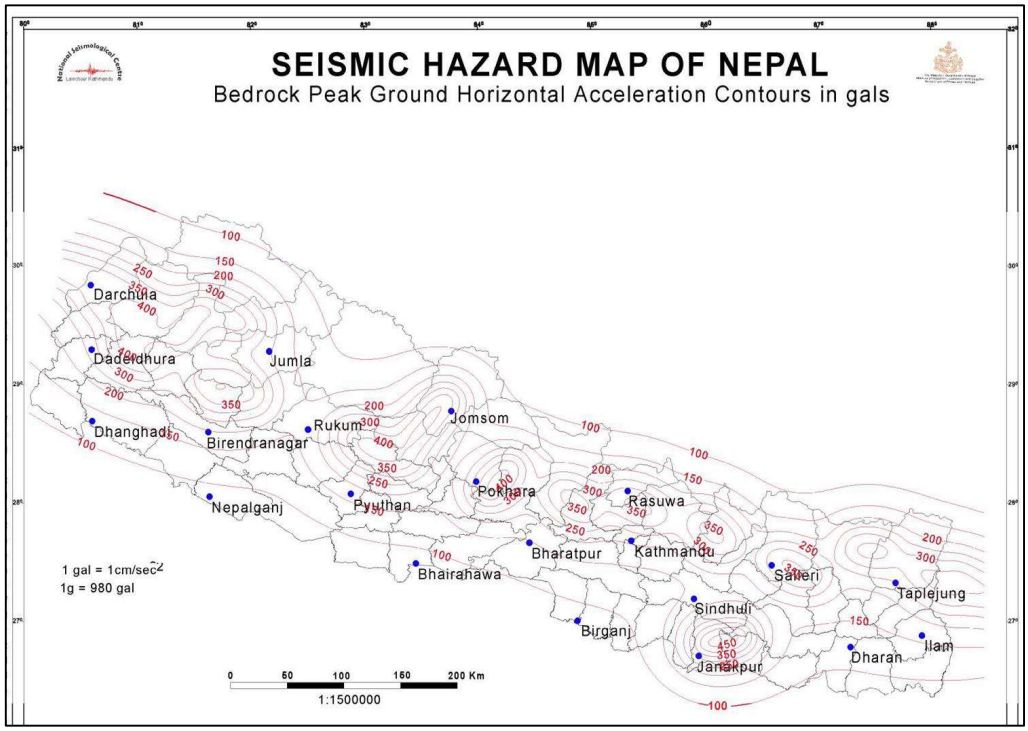

Figure 8-2: Seismic Hazard Map of Nepal Showing Bedrock Peak Ground Horizontal Acceleration Contour

8.2 Seismic Design Parameter

Taking into the account of the above two guidelines published by two different entities Government of Nepal, peak ground acceleration falls between 0.3 to 0.4 associated to a return period of 475 years.

8.3 Evaluation of Liquefaction Triggering: SPT Method

Liquefaction is defined as a phenomenon that occurs in saturated sandy soils that involves the compete transfer of overburden stress from the soil skeleton to the pore fluid under undrained conditions, with the commensurate increase in pore water pressure and reduction in effective stress.

The simplified liquefaction triggering evaluation procedure was first developed by Professor Robert V. Whitman and then subsequently and independently developed by Professor H.B. Seed and I.M. Idriss.

8.3.1 Analysis of Liquefaction Potential

When fine or medium saturated loose sand deposit is subjected to a sudden shock (generated by an earthquake) the mass will densify and consolidate. The pore-water pressure within such layers will increase and results in decrease in effective stress and shear strength of the soil. If the shear strength drops below the applied cyclic shear loadings, the layer is expected to transition to a semi fluid state until excess pore-water pressure dissipates. When liquefaction takes place in a particular soil then the bearing capacity of the soil will be reduced and the soil will fail.

We have followed Seed and Idriss (1971) modified by Idriss and Boulanger (2008) guidelines for the analysis of liquefaction triggering, SPT method. The factor of safety for the liquefaction potential is defined as the ratio of Cyclic Resistance ratio (CRR) and Cyclic stress ratio (CSR). If the ratio is less than one, there is a potential liquefaction in case of the earthquake.

$$CSR = \frac{\tau_{av}}{\sigma'_v} = 0.65 \left(\frac{a_{max}}{g}\right) \left(\frac{\sigma_v}{\sigma'_v}\right) r_d \quad (1)$$

Where,

a_{max} is peak horizontal acceleration

σ_v and σ'_V is total and effective vertical stress

r_d is stress reduction factor

$$r_d = \exp\{\alpha(z) + \beta(z) \times M_w\}; z \leq 34 \text{ m} \quad (2)$$

$$(\alpha) = -1.021 - 1.126 SIN\left(\frac{z}{11.73} + 5.133\right); z \text{ in m} \quad (3)$$

$$\beta(z) = 0.106 + 0.118 SIN9\left(\frac{z}{11.28} + 5.142\right); z \text{ in m} \quad (4)$$

$$(MSF) = 6.9 \exp\left(\frac{M_w}{4}\right) - 0.058 ; \leq 1.8 \quad (5)$$

Where MSF is Magnitude scaling factor

$$N_{1,60cs} = N_{field} * C_N * C_S + \Delta N_{1,60} \quad (6)$$

$$C_N = \left(\frac{P_a}{\sigma'_{vo}}\right)^{\alpha(N_{1,60cs})} \leq 1.7 \quad (7)$$

$$\alpha(N_{1,60cs}) = 0.78 - 0.0768\sqrt{N_{1,60cs}} ; N_{1,60cs} \leq 46 \frac{\text{blws}}{\text{ft}} \quad (8)$$

$$P_a = 101.3\ \text{kPa} \quad (9)$$

$$\nabla N_{1,60} = \exp\left(1.63 + \frac{9.7}{FC + 0.01} - \left(\frac{15.7}{FC + 0.01}\right)^2\right); FC \text{ in } \% \quad (10)$$

$$CRR_{M7.5} = \exp\left\{\frac{N_{1,60cs}}{14.1} + \left(\frac{N_{1,60cs}}{126}\right)^2 - \left(\frac{N_{1,60cs}}{23.6}\right)^3 + \left(\frac{N_{1,60cs}}{25.4}\right)^4 - 2.8\right\} \leq 0.6 \quad (11)$$

$$K_\sigma = 1 - C_\sigma \ln\left(\frac{\sigma'_{vo}}{P_a}\right) \leq 0.3 \quad (12)$$

$$C_\sigma = \frac{1}{18.9 - 2.55\sqrt{N_{1,60cs}}} \leq 0.3 \quad (13)$$

$$FS_{Liq} = \frac{CRR_{M7.5} K_\sigma}{CSR_{M7.5}} \quad (14)$$

The liquefaction triggering analysis based on SPT was analyzed for four borings locations (T238N, T240N, T17/1N and TW198) and found to be non-liquefiable. The detail calculation sheets for Liquefaction Analysis of mentioned tower location are attached in respective annexures. In remaining two locations T138N and T140N, DCPT was performed throughout the depth of boring and found that there is dominance of Gravel and Boulder. Excess porewater pressure will not be generated under such conditions while transferring load from soil skeleton to adjacent pore water. As pore water pressure do not rises progressive loss of strength does not occur. Thus, liquefaction is not likely to occur. Moreover, it is not possible to retrieve samples like SPT during DCPT to obtain fines content requiring to calculate FoS by SPT method.

8.3.2 Mitigation Measures for Liquefaction

To mitigate the effects of liquefaction, the following measures can be taken:

(a) Soil Improvement: Soil improvement techniques can be used to densify the soil and increase its strength, reducing the potential for liquefaction. Methods such as compaction, vibro-compaction, dynamic compaction, compaction grouting and soil mixing can be employed as per site requirements to improve the soil's resistance to liquefaction.

(b) Drainage: Good drainage can help to reduce the risk of liquefaction by removing excess water from the soil. This can be achieved by installing drainage systems such as stone column and surface drainage channels.

(c) Foundations: The design and construction of foundations can be modified to reduce the risk of liquefaction. Measures such as increasing the depth of the foundation or using wider footings can help to stabilize the building.

(d) Seismic Design: Buildings can be designed to withstand seismic forces, including the potential for liquefaction. This can include the use of reinforced concrete or steel frames, as well as the incorporation of seismic isolation or energy dissipation systems.

(e) Monitoring: Monitoring the soil and groundwater conditions can help to identify areas that are at risk of liquefaction. This can include the use of piezometers, seismometers, and other sensors to measure changes in the soil and groundwater levels.

(f) Overall, a comprehensive approach that includes a combination of these measures can help to reduce the risk of liquefaction and mitigate its effects in areas prone to earthquakes.

9 Result and Recommendation

The bore hole logs of bore hole were given in Annex A of this report.

A through perusal of the bore hole reveals that:

(a) The sub soil strata in the boreholes mainly consists of Gravel and Cobble mixed soil with sand, Gravel and Boulder with sand in tower locations T140N, T138N, T238N and T240N.

(b) The sub soil strata in the boreholes mainly varies from Clayey Sand, Poorly Graded Sand, Poorly Graded Sand with Clay and Gravel at T17/1N tower location.

(c) The sub soil strata in the boreholes mainly consists of Well Graded Gravel with Sand and Silt at TW198 tower location.

(d) Most of the tower locations are located near to riverbank (4 out of 6 locations) so, due to the presence of cobble and boulder DCPT was performed and obtained DCPT value is high which might not represent the actual subsurface strata. Considering the potential bed scour by the river, depth of the ground water table and earthquake induced liquefaction in the sandy strata, it will be prudent decision to opt for deep foundation (cast in place piles, CIP).

(e) GWT was observed at 3 tower location (T17/1N, T240N and T138N) site however during monsoon season the water table might rise and could be observed in T140N as well.

(f) The particle size gradation curve shows poorly graded sand with silt and further cobble, coarse gravel to fine sand.

Following results are based on the findings of the geotechnical engineering field subsurface exploration, geotechnical laboratory testing, and geotechnical engineering analyses. Recommendation is provided at each tower based on the site condition and location. Conclusion and recommendations have also drawn upon previous experience with similar site/soil conditions.

(a) Adopt a safe bearing capacity for spread and Mat/Raft foundation at different depths of each site locations given in the annexes.

(b) As per the discussions with client the existing tower location at changed portion of Hetauda section (T137N, T138N and T139N) can be shifted near to Rapti river bank. In this case the new proposed location possesses the risk of scouring of the foundation strata during the high flood event. So, it is recommended to opt for deep foundation (CIP).

(c) The changed portion at section of New Butwal - India Border 400 kV TL is along the river trench of terai region. The obtained SPT value indicates medium dense type of soil. The obtained bearing capacity at different depths and size of foundation is sufficient enough which varies from 17 t/m^2 to 60 t/m^2. However, considering the potential bed scour by the river, depth of the ground water table and earthquake induced liquefaction in the sandy strata, it will be prudent decision to adopt deep foundation (cast in place piles, CIP).

(d) T240N tower location belongs to changed portion at section of New Damauli – Ratmate 400 kV TL section. This tower location is located near Trishuli riverbank so, this site possesses the high risk of foundation scouring and inundation during the event of high flood event. Considering this it is recommended to have deep foundation (CIP) Furthermore, it will be prudent decision to opt deep foundation in all such tower location where investigation has not been carried out.

(e) It is recommended to evaluate the scour potential of the river (for design flood) during the analysis of the foundation (shallow/deep).

(f) The tower should be designed for the permissible differential settlements and tilt as per the Table 1 (clause 16.3.4) IS Code:1904 (1986).

(g) As described in the chapter SEISMICITY in this report, Nepal is very sensitive to experience very strong earthquake eventually. Therefore, the Foundation Design Engineer must pay due attention on seismic forces; it is recommended to follow the seismic design code NBC: 105-2020 or IS: 1893-2016 for analysis and design of the tower.

(h) As a designer, it is important to take into consideration environmental legislation and procedures for the disposal of excavated materials during the design phase of the project. This involves understanding and complying with local, state, and federal regulations related to the management and disposal of soil and other materials that may be excavated during construction.The designer may also need to work with regulatory agencies and other stakeholders to ensure compliance with environmental regulations and to address any concerns related to the project's impact on the environment.

(i) It is recommended to monitor the water table through a long period by installing piezometers to have a good idea of the groundwater.

(j) No bed rock was encountered during site investigation.

(k) Allowable bearing pressure should be re-evaluated during the design stage once the actual foundation width, depth, shape, tilt and ground slope are known. In addition, the impact of raising the elevation of the ground surface to accommodate the proposed development should be further studied.

(l) The slope of the excavation should be maintained as per site conditions to prevent the slope from collapsing during excavation or construction period.

(m) Presence of seepage water and consideration of probable rise in water table in monsoon, side fall is eminent. So, at the time of construction of foundation, it is recommended to design appropriate site protection measures based on soil properties obtained on this report.

(n) An experienced Engineer should inspect excavation of last 30 cm to founding level before the blending of lean concrete. If the soil condition is found different from originally anticipated, additional investigation or redesign of foundation should be carried out.

(o) It is recommended to carry out the MASW test to measure the shear wave velocity of the tower foundation location, which will help us understand the risk further.

(p) It is important that a geotechnician must be notified when cohesive soils are encountered to ensure that the design of the foundations is still adequate.

The detail calculations sheets and laboratory data of New Damauli-Ratamate 400 kV D/C TL, Ratamate New Heatuda 400 kV D/C TL, Indo Nepal Border - New Butwal 400 kV D/C TL and New Butwal - New Damauli 400 kV D/C TL is given in Appendix C to Appendix-H.

The Summary of Bearing Capacity for Spread Footing and Mat Footing are highlighted in Table 9-1 to Table 9-7.

Table 9-1:Bearing Capacity Results of T238N Tower Location Under Changed Portion of New Damauli-Ratamate 400 Kv D/C TL

Location	Foundation Classification	Depth of Footing (m) considered for bearing capacity calculation	Size of footing considered for bearing capacity	Bearing Capacity kN/m^2		Remarks
				Based on shear Faliure criteria	Based on 40 mm settlement Criteria	
T238N (New Damauli-Ratamate 400 kV D/C TL)	**DFR**	1	1 m X 1 m	196	421	Note that the allowable bearing capacity of a footing is controlled by shear failure considerations for narrow footing widths. However, as the footing width increases, the allowable bearing capacity is limited by the settlement potential of the soils supporting the footing. (FHWA-SA-02-054, Shallow Foundation)
			1.5 m X 1.5 m	235	359	
			2 m X 2 m	274	330	
			2.5 m X 2.5 m	313	313	
			3 m X 3 m	352	302	
			4 m X 4 m	430	288	
			5 m X 5 m	508	280	
		2	1 m X 1 m	275	421	
			1.5 m X 1.5 m	294	359	
			2 m X 2 m	314	330	
			2.5 m X 2.5 m	333	313	
			3 m X 3 m	353	302	
			4 m X 4 m	392	288	
			5 m X 5 m	431	280	
		3	1 m X 1 m	392	398	
			1.5 m X 1.5 m	412	339	
			2 m X 2 m	431	311	
			2.5 m X 2.5 m	451	295	

Location	Foundation Classification	Depth of Footing (m) considered for bearing capacity calculation	Size of footing considered for bearing capacity	Bearing Capacity kN/m^2		Remarks
				Based on shear Faliure criteria	Based on 40 mm settlement Criteria	
			3 m X 3 m	470	285	
			4 m X 4 m	509	272	
			5 m X 5 m	548	265	
		4	1 m X 1 m	894	1264	
			1.5 m X 1.5 m	932	1077	
			2 m X 2 m	970	989	
			2.5 m X 2.5 m	1008	938	
			3 m X 3 m	1046	905	
			4 m X 4 m	1122	864	
			5 m X 5 m	1198	840	
		5	1 m X 1 m	1099	1264	
			1.5 m X 1.5 m	1137	1077	
			2 m X 2 m	1175	989	
			2.5 m X 2.5 m	1213	938	
			3 m X 3 m	1251	905	
			4 m X 4 m	1327	864	
			5 m X 5 m	1403	840	
Recommendations	1. Adopt a safe bearing capacity for spread and Mat/Raft foundation at different depths. 2. Nepal is very sensitive to experience very strong earthquake eventually. Therefore, the Foundation Design Engineer must pay due attention on seismic forces; it is recommended to follow the seismic design code NBC: 105-2020 or IS: 1893-2016 for analysis and design of the tower.					

Table 9-2: Bearing Capacity Results of T240N Tower Location Under Changed Portion of New Damauli-Ratamate 400 kV D/C TL

Location	Foundation Classification	Depth of Footing (m) considered for bearing capacity calculation	Size of footing considered for bearing capacity	Bearing Capacity kN/m²		Remarks
				Based on shear Faliure criteria	Based on 40 mm settlement Criteria	
T240N (New Damauli-Ratamate 400 kV D/C TL)	WET	1	1 m X 1 m	196	421	Note that the allowable bearing capacity of a footing is controlled by shear failure considerations for narrow footing widths. However, as the footing width increases, the allowable bearing capacity is limited by the settlement potential of the soils supporting the footing. (FHWA-SA-02-054, Shallow Foundation)
			1.5 m X 1.5 m	235	359	
			2 m X 2 m	274	330	
			2.5 m X 2.5 m	313	313	
			3 m X 3 m	352	302	
			4 m X 4 m	430	288	
			5 m X 5 m	508	280	
		2	1 m X 1 m	275	421	
			1.5 m X 1.5 m	294	359	
			2 m X 2 m	314	330	
			2.5 m X 2.5 m	333	313	
			3 m X 3 m	353	302	
			4 m X 4 m	392	288	
			5 m X 5 m	431	280	
		3	1 m X 1 m	690	2270	
			1.5 m X 1.5 m	728	1935	
			2 m X 2 m	766	1777	
			2.5 m X 2.5 m	804	1685	
			3 m X 3 m	842	1626	
			4 m X 4 m	918	1553	
			5 m X 5 m	994	1510	
		4	1 m X 1 m	894	2153	

Location	Foundation Classification	Depth of Footing (m) considered for bearing capacity calculation	Size of footing considered for bearing capacity	Bearing Capacity kN/m^2		Remarks
				Based on shear Faliure criteria	Based on 40 mm settlement Criteria	
			1.5 m X 1.5 m	932	1835	
			2 m X 2 m	970	1685	
			2.5 m X 2.5 m	1008	1598	
			3 m X 3 m	1046	1542	
			4 m X 4 m	1122	1472	
			5 m X 5 m	1198	1432	
		5	1 m X 1 m	1099	2153	
			1.5 m X 1.5 m	1137	1835	
			2 m X 2 m	1175	1685	
			2.5 m X 2.5 m	1213	1598	
			3 m X 3 m	1251	1542	
			4 m X 4 m	1327	1472	
			5 m X 5 m	1403	1432	

Location	Foundation Classification	Depth of Footing (m) considered for bearing capacity calculation	Size of footing considered for bearing capacity	Bearing Capacity kN/m²		Remarks
				Based on shear Faliure criteria	Based on 40 mm settlement Criteria	
Recommendations	1. This tower locations is located near to Trishuli riverbank so, due to the presence of cobble and boulder DCPT was performed, the obtained DCPT value might not represent the actual subsurface strata. Considering the potential bed scour by the river, depth of the ground water table and earthquake induced liquefaction in the sandy strata, it will be prudent decision to opt for deep foundation (cast in place piles, CIP). 2. Adopt a safe bearing capacity for spread and Mat/Raft foundation at different depths. 3. Nepal is very sensitive to experience very strong earthquake eventually. Therefore, the Foundation Design Engineer must pay due attention on seismic forces; it is recommended to follow the seismic design code NBC: 105-2020 or IS: 1893-2016 for analysis and design of the tower. 4. It will be wise decision to adopt deep foundation in all such tower location in the vicinity where investigation has not been carried out.					

Table 9-3: Bearing Capacity Results of T138N Tower Location Under Changed Portion of Ratamate New Heatuda 400 kV D/C TL

Location	Foundation Classification	Depth of Footing (m) considered for bearing capacity calculation	Size of footing considered for bearing capacity	Bearing Capacity kN/m²		Remarks
				Based on shear Faliure criteria	Based on 40 mm settlement Criteria	
T138N (Ratamate New Heatuda 400 kV D/C TL)	**WET**	1	1 m X 1 m	196	257	Note that the allowable bearing capacity of a footing is controlled by shear failure considerations for narrow footing widths. However, as the footing width
			1.5 m X 1.5 m	235	219	
			2 m X 2 m	274	201	

Location	Foundation Classification	Depth of Footing (m) considered for bearing capacity calculation	Size of footing considered for bearing capacity	Bearing Capacity kN/m^2		Remarks
				Based on shear Faliure criteria	Based on 40 mm settlement Criteria	
			2.5 m X 2.5 m	313	191	increases, the allowable bearing capacity is limited by the settlement potential of the soils supporting the footing. (FHWA-SA-02-054, Shallow Foundation)
			3 m X 3 m	352	184	
			4 m X 4 m	430	176	
			5 m X 5 m	508	171	
		2	1 m X 1 m	275	257	
			1.5 m X 1.5 m	294	219	
			2 m X 2 m	314	201	
			2.5 m X 2.5 m	333	191	
			3 m X 3 m	353	184	
			4 m X 4 m	392	176	
			5 m X 5 m	431	171	
		3	1 m X 1 m	690	2270	
			1.5 m X 1.5 m	728	1935	
			2 m X 2 m	766	1777	
			2.5 m X 2.5 m	804	1685	
			3 m X 3 m	842	1626	
			4 m X 4 m	918	1553	
			5 m X 5 m	994	1510	
		4	1 m X 1 m	894	1592	
			1.5 m X 1.5 m	932	1356	
			2 m X 2 m	970	1246	
			2.5 m X 2.5 m	1008	1181	
			3 m X 3 m	1046	1140	

Location	Foundation Classification	Depth of Footing (m) considered for bearing capacity calculation	Size of footing considered for bearing capacity	Bearing Capacity kN/m^2		Remarks
				Based on shear Faliure criteria	Based on 40 mm settlement Criteria	
			4 m X 4 m	1122	1088	
			5 m X 5 m	1198	1058	
		5	1 m X 1 m	1099	1592	
			1.5 m X 1.5 m	1137	1356	
			2 m X 2 m	1175	1246	
			2.5 m X 2.5 m	1213	1181	
			3 m X 3 m	1251	1140	
			4 m X 4 m	1327	1088	
			5 m X 5 m	1403	1058	
Recommendations	1. This tower locations is located near to Rapti riverbank so, due to the presence of cobble and boulder DCPT was performed, the obtained DCPT value might not represent the actual subsurface strata. Considering the potential bed scour by the river, depth of the ground water table and earthquake induced liquefaction in the sandy strata, it will be prudent decision to opt for deep foundation (cast in place piles, CIP). 2. Adopt a safe bearing capacity for spread and Mat/Raft foundation at different depths. 3. Nepal is very sensitive to experience very strong earthquake eventually. Therefore, the Foundation Design Engineer must pay due attention on seismic forces; it is recommended to follow the seismic design code NBC: 105-2020 or IS: 1893-2016 for analysis and design of the tower. 4. It will be wise decision to adopt deep foundation in all such tower location in the vicinity where investigation has not been carried out.					

Table 9-4: Bearing Capacity Results of T140N Tower Location Under Changed Portion of Ratamate New Heatuda 400 kV D/C TL

Location	Foundation Classification	Depth of Footing (m) considered for bearing capacity calculation	Size of footing considered for bearing capacity	Bearing Capacity kN/m²		Remarks
				Based on shear Faliure criteria	Based on 40 mm settlement Criteria	
T140N (Ratamate New Heatuda 400 kV D/C TL)	DRY	1	1 m X 1 m	357	1873	Note that the allowable bearing capacity of a footing is controlled by shear failure considerations for narrow footing widths. However, as the footing width increases, the allowable bearing capacity is limited by the settlement potential of the soils supporting the footing. (FHWA-SA-02-054, Shallow Foundation)
			1.5 m X 1.5 m	433	1596	
			2 m X 2 m	509	1465	
			2.5 m X 2.5 m	585	1390	
			3 m X 3 m	661	1341	
			4 m X 4 m	813	1280	
			5 m X 5 m	965	1245	
		2	1 m X 1 m	485	1873	
			1.5 m X 1.5 m	523	1596	
			2 m X 2 m	561	1465	
			2.5 m X 2.5 m	599	1390	
			3 m X 3 m	637	1341	
			4 m X 4 m	713	1280	
			5 m X 5 m	789	1245	
		3	1 m X 1 m	590	1404	
			1.5 m X 1.5 m	728	1197	
			2 m X 2 m	766	1099	
			2.5 m X 2.5 m	804	1042	
			3 m X 3 m	842	1006	
			4 m X 4 m	918	960	
			5 m X 5 m	994	934	
		4	1 m X 1 m	894	1919	
			1.5 m X 1.5 m	932	1635	

Location	Foundation Classification	Depth of Footing (m) considered for bearing capacity calculation	Size of footing considered for bearing capacity	Bearing Capacity kN/m^2		Remarks
				Based on shear Faliure criteria	Based on 40 mm settlement Criteria	
			2 m X 2 m	970	1502	
			2.5 m X 2.5 m	1008	1425	
			3 m X 3 m	1046	1374	
			4 m X 4 m	1122	1312	
			5 m X 5 m	1198	1276	
		5	1 m X 1 m	1099	191	
			1.5 m X 1.5 m	1137	1635	
			2 m X 2 m	1175	1502	
			2.5 m X 2.5 m	1213	1425	
			3 m X 3 m	1251	1374	
			4 m X 4 m	1327	1312	
			5 m X 5 m	1403	1276	
Recommendations	1. This tower locations is located near to Rapti riverbank so, due to the presence of cobble and boulder DCPT was performed, the obtained DCPT value might not represent the actual subsurface strata. Considering the potential bed scour by the river, depth of the ground water table and earthquake induced liquefaction in the sandy strata, it will be prudent decision to opt for deep foundation (cast in place piles, CIP). 2. Adopt a safe bearing capacity for spread and Mat/Raft foundation at different depths. 3. Nepal is very sensitive to experience very strong earthquake eventually. Therefore, the Foundation Design Engineer must pay due attention on seismic forces; it is recommended to follow the seismic design code NBC: 105-2020 or IS: 1893-2016 for analysis and design of the tower. 4. It will be wise decision to adopt deep foundation in all such tower location in the vicinity where investigation has not been carried out.					

Table 9-5: Bearing Capacity Results of T17/1N Tower Location Under Changed Portion of Indo Nepal Border - New Butwal 400 kV D/C TL

Location	Foundation Classification	Depth of Footing (m) considered for bearing capacity calculation	Size of footing considered for bearing capacity	Bearing Capacity kN/m²		Remarks
				Based on shear Faliure criteria	Based on 40 mm settlement Criteria	
T17/1N (Indo Nepal Border - New Butwal 400 kV D/C TL)	WET	1	1 m X 1 m	172	421	Note that the allowable bearing capacity of a footing is controlled by shear failure considerations for narrow footing widths. However, as the footing width increases, the allowable bearing capacity is limited by the settlement potential of the soils supporting the footing. (FHWA-SA-02-054, Shallow Foundation)
			1.5 m X 1.5 m	205	359	
			2 m X 2 m	239	330	
			2.5 m X 2.5 m	272	313	
			3 m X 3 m	306	302	
			4 m X 4 m	373	288	
			5 m X 5 m	440	280	
		2	1 m X 1 m	256	421	
			1.5 m X 1.5 m	274	359	
			2 m X 2 m	291	330	
			2.5 m X 2.5 m	309	313	
			3 m X 3 m	327	302	
			4 m X 4 m	362	288	
			5 m X 5 m	398	280	
		3	1 m X 1 m	366	515	
			1.5 m X 1.5 m	384	439	
			2 m X 2 m	402	403	
			2.5 m X 2.5 m	419	382	
			3 m X 3 m	437	369	
			4 m X 4 m	473	352	
			5 m X 5 m	508	342	
		4	1 m X 1 m	476	585	
			1.5 m X 1.5 m	498	499	

Location	Foundation Classification	Depth of Footing (m) considered for bearing capacity calculation	Size of footing considered for bearing capacity	Bearing Capacity kN/m^2		Remarks
				Based on shear Faliure criteria	Based on 40 mm settlement Criteria	
			2 m X 2 m	512	458	
			2.5 m X 2.5 m	530	434	
			3 m X 3 m	547	419	
			4 m X 4 m	583	400	
			5 m X 5 m	618	389	
		5	1 m X 1 m	587	585	
			1.5 m X 1.5 m	604	499	
			2 m X 2 m	622	458	
			2.5 m X 2.5 m	640	434	
			3 m X 3 m	657	419	
			4 m X 4 m	693	400	
			5 m X 5 m	728	389	
Recommendations	1. This tower location is located near to Jharai Khola. Though he obtained SPT value indicates medium dense type of soil, considering the potential bed scour by the river, depth of the ground water table and earthquake induced liquefaction in the sandy strata, it will be prudent decision to adopt deep foundation (cast in place piles, CIP). 2. Adopt a safe bearing capacity for spread and Mat/Raft foundation at different depths. 3. Nepal is very sensitive to experience very strong earthquake eventually. Therefore, the Foundation Design Engineer must pay due attention on seismic forces; it is recommended to follow the seismic design code NBC: 105-2020 or IS: 1893-2016 for analysis and design of the tower. 4. It will be wise decision to adopt deep foundation in all such tower location in the vicinity where investigation has not been carried out.					

Table 9-6: Bearing Capacity Results of T198N Tower Location Under Changed Portion of New Butwal - New Damauli 400 kV D/C TL

Location	Foundation Classification	Depth of Footing (m) considered for bearing capacity calculation	Size of footing considered for bearing capacity	Bearing Capacity kN/m²		Remarks
				Based on shear Faliure criteria	Based on 40 mm settlement Criteria	
TW198 (New Butwal - New Damauli 400 kV D/C TL)	**DFR**	1	1 m X 1 m	224	702	Note that the allowable bearing capacity of a footing is controlled by shear failure considerations for narrow footing widths. However, as the footing width increases, the allowable bearing capacity is limited by the settlement potential of the soils supporting the footing. (FHWA-SA-02-054, Shallow Foundation)
			1.5 m X 1.5 m	269	598	
			2 m X 2 m	314	549	
			2.5 m X 2.5 m	360	521	
			3 m X 3 m	405	503	
			4 m X 4 m	496	480	
			5 m X 5 m	586	467	
		2	1 m X 1 m	329	702	
			1.5 m X 1.5 m	353	598	
			2 m X 2 m	377	549	
			2.5 m X 2.5 m	401	521	
			3 m X 3 m	424	503	
			4 m X 4 m	472	480	
			5 m X 5 m	520	467	
		3	1 m X 1 m	532	936	
			1.5 m X 1.5 m	560	798	
			2 m X 2 m	588	733	
			2.5 m X 2.5 m	616	695	
			3 m X 3 m	644	670	
			4 m X 4 m	700	640	
			5 m X 5 m	755	622	
		4	1 m X 1 m	894	1100	
			1.5 m X 1.5 m	932	937	

			2 m X 2 m	970	861	
			2.5 m X 2.5 m	1008	817	
			3 m X 3 m	1046	788	
			4 m X 4 m	1122	752	
			5 m X 5 m	1198	731	
		5	1 m X 1 m	1099	1100	
			1.5 m X 1.5 m	1137	937	
			2 m X 2 m	1175	861	
			2.5 m X 2.5 m	1213	817	
			3 m X 3 m	1251	788	
			4 m X 4 m	1327	752	
			5 m X 5 m	1403	731	
Recommendations	1. Adopt a safe bearing capacity for spread and Mat/Raft foundation at different depths. 2. As described in the chapter SEISMICITY in this report, Nepal is very sensitive to experience very strong earthquake eventually. Therefore, the Foundation Design Engineer must pay due attention on seismic forces; it is recommended to follow the seismic design code NBC: 105-2020 or IS: 1893-2016 for analysis and design of the tower.					

Table 9-7: Summary of Bearing Capacity for Mat Foundation

Location	Depth of Footing considered for bearing capacity calculation	Based on 65 mm settlement Criteria kN/m^2
T238N (New Damauli-Ratamate 400 kV D/C TL)	1	229
	3	216
	4	686
	6	1232
	7	1016
	9	914
	10	749
	12	432
T240N (New Damauli-Ratamate 400 kV D/C TL)	1	229
	3	1232
	4	1168
	6	1232
	7	1549
	9	1016
	10	1232
	12	1232
T138N (Ratamate New Heatuda 400 kV D/C TL)	1	140
	3	1232
	4	864
	6	1232
	7	749
	9	686
	10	1232
	12	1016
T140N (Ratamate New Heatuda 400 kV D/C TL)	1	1016
	3	800
	4	1041
	6	1168
	7	686
	9	826
	10	635
	12	1143
T17/1N (Indo Nepal Border - New Butwal 400 kV D/C TL)	1	229
	3	279
	4	318
	6	254
	7	762
	9	699

Location	Depth of Footing considered for bearing capacity calculation	Based on 65 mm settlement Criteria kN/m^2
	10	889
	12	597
TW198 (New Butwal - New Damauli 400 kV D/C TL)	1	381
	3	508
	4	597
	6	1054
	7	1232
	9	1156
	10	1016
	12	1232

10 References

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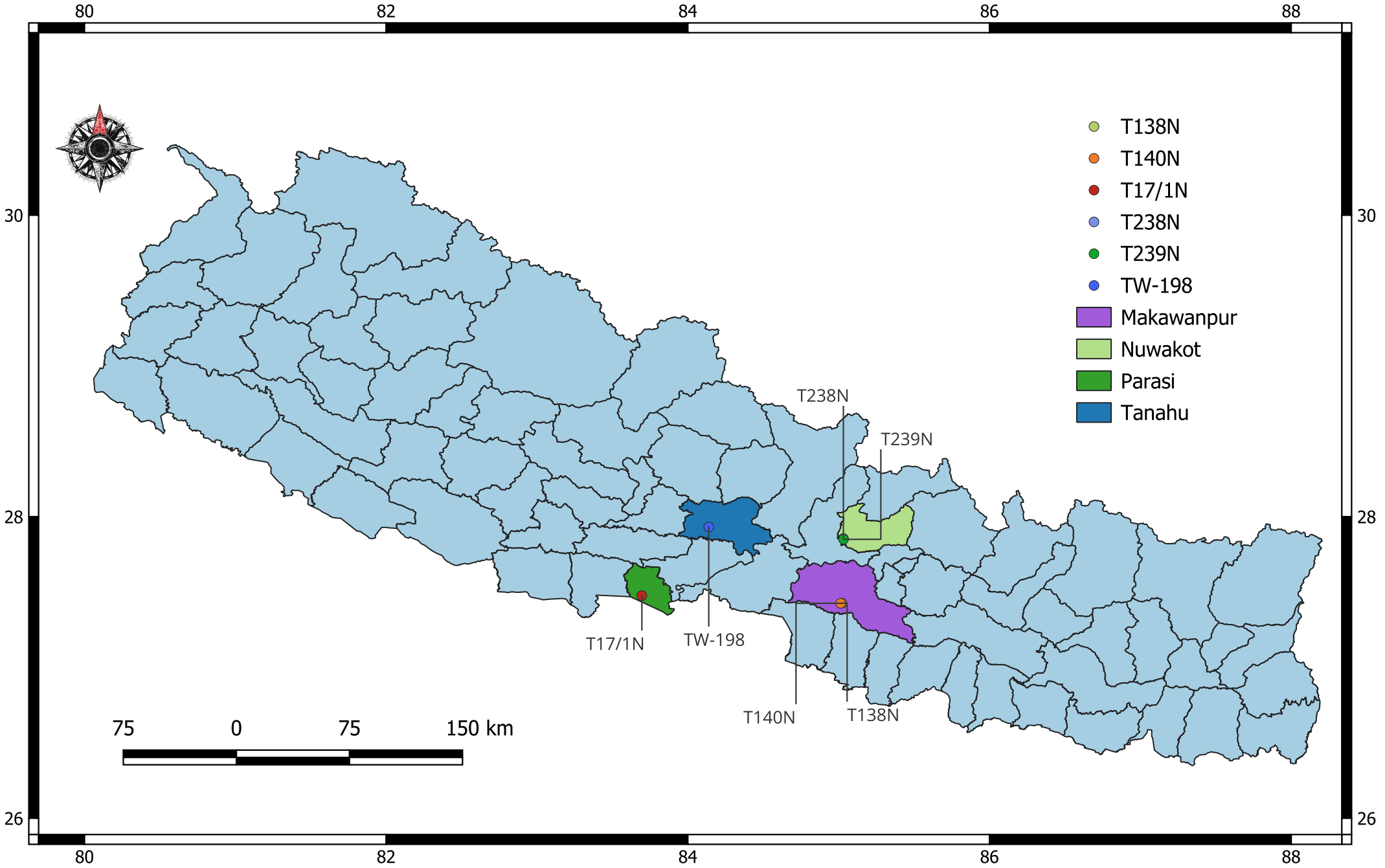
APPENDIX-A

Borehole Log and Location Plan

Districts Showing Borehole Location in Map of Nepal



170000

175000

3050000

3050000

3045000

3045000

170000

175000

T51N

TEMPLE

T50/1N

T48/AN

T47N

AP48B

T46N

T45N

T45/1N

T41N

T21N

T20N

T19N

T18N

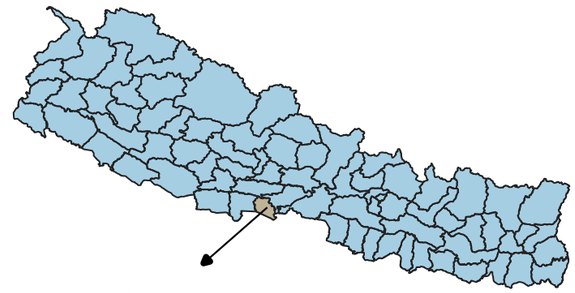
T17/2N

T17/1N

T16N

N

Location Map of Borehole Location and Associated Tower Locations for 30 km of Changes in 400 kV TL Route Alignment

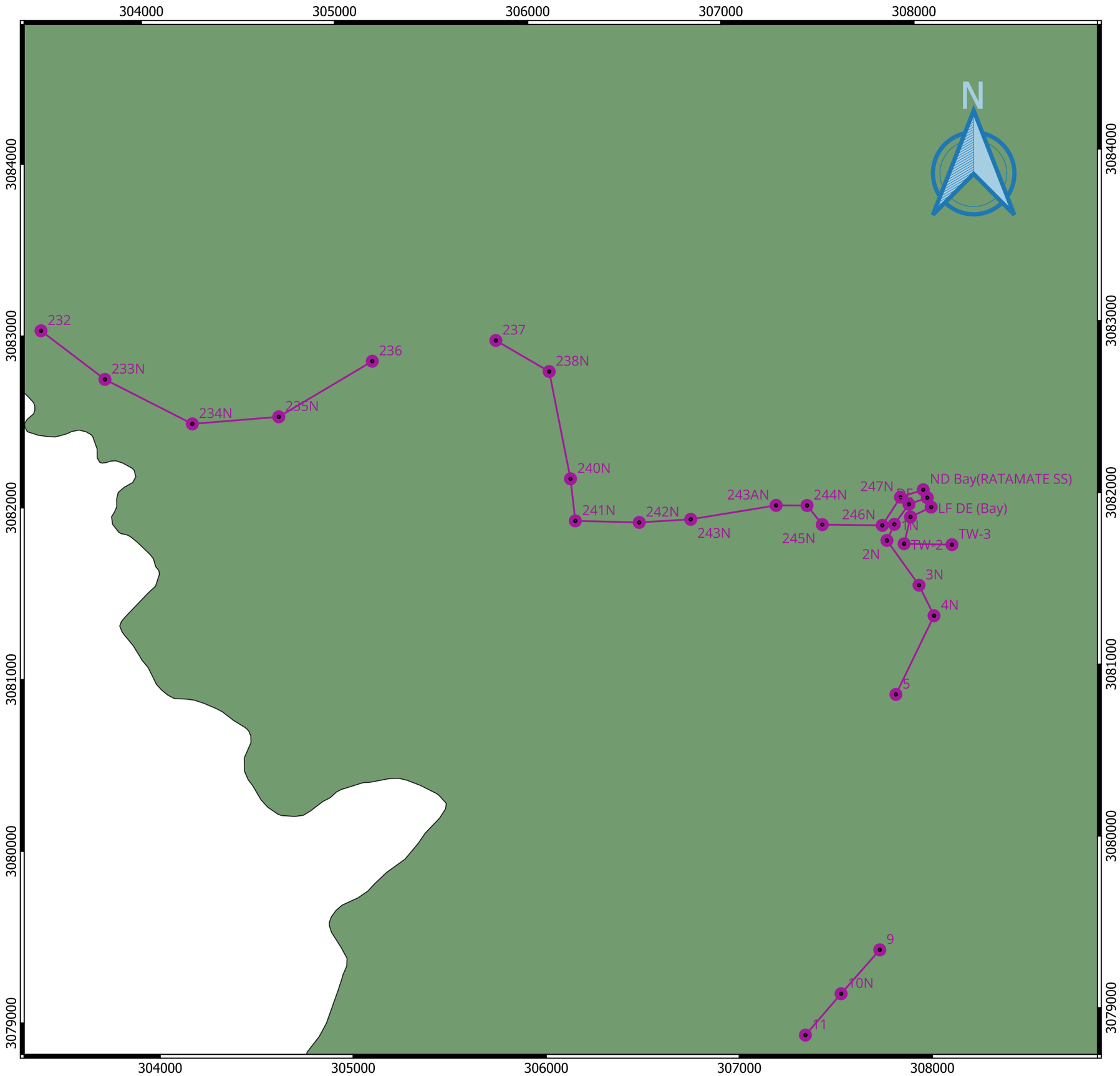


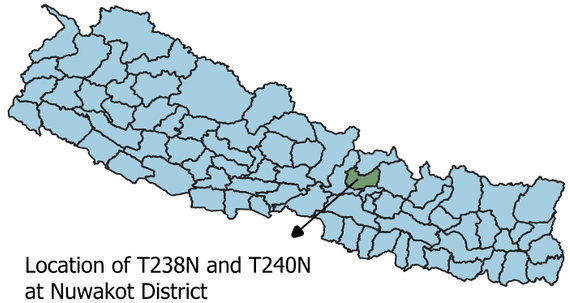
Location of 17/1 at Parasi District

Changed Portion

- Tower Locations
- Transmission Line
- Parasi District
- Districts of Nepal

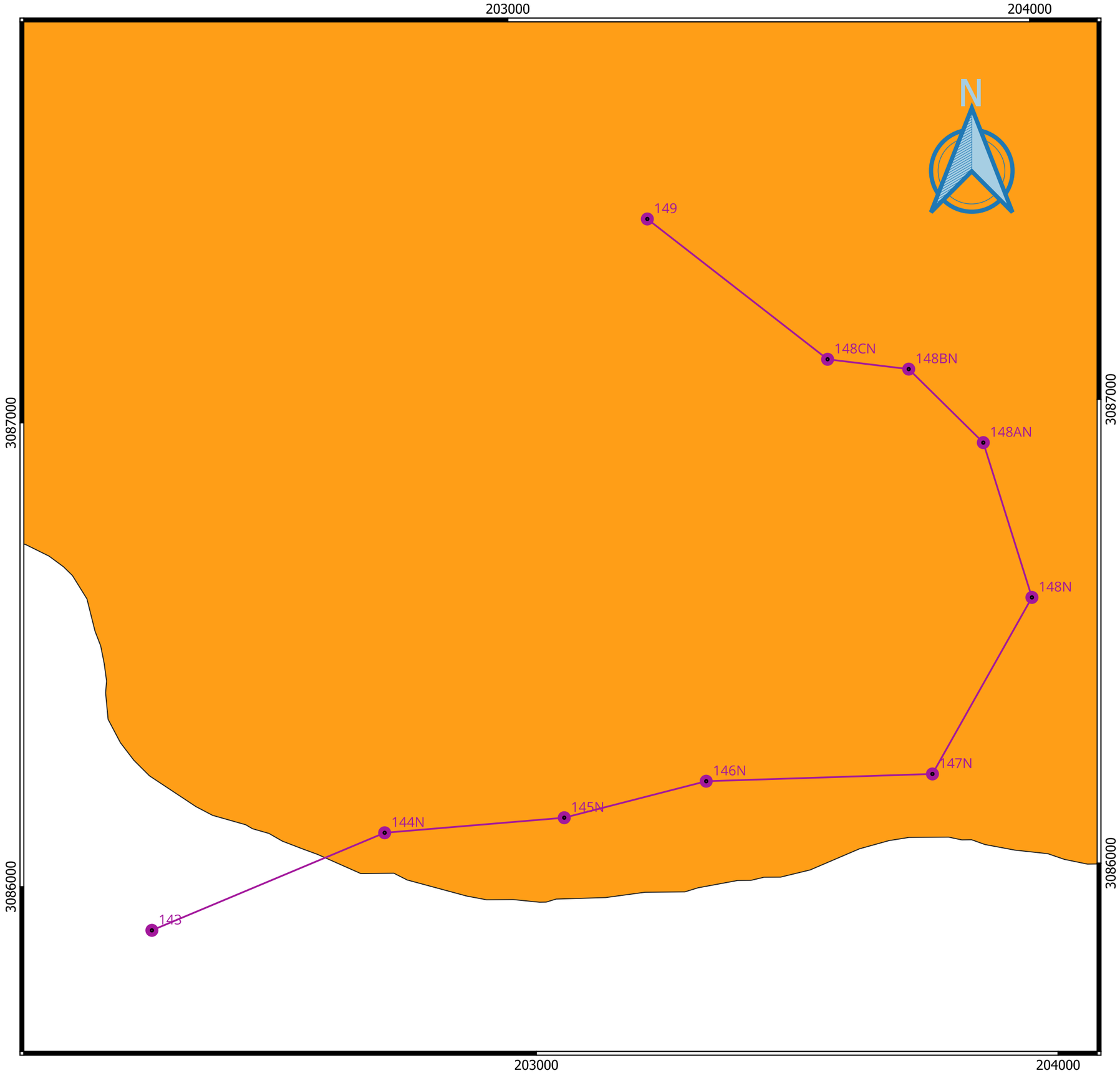
Location Map of Borehole Location and Associated Tower Locations for 30 km of Changes in 400 kV TL Route Alignment

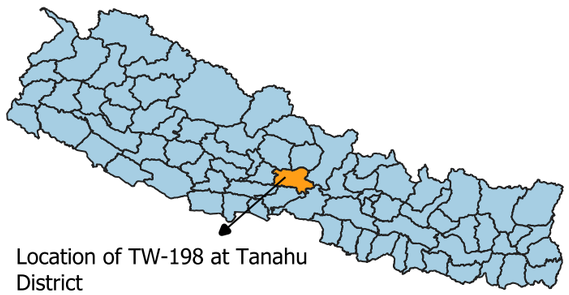




- Tower Location
- Transmission Line
- Districts of Nepal
- Nuwakot District

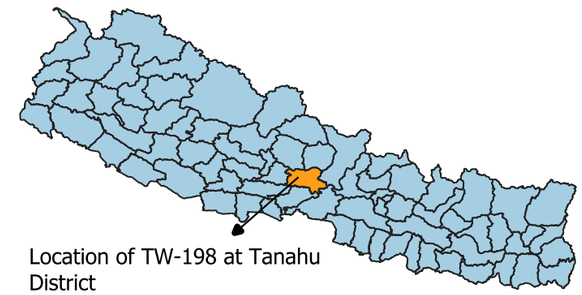
Location Map of Borehole Location and Associated Tower Locations for 30 km of Changes in 400 kV TL Route Alignment

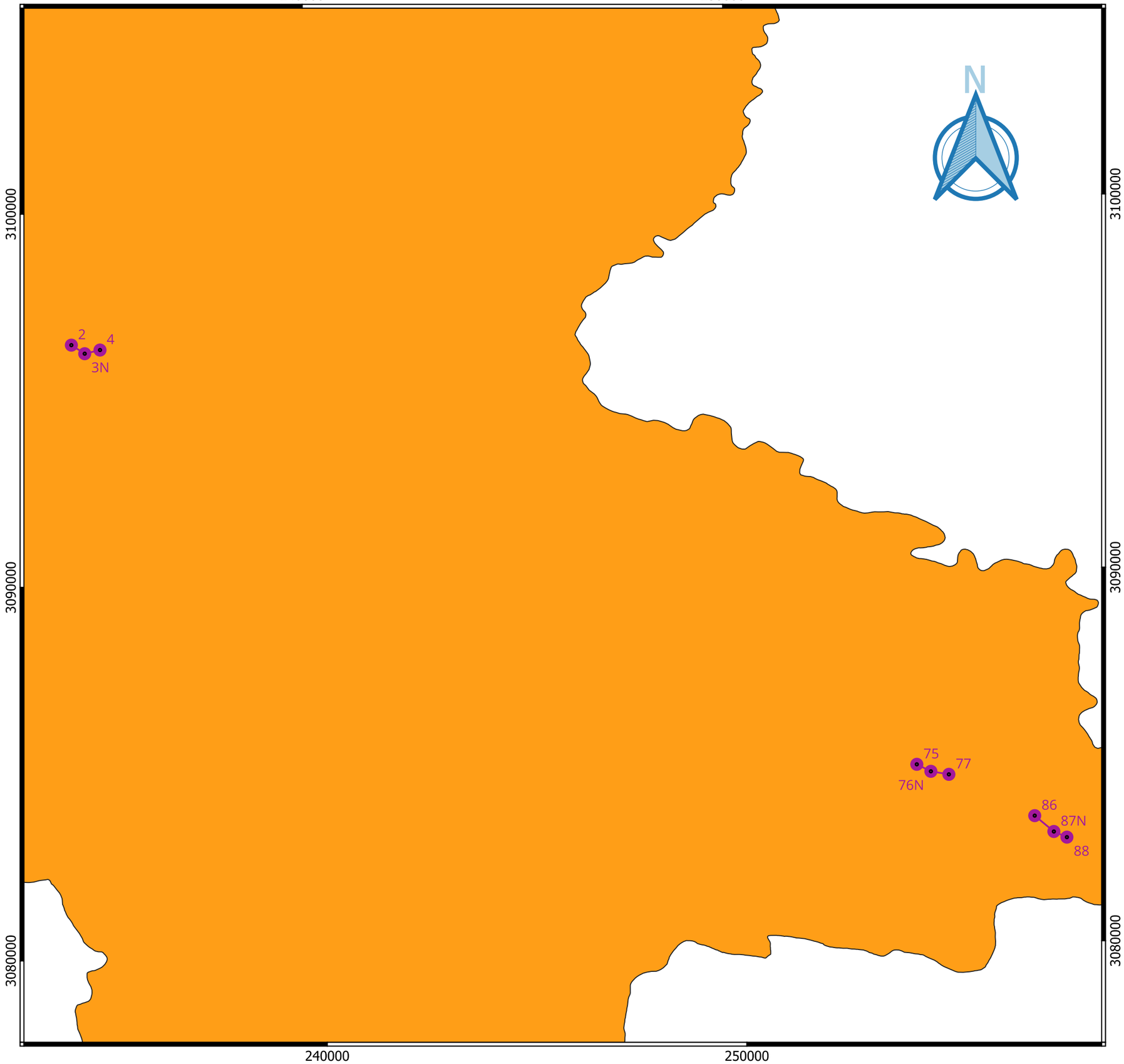




- Tower Location
- Transmission Line
- Districts of Nepal
- Tanahu District

Location Map of Borehole Location and Associated Tower Locations for 30 km of Changes in 400 kV TL Route Alignment

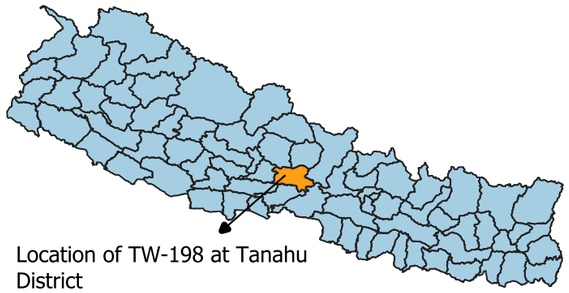




- Tower Location
- Transmission Line
- Districts of Nepal
- Tanahu District

218000
219000
3094000
3093000
3092000
N
198
200

Location Map of Borehole Location and Associated Tower Locations for 30 km of Changes in 400 kV TL Route Alignment

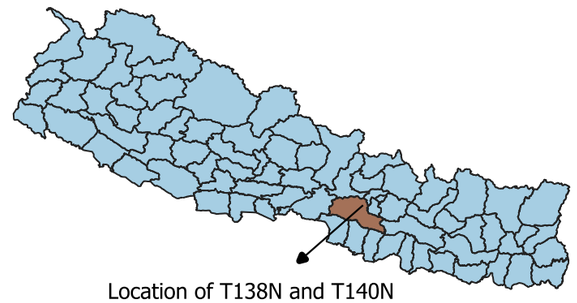


Location of TW-198 at Tanahu District

- Tower Location
- Transmission Line
- Districts of Nepal
- Tanahu District

303000
304000
3037000
3036000
3035000
N
132
133N
133AN
134N
135N
136N
137N
138N
139N
140N
141N
142N (NEA "QC")
143N (NEA "QC")
144N
145N
146N
Gantry

Location Map of Borehole Location and Associated Tower Locations for 30 km of Changes in 400 kV TL Route Alignment



Location of T138N and T140N
at Makwanpur District

- Tower Location
- Transmission Line
- Makwanpur District
- Districts of Mepal

Traceable Measurement Pvt. Ltd.
Drilling Log

Project:	Soil Investigation Works of Consulting Services for Detailed Survey and Updated Line Design for 30 km of Changes in 400kV Transmission Line Route Alignment		
Location:	New Damauli-Ratamate 400 kV D/C TL	Position Cordinate	
Client:	MCA-N	Easting (m)	Northing (m)
Borehole No:	T238N	306079	3082750
Dates	Started: 29/09/2079		
	Finished: 9/31/2079		
Method:	SPT and DCPT	Water Table :-	Dry
Hammer Type:	Monkey Hammer		

Material Description	Symbol	Depth, m	Sample No. &Type	No. of blows 15/10 cm	No. of blows 15/10 cm	No. of blows 15/10 cm	N-Value	Ncr-Value
Well Graded Sand with Gravel; moist, brown, fine to coarse grained sand	SW	- 1	SPT	10	9	12	21	
		- 2						
		- 3	SPT	9	10	10	20	
Gravel and Cobble mixed Soil with Sand		- 4	DCPT					50/15
		- 5						
		- 6	DCPT					50/3
		- 7	DCPT					50/9
		- 8						
		- 9	DCPT					50/10
		- 10	DCPT	25	25/5	50/15		125/30
		- 11						
		- 12	DCPT					50/20

N-Value SPT DCPT

End Depth * **Completed at 12.00m** **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

Notes:

1. Bottom of Boring at 20.0 m. SPT was conducted upto depth of 3 m and DCPT was conducted from 3m to 12 m.
2. Boring terminated at selected depth.
3. Boring backfilled with auger cuttings upon completion.
4. Emperical Relation Between DCPT (Ncr) and SPT (N) values:

Ncr = 1.5 N for depths upto 3.00 m
Ncr = 1.75 N for depths 3.00 m to 6.00 m
Ncr = 2.00 N for depths greater than 6.00 m
Where,
Ncr = recorded DCPT values
N = SPT values

TRACEABLE MEASUREMENTS

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Traceable Measurement Pvt. Ltd.
Drilling Log

Project:	Soil Investigation Works of Consulting Services for Detailed Survey and Updated Line Design for 30 km of Changes in 400kV Transmission Line Route Alignment		
Location:	New Damauli-Ratamate 400 kV D/C TL	Position Cordinate	
Client:	MCA-N	Easting (m)	Northing (m)
Borehole No:	T240N	306317	3082408
Dates	Started: 08/08/2079		
	Finished: 09/08/2079		
Method:	**Rotary Boring**	Water Table :-	4.5m
Hammer Type:	Monkey Hammer		

Material Description	Symbol	Depth, m	Sample No. &Type	No. of blows 15/10 cm	15/10 cm	15/10 cm	N-Value	Ncr-Value
Poorly Graded Sand with Silt; moist, dark brown, fine to coarse grained sand	SP-SM	- 1	SPT	10	9	12	21	
Gravel and Cobble mixed Soil with Sand		- 2						
		- 3	DCPT	50/10				50/10
		- 4	DCPT	50/9				50/9
		- 5						
		- 6	DCPT	50/8				50/8
		- 7						
		- 8	DCPT	50/6				50/6
		- 9	DCPT	50/9				50/9
		- 10						
		- 11	DCPT	50/7				50/7
		- 12	DCPT	50/5				50/5

N-Value SPT DCPT

End Depth * Completed at 12.00m **Ground: Dry**

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

Notes:

1. Bottom of Boring at 20.0 m. SPT was conducted upto depth of 2 m and DCPT was conducted from 3m to 12 m.
2. Boring terminated at selected depth.
3. Boring backfilled with auger cuttings upon completion.
4. Emperical Relation Between DCPT (Ncr) and SPT (N) values:

Ncr = 1.5 N for depths upto 3.00 m
Ncr = 1.75 N for depths 3.00 m to 6.00 m
Ncr = 2.00 N for depths greater than 6.00 m
Where,
Ncr = recorded DCPT values
N = SPT values

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Drilling Log

Project:	Soil Investigation Works of Consulting Services for Detailed Survey and Updated Line Design for 30 km of Changes in 400kV Transmission Line Route Alignment		
Location:	Ratamate New Heatuda 400 kV D/C TL	Position Cordinate	
Client:	MCA-N	Easting (m)	Northing (m)
Borehole No:	T138N	304271	3035190
Dates	Started: 09/09/2079		
	Finished: 12/09/2079		
Method:	**DCPT**	Water Table :-	7.3m
Hammer Type:	Monkey Hammer		

Material Description	Symbol	Depth, m	Sample No. &Type	No. of blows 10 cm	No. of blows 10 cm	No. of blows 10 cm	N-Value	Ncr-Value
Gravel and Boulder with sand		- 1	DCPT	4	11	7		22
		- 2						
		- 3	DCPT					50/9
		- 4	DCPT					50/12
		- 5						
		- 6	DCPT					50/6
		- 7	DCPT					50/12
		- 8						
		- 9	DCPT					50/13
		- 10	DCPT					50/7
		- 11						
		- 12	DCPT					50/9

N-Value SPT / DCPT

End Depth * **Completed at 12.00m** **Ground: Dry**

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

Notes:

1. Bottom of Boring at 20.0 m.
2. Boring terminated at selected depth.
3. Boring backfilled with auger cuttings upon completion.
4. Emperical Relation Between DCPT (Ncr) and SPT (N) values:

Ncr = 1.5 N for depths upto 3.00 m
Ncr = 1.75 N for depths 3.00 m to 6.00 m
Ncr = 2.00 N for depths greater than 6.00 m
Where,
Ncr = recorded DCPT values
N = SPT values

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Drilling Log

Project:	Soil Investigation Works of Consulting Services for Detailed Survey and Updated Line Design for 30 km of Changes in 400kV Transmission Line Route Alignment		
Location:	Ratamate New Heatuda 400 kV D/C TL	Position Cordinate	
Client:	MCA-N	Easting (m)	Northing (m)
Borehole No:	T140N	303560	3035120
Dates	Started: 14/09/2079		
	Finished: 15/09/2079		
Method:	DCPT	Water Table :-	Dry
Hammer Type:	Monkey Hammer		

Material Description	Symbol	Depth, m	Sample No. &Type	No. of blows 10 cm	10 cm	10 cm	N-Value	Ncr-Value
Gravel and Boulder with sand		1	DCPT					50/12
		2						
		3	DCPT					50/15
		4	DCPT					50/10
		5						
		6	DCPT					50/9
		7	DCPT					50/13
		8						
		9	DCPT					50/11
		10	DCPT					50/14
		11						
		12	DCPT					50/8

N-Value SPT DCPT

End Depth * Completed at 12.00m 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

Notes:

1. Bottom of Boring at 20.0 m.
2. Boring terminated at selected depth.
3. Boring backfilled with auger cuttings upon completion.
4. Emperical Relation Between DCPT (Ncr) and SPT (N) values:

Ncr = 1.5 N for depths upto 3.00 m
Ncr = 1.75 N for depths 3.00 m to 6.00 m
Ncr = 2.00 N for depths greater than 6.00 m
Where,
Ncr = recorded DCPT values
N = SPT values

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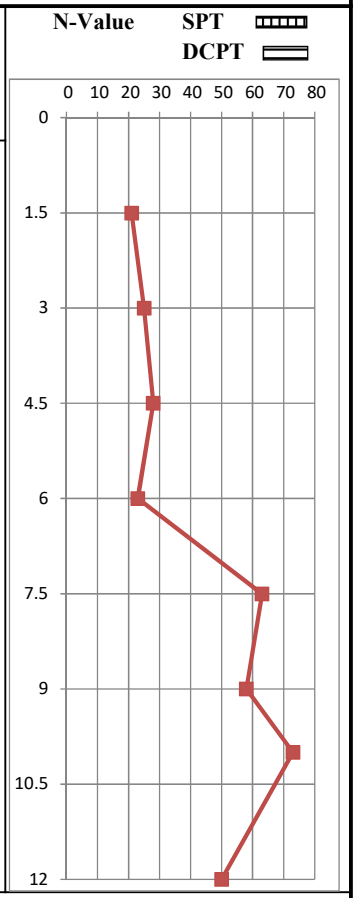
Drilling Log

Project:	Soil Investigation Works of Consulting Services for Detailed Survey and Updated Line Design for 30 km of Changes in 400kV Transmission Line Route Alignment		
Location:	Indo Nepal Border - New Butwal 400 kV D/C TL	Position Cordinate	
Client:	MCA-N	Easting (m)	Northing (m)
Borehole No:	T17/1N	173344	3043566
Dates	Started: 17/09/2079		
	Finished: 20/09/2079		
Method:	**Rotary Boring and SPT**	Water Table :-	6m
Hammer Type:	Monkey Hammer		

Material Description	Symbol	Depth, m	Sample No. &Type	No. of blows 15 cm	15 cm	15 cm	Nc-Value	N-Value
Clayey Sand; wet, grey, fine to coarse grained sand	SC	1	SPT	8	10	11		21
Poorly Graded Sand with Fat Clay ; wet, grey, fine to coarse grained sand	(SP-SC)	2						
		3	SPT	10	14	11		25
		4	SPT	9	13	15		28
Poorly Graded Sand with Elastic Silt; moist, brown, contains root, fine to coarse grained sand	SP-SM	5						
		6	SPT	8	11	12		23
Poorly Graded Sand; moist, brown, fine to coarse grained sand	SP	7	SPT	20	28	35		63
Clayey Sand with Gravel; moist, brown, fine to coarse grained sand	SP	8						
		9	SPT	15	25	33		58
Poorly Graded Sand with Clay; moist, brown, fine to coarse grained sand	(SP-SC)	10						
		11	SPT	22	33	40		73
		12	SPT	35	50/5			50



End Depth * **Completed at 12.00m** **Ground: Dry**

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

Notes:

1. Bottom of Boring at 20.0 m. SPT was conducted upto depth of 12 m.
2. Boring terminated at selected depth.
3. Boring backfilled with auger cuttings upon completion.
4. Emperical Relation Between DCPT (Ncr) and SPT (N) values:

Ncr = 1.5 N for depths upto 3.00 m
Ncr = 1.75 N for depths 3.00 m to 6.00 m
Ncr = 2.00 N for depths greater than 6.00 m
Where,
Ncr = recorded DCPT values
N = SPT values

TRACEABLE MEASUREMENTS

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Drilling Log

Project:	Soil Investigation Works of Consulting Services for Detailed Survey and Updated Line Design for 30 km of Changes in 400kV Transmission Line Route Alignment		
Location:	New Butwal - New Damauli 400 kV D/C TL	Position Cordinate	
Client:	MCA-N	Easting (m)	Northing (m)
Borehole No:	TW-198	218356	3092898
Dates	Started: 24/09/2079		
	Finished: 27/09/2079		
Method:	**Rotary Boring and SPT**	Water Table :-	
Hammer Type:	Monkey Hammer		

Material Description	Symbol	Depth, m	Sample No. &Type	No. of blows 15/10 cm	15/10 cm	15/10 cm	N-Value	Ncr-Value
Well Graded Gravel with Sand; moist, brown, fine to coarse grained sand	GW	1	SPT	10	15	18	33	
		2						
		3	SPT	12	18	25	43	
		4	SPT	15	15	35	50	
Well Graded Gravel with Silt and Sand; moist, brown, fine to coarse grained sand	GW GM	5						
		6	DCPT	50/10			50/10	
Well Graded Gravel with Sand; moist, brown, fine to coarse grained sand	GW	7	DCPT	50/5			50/5	
		8						
		9	DCPT	50/8			50/8	
Well Graded Gravel with Silt and Sand; moist, brown, fine to coarse grained sand	GW GM	10	DCPT	50/9			50/9	
Well Graded Gravel with Silt and Sand; moist, brown, fine to coarse grained sand	GW	11						
		12	DCPT	50/7			50/7	

N-Value SPT DCPT

End Depth * **Completed at 12.00m** **Ground: Dry**

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

Notes:

1. Bottom of Boring at 20.0 m. SPT was conducted upto depth of 4.5 m and DCPT was conducted from 3m to 12 m.
2. Boring terminated at selected depth.
3. Boring backfilled with auger cuttings upon completion.
4. Emperical Relation Between DCPT (Ncr) and SPT (N) values:

Ncr = 1.5 N for depths upto 3.00 m
Ncr = 1.75 N for depths 3.00 m to 6.00 m
Ncr = 2.00 N for depths greater than 6.00 m
Where,
Ncr = recorded DCPT values
N = SPT values

TRACEABLE MEASUREMENTS

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APPENDIX-B
Lab Test Summary

Summary of Laboratory Tests:

											Shear Strength Parameters	
Borings No.	Sample Depth (m) / Elevation (m)	Sample Type	Description of Specimen	Natural Mositure (%)	Specific Gravity	Liquid Limit	Plasticity Index	% Passing No. 200 Sieve	Percent Sand	Percent Gravel	Effective Friction Angle (ϕ')	Effective Cohesion (KPa,c')
T17/1N	0-1.5	SS	Clayey Sand (SC)	26.9	2.516	40	22	16	84	-	*14	10
T17/1N	1.5 - 4.5	SS	Poorly Graded Sand with Fat Clay (SP-SC)	25.6	2.47	60	20	11	89	-	*19	31
T17/1N	4.5-6.0	SS	Poorly Graded Sand with Elastic Silt (SP-SM)	25.4	2.615	66	32	14	86	-	*19	33
T17/1N	6.0-7.5	SS	Poorly Graded Sand (SP)	22.3	2.642	-	-		100	-	34	0
T17/1N	7.5-9.0	SS	Clayey Sand with Gravel (SC)	20.3	2.678	-	-	24	63	13	24	23
T17/1N	12.0	SS	Poorly Graded Sand with Clay (SP-SC)	24.2	2.685	-	-	8	92	-	31	9
T240N	0-1.5	SS	Poorly GradedSand with Silt (SP-SM)	19.4	2.686	-	-	12	85	2	31	6
T238N	0-3.0	SS	Well Graded Sand with Gravel(SW)	16.3	2.501	-	-	3	73	24	34	0
TW198	0-1.5	SS	Well Graded Gravel with Sand (GW)	16.9	2.629	-	-	2	29	69	-	-
TW198	1.5 - 4.5	SS	Well Graded Gravel with Sand (GW)	13.7	2.655	-	-	2	43	55	-	-
TW198	4.5-6.0	SS	Well Graded Gravel with Sand and Silt (GW-GM)	10.7	2.617	-	-	5	28	67	-	-
TW198	6.0-9.0	SS	Well Graded Gravel with Sand (GW)	11.8	-	-	-	4	35	61	33	0
TW198	10	SS	Well Graded Gravel with Sand and Silt (GW-GM)	13.9	-	-	-	5	27	68.0	-	-
TW198	12.0	SS	Well Graded Gravel with Sand (GW)	-	2.632	-	-	4	24	72	34	0

TRACEABLE MEASUREMENTS

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MSc. Virginia Tech

Compiled By: Manab Rijal
Date: Jan. 10, 2023

APPENDIX-C
Laboratory Data and Detail Analysis of New Damauli-Ratamate 400 kV D/C TL (T238N)

Traceable Measurement Pvt. Ltd.
Drilling Log

Project:	Soil Investigation Works of Consulting Services for Detailed Survey and Updated Line Design for 30 km of Changes in 400kV Transmission Line Route Alignment		
Location:	New Damauli-Ratamate 400 kV D/C TL	Position Cordinate	
Client:	MCA-N	Easting (m)	Northing (m)
Borehole No:	T238N	306079	3082750
Dates	Started: 29/09/2079		
	Finished: 9/31/2079		
Method:	SPT and DCPT	Water Table :-	Dry
Hammer Type:	Monkey Hammer		

Material Description	Symbol	Depth, m	Sample No. &Type	No. of blows 15/10 cm	No. of blows 15/10 cm	No. of blows 15/10 cm	N-Value	Ncr-Value
Well Graded Sand with Gravel; moist, brown, fine to coarse grained sand	SW	- 1	SPT	10	9	12	21	
		- 2						
		- 3	SPT	9	10	10	20	
Gravel and Cobble mixed Soil with Sand		- 4	DCPT					50/15
		- 5						
		- 6	DCPT					50/3
		- 7	DCPT					50/9
		- 8						
		- 9	DCPT					50/10
		- 10	DCPT	25	25/5	50/15		125/30
		- 11						
		- 12	DCPT					50/20

N-Value **SPT** **DCPT**

End Depth *** Completed at 12.00m** **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

Notes:

1. Bottom of Boring at 20.0 m. SPT was conducted upto depth of 3 m and DCPT was conducted from 3m to 12 m.
2. Boring terminated at selected depth.
3. Boring backfilled with auger cuttings upon completion.
4. Emperical Relation Between DCPT (Ncr) and SPT (N) values:

Ncr = 1.5 N for depths upto 3.00 m
Ncr = 1.75 N for depths 3.00 m to 6.00 m
Ncr = 2.00 N for depths greater than 6.00 m
Where,
Ncr = recorded DCPT values
N = SPT values

TRACEABLE MEASUREMENTS

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MSc. Virginia Tech

Traceable Measurements Pvt. Ltd

Lalitpur-2, Sanepa, Nepal

Determination of Moisture Content

Project	:	Soil Investigation Works of Services & updated line Design for 30 km of Changes in 400kv Transmission Line Route Aligment of MCA-Nepal		
Location	:	T238N		
Sample Description	:	SPT Sample		
Bore Hole No	:	1	**Date Of Sampling**	29/07/2079
Lab Ref No.	:		**Date Of Test**	

NATURAL MOISTURE CONTENT

Depth m.	**0-3m**					
Container No.	**210**	**48**	**76**			
Weight of Wet Soil + Container,g	**64.2**	**57.4**	**61.2**			
Weight of Dry Soil + Container,g	**58.6**	**50.4**	**53.6**			
Weight of Water, g	**5.6**	**7.0**	**7.6**			
Weight of container, g	**13.5**	**11.3**	**13.0**			
Weight of Dry Soil, g	**45.1**	**39.1**	**40.6**			
Water Content, W %	**12.4**	**17.9**	**18.7**			
Average Water Content, W %	**16.3**					

Tested By:	Verified By:
TRACEABLE MEASUREMENTS	Geotechnical Engineer, Traceable Measurements MSc. Virginia Tech

Traceable Measurements Pvt. Ltd

Lalitpur-2, Sanepa, Nepal

TEST FOR SPECIFIC GRAVITY OF SOIL

Project : Soil Investigation Works of Services & updated line Design for 30 km of Changes in 400kv Transmission Line Route Aligment of MCA-Nepal

Client Name : MCA-Nepal

Location : T238N

SAMPLE LABEL INFORMATION

Date of Sampling :

Date of Testing :-

D H # BH01

Depth 0-3m

Description of Sample
100 % pass through 4.75 mm

Test No	1	2	
Wt. of Pycnometer, gm (A)	96.4	101.2	
Wt. of Pycnometer + Sample, gm (B)	116.2	121.4	
Wt. of Pycnometer + Sample + Water, gm (C)	220.4	224.5	
Wt. of Pycnometer + Water, gm (D)	208.4	212.5	
Specific Gravity = (B-A)/((D-A)-(C-B))	2.538	2.463	
Average Value	2.501		

Tested By :	Verified By:

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PARTICLE SIZE ANALYSIS ASTM D-6913

Project Information

Project Name:	MCA-Nepal
Project Number:	
Location:	T238N

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:	0-3m
Sample type:	
Sampled by:	

Laboratory Comments/Observations

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

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)	484.50
Mass of washed soil (g)	
Mass loss in wash (g)	

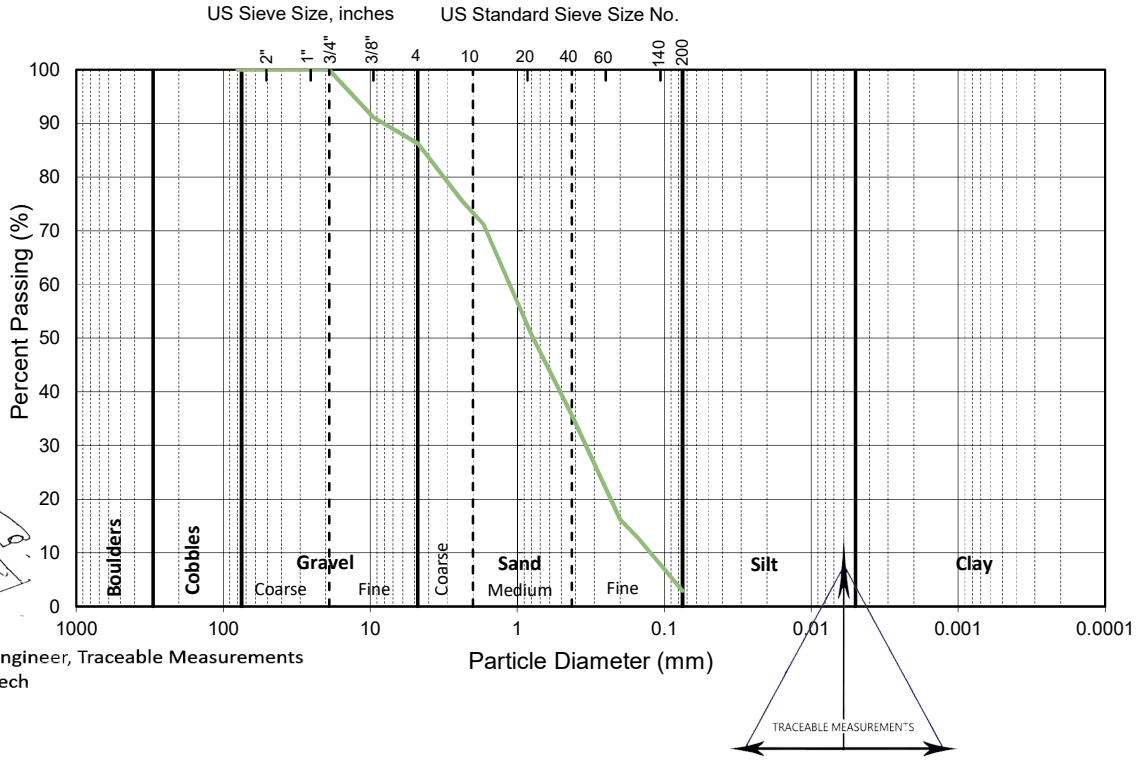
Summary Parameter

Coarser than Gravel%	0
Gravel%	24
Sand%	73
Fines%	3
D60, mm:	1.13
D30, mm:	0.34
D10, mm:	0.12
Cc:	0.84
Cu:	9.10

S.N	(mm)	Wt Ret	% Ret	Cum % Ret	% Pass
1	80	0.00	0.00	0.00	100.00
2	38.1	0.00	0.00	0.00	100.00
3	25.4	0.00	0.00	0.00	100.00
4	19.1	0.00	0.00	0.00	100.00
5	9.5	42.80	8.83	8.83	91.17
6	4.75	23.70	4.89	13.73	86.27
7	2.36	52.0	10.73	24.46	75.54
8	1.70	20.9	4.31	28.77	71.23
9	0.8	99.6	20.56	49.33	50.67
10	0.425	72.9	15.05	64.38	35.62
11	0.20	93.9	19.38	83.76	16.24
12	0.15	17.1	3.53	87.29	12.71
13	0.075	47.4	9.78	97.07	2.93
Pan		14.2			
Tot Pan		14.20	2.93	100.00	0.00
Fineness Mod.				3.61	

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

Well Graded Sand with Gravel



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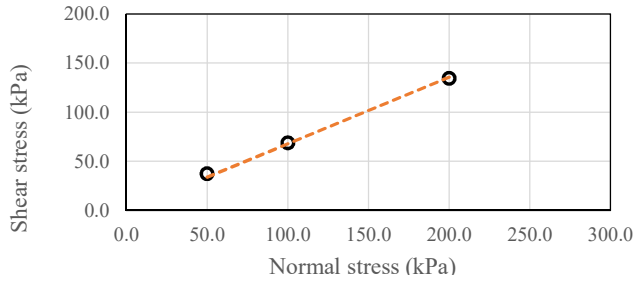
TRACEABLE MEASUREMENTS

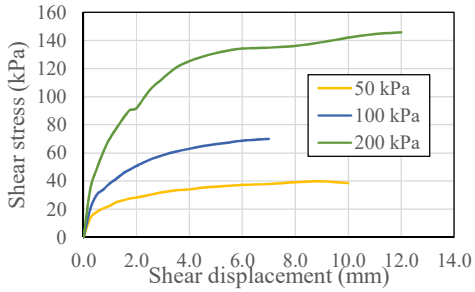
PAN: 604248398, Reg. No. 148209/72/073
TRACEABLE MEASUREMENTS PVT. LTD.
Tel. 01-5413270; Sanepa, Lalitpur.

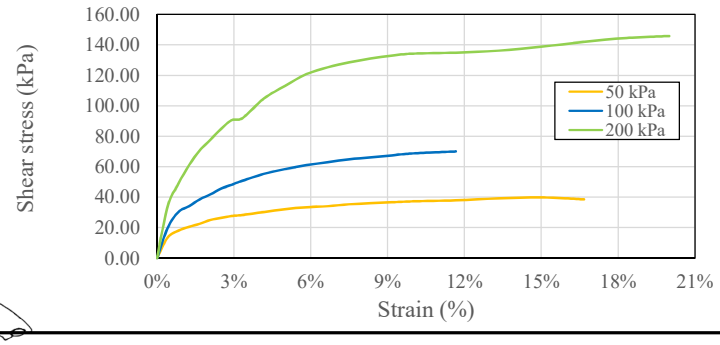
Direct Shear Test

Project Name	:	**MCA-Nepal**		
Location	:	**T238N**		
Bore Hole No	:	**1**	**PRG factor:**	**0.002312**
Bore Hole Depth	:	**0-3m**	**Area:**	**0.0036**

Hz Dial Gauge reading (x 0.01mm)	Normal Strain (%)	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	0.00	0	0.00	0	0.00	
25	0.4%	21	13.49	31	19.91	53	34.04	
50	0.8%	28	17.98	47	30.18	76	48.81	
75	1%	32	20.55	53	34.04	95	61.01	
100	1.7%	35	22.48	60	38.53	110	70.64	
125	2.1%	39	25.05	65	41.74	121	77.71	
150	3%	41	26.33	71	45.60	132	84.77	
175	2.9%	43	27.62	75	48.17	141	90.55	
200	3.3%	44	28.26	79	50.74	143	91.84	
250	4%	47	30.18	86	55.23	163	104.68	
300	5.0%	50	32.11	91	58.44	176	113.03	
350	5.8%	52	33.40	95	61.01	188	120.74	
400	7%	53	34.04	98	62.94	195	125.23	
450	7.5%	55	35.32	101	64.86	200	128.44	
500	8.3%	56	35.96	103	66.15	204	131.01	
550	9.2%	57	36.61	105	67.43	207	132.94	
600	10%	58	37.25	107	68.72	209	134.22	
700	11.7%	59	37.89	109	70.00	210	134.87	
800	13.3%	61	39.18			212	136.15	
900	15%	62	39.82			216	138.72	
1000	16.7%	60	38.53			221	141.93	
1100	18.3%					225	144.50	
1200	20%					227	145.78	
1300	21.7%							
1400	23.3%							
1500	25%							
1600	26.7%							







ϕ'	**34**	Degree
c'	**0.00**	kN/m^2

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Soil Investigation Works of Consulting Services & updated line Design for 30 km of Changes in 400kv Transmission Line Route Aligment of MCA-Nepal

Bearing capacity analysis of the Shallow Foundation

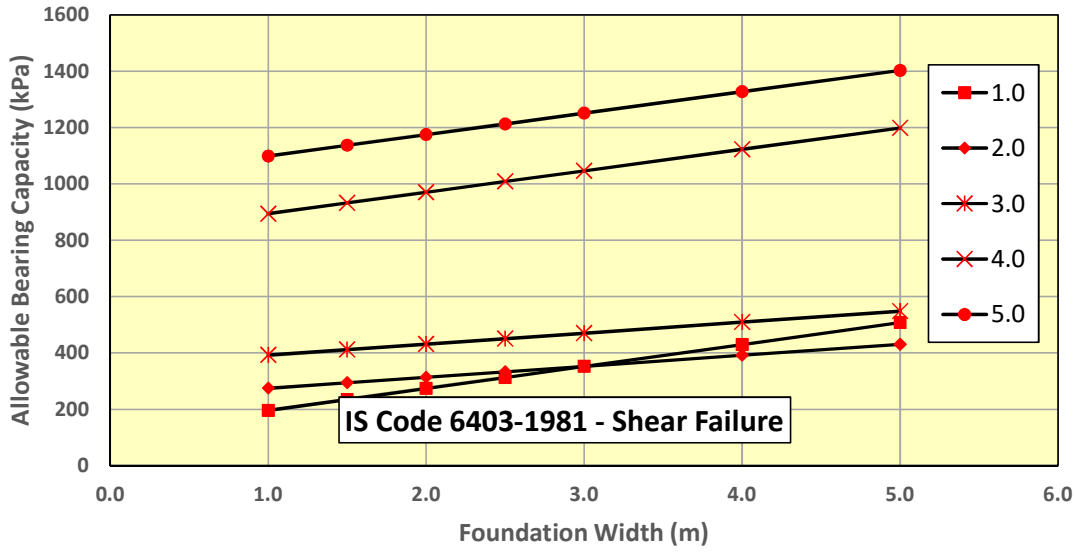
This calculation based on the IS:6403-1981. The allowable bearing capacity is based on the shear failure of soil. The effective internal angle of friction is adopted either from direct shear test result or empirical correlation or approximated using engineering judgement and experience between SPT N value and angle of friction.

New Damauli-Ratamate 400 kV D/C TL

Bore Hole No. - T238N

Depth of Foundation, D_f (m)	1.0	2.0	3.0	4.0	5.0
Friction angle	31	31	31	35	35
SPT N Value	21	21	20	57	57
Unit wt. of soil, kN/m^3	18	18	18	19	19
Buoyant Unit wt. of soil. kN/m^3	8	8	8	9	9
Cohesion. kN/m^2	0	0	0	0	0
Water Reduction Factor W_γ	1	0.5	0.5	0.5	0.5
N_q	20.63	20.63	20.63	33.30	33.30
N_c	32.67	32.67	32.67	46.12	46.12
N_γ	25.99	25.99	25.99	48.03	48.03

	Net Allowable Bearing, kN/m^2 (IS: 6403-1981 Shear Failure)				
Depth of Foundation, D_f (m)	1.0	2.0	3.0	4.0	5.0
Width of foundation, B (m)					
1.0	196	275	392	894	1099
1.5	235	294	412	932	1137
2.0	274	314	431	970	1175
2.5	313	333	451	1008	1213
3.0	352	353	470	1046	1251
4.0	430	392	509	1122	1327
5.0	508	431	548	1198	1403



Note: For footing size greater than 2 m bearing capacity is usually governed by settlement criterion. Please refer to bearing capacity evaluated based on settlement criterion.

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TRACEABLE MEASUREMENTS

Soil Investigation Works of Consulting Services & updated line Design for 30 km of Changes in 400kv Transmission Line Route Aligment of MCA-Nepal

Bearing capacity analysis of the Shallow Foundation

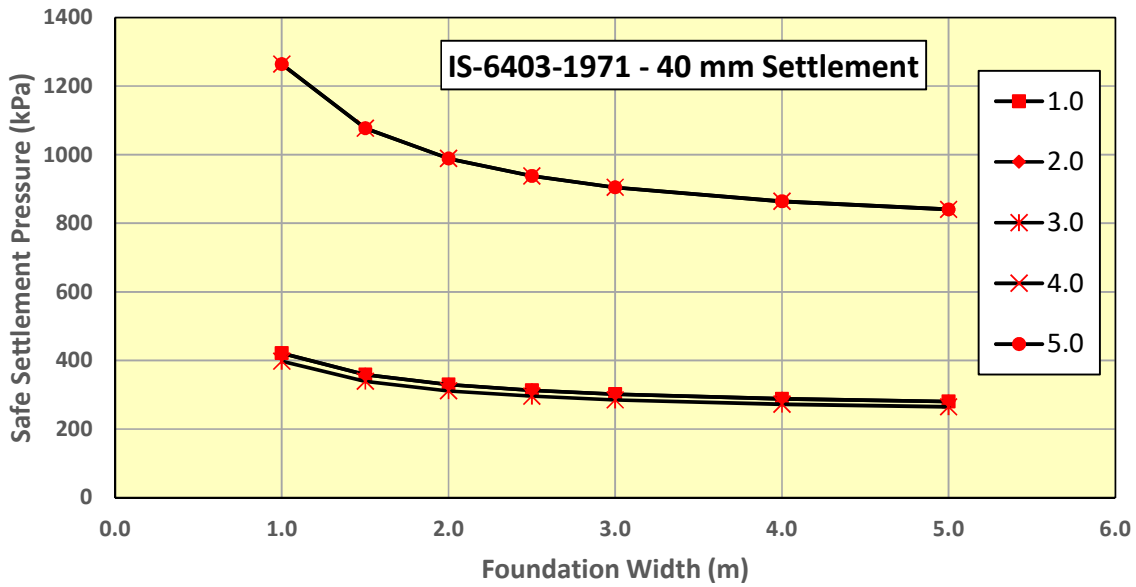
This calculation based on the IS:6403-1971. The allowable bearing capacity is based on the settlement of 40 mm. The effective internal angle of friction is adopted either from direct shear test result or empirical correlation or approximated using engineering judgement and experience between SPT N value and angle of friction.

New Damauli-Ratamate 400 kV D/C TL

Bore Hole No. - T238N

Depth of Foundation, D_f (m)	1.0	2.0	3.0	4.0	5.0
Friction angle	31	31	31	35	35
SPT N Value	21	21	20	57	57
Unit wt of soil kN/m3	18	19	19	19	19
Water Reduction Factor Wγ	1	0.5	0.5	0.5	0.5

	Net Allowable Bearing, kN/m^2 (IS:6403-1971-40 mm Settlement)				
Depth of Foundation, D_f (m)	1.0	2.0	3.0	4.0	5.0
Width of foundation, B (m)					
1.0	421	421	398	1264	1264
1.5	359	359	339	1077	1077
2.0	330	330	311	989	989
2.5	313	313	295	938	938
3.0	302	302	285	905	905
4.0	288	288	272	864	864
5.0	280	280	265	840	840



Note: For footing size greater than 2 m bearing capacity is usually governed by settlement criterion.

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TRACEABLE MEASUREMENTS

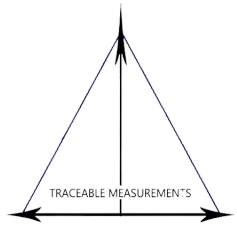
Soil Investigation Works of Services & updated line Design for 30 km of Changes in 400kv Transmission Line Route Aligment of MCA-Nepal
Bearing capacity analysis of the Mat foundation

This calculation is based on the SPT N-value.

Bore Hole No. - T238N **Safe Settlement Bearing Pressure kN/m^2 (IS:6403-65 mm Settlement)**

Depth of Foundation, D_f (m)	1	3	4	6	7	9	10	12
SPT N Value	21	20	57	100	83	75	62	37
Unit wt of soil kN/m3	18	18	19	19	19	19	19	19
Water Reduction Factor Wγ	1	1	1	1	1	1	1	1

Depth of Foundation, D_f (m)	1.0	3.0	4.0	6.0	7.0	9.0	10.0	12.0
Safe Settlement Bearing Pressure, kN/m^2	229	216	686	1232	1016	914	749	432
Modulus of Subgrade Reaction, Ks (kN/m^3)	18288	17272	54864	98552	81280	73152	59944	34544



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Prepared By: Manab Rijal

Soil Investigation Works of Services & updated line Design for 30 km of Changes in 400kv Transmission Line Route Aligment of MCA-Nepal

New Damauli-Ratamate 400 kV D/C TL

Depth to GW	NE	m
PGA	0.3	g
Mw	7.8	
P_a	101.3	kPA

Borehole -T238N

Input

NE: Water Table not Encountered

Depth (m)	N_{field}	Total unit wt. γ_t (KN/m^3)	Fines content	σ (kN/m^2)	u (kN/m^2)	σ' (kN/m^2)	α(z)	β(z)	r_d	MSF	$N_{1,60}$	ΔN1,60	$N_{1,60cs}$	$CSR_{M7.5}$	$CRR_{M7.5}$	C_σ	k_σ	FS
1.0	21	18.0	3	18	0	18	-0.03	0.00	1.00	0.92	30	0.00	30	0.21	0.46	0.20	1.10	NL
3.0	20	18.0	3	54	0	54	-0.13	0.02	0.99	0.92	22	0.00	22	0.21	0.23	0.14	1.09	NL
4.0	57	19.0	3	73	0	73	-0.20	0.02	0.98	0.92	52	0.00	52	0.21	0.60	0.30	1.10	NL
6.0	100	19.0	3	111	0	111	-0.34	0.04	0.96	0.92	81	0.00	81	0.20	0.60	-0.25	1.02	NL
7.0	83	19.0	3	130	0	130	-0.42	0.05	0.95	0.92	65	0.00	65	0.20	0.60	-0.62	1.10	NL
9.0	75	19.0	3	168	0	168	-0.59	0.07	0.93	0.92	54	0.00	54	0.20	0.60	0.30	0.85	NL
10.0	63	19.0	3	187	0	187	-0.68	0.08	0.92	0.92	44	0.00	44	0.19	0.60	0.30	0.82	NL

Notes: 1) If above the water table, not subject to liquefaction

2) Fines content > 35%; Liquid Limit (LL) > 35%; and natural moisture content within 90% of the LL (i.e., 'Chinese Criteria'), not subject to liquefaction

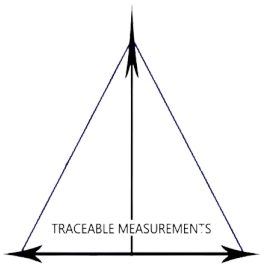
3) Cyclical Resistance Ratio (CRR) equal to or greater than 0.5, not subject to liquefaction.

4) Clean sand $(N1)_{60}$ equivalent equal to or greater than 34, not subject to liquefaction.

5) Fines content 50% or greater, not subject to liquefaction.

6) NL = Non-Liquefiable.

7) FS<1 indicates liquifiable soils.



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APPENDIX-D
Laboratory Data and Detail Analysis of New Damauli-Ratamate 400 kV D/C TL (T240N)

Traceable Measurement Pvt. Ltd.
Drilling Log

Project:	Soil Investigation Works of Consulting Services for Detailed Survey and Updated Line Design for 30 km of Changes in 400kV Transmission Line Route Alignment		
Location:	New Damauli-Ratamate 400 kV D/C TL	Position Cordinate	
Client:	MCA-N	Easting (m)	Northing (m)
Borehole No:	T240N	306317	3082408
Dates	Started: 08/08/2079		
	Finished: 09/08/2079		
Method:	**Rotary Boring**	Water Table :-	4.5m
Hammer Type:	Monkey Hammer		

Material Description	Symbol	Depth, m	Sample No. &Type	No. of blows 15/10 cm	15/10 cm	15/10 cm	N-Value	Ncr-Value
Poorly Graded Sand with Silt; moist, dark brown, fine to coarse grained sand	SP-SM	- 1	SPT	10	9	12	21	
Gravel and Cobble mixed Soil with Sand		- 2						
		- 3	DCPT	50/10				50/10
		- 4	DCPT	50/9				50/9
		- 5						
		- 6	DCPT	50/8				50/8
		- 7						
		- 8	DCPT	50/6				50/6
		- 9	DCPT	50/9				50/9
		- 10						
		- 11	DCPT	50/7				50/7
		- 12	DCPT	50/5				50/5

N-Value **SPT** **DCPT**

End Depth *** Completed at 12.00m** **Ground: Dry**

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

Notes:

1. Bottom of Boring at 20.0 m. SPT was conducted upto depth of 2 m and DCPT was conducted from 3m to 12 m.
2. Boring terminated at selected depth.
3. Boring backfilled with auger cuttings upon completion.
4. Emperical Relation Between DCPT (Ncr) and SPT (N) values:

Ncr = 1.5 N for depths upto 3.00 m
Ncr = 1.75 N for depths 3.00 m to 6.00 m
Ncr = 2.00 N for depths greater than 6.00 m
Where,
Ncr = recorded DCPT values
N = SPT values

TRACEABLE MEASUREMENTS

Geotechnical Engineer, Traceable Measurements
MSc. Virginia Tech

Traceable Measurements Pvt. Ltd

Lalitpur-2, Sanepa, Nepal

Determination of Moisture Content

Project	:	Soil Investigation Works of Services & updated line Design for 30 km of Changes in 400kv Transmission Line Route Aligment of MCA-Nepal
Location	:	T240N
Sample Description	:	SPT Sample
Bore Hole No	:	1 **Date Of Sampling**
Lab Ref No.	:	**Date Of Test**

NATURAL MOISTURE CONTENT

Depth m.	**0-1.5m**					
Container No.	**15**	**50**	**48**			
Weight of Wet Soil + Container,g	**52.2**	**47.1**	**59.6**			
Weight of Dry Soil + Container,g	**45.9**	**41.9**	**51.7**			
Weight of Water, g	**6.3**	**5.2**	**7.9**			
Weight of container, g	**14.4**	**13.9**	**11.5**			
Weight of Dry Soil, g	**31.5**	**28.0**	**40.2**			
Water Content, W %	**20.0**	**18.6**	**19.7**			
Average Water Content, W %	**19.4**					

Tested By:	Verified By:
TRACEABLE MEASUREMENTS	Geotechnical Engineer, Traceable Measurements MSc. Virginia Tech

Traceable Measurements Pvt. Ltd

Lalitpur-2, Sanepa, Nepal

TEST FOR SPECIFIC GRAVITY OF SOIL

Project : MCA-Nepal

Client Name : Nepal Electricity Authority (NEA), Nepal

Location : T240N

SAMPLE LABEL INFORMATION

Date of Sampling :

Date of Testing :-

Description of Sample
100 % pass through 4.75 mm

D H # BH01

Depth 0-1.5m

Test No	1	2	
Wt. of Pycnometer, gm (A)	100	96.7	
Wt. of Pycnometer + Sample, gm (B)	120.0	116.7	
Wt. of Pycnometer + Sample + Water, gm (C)	224.2	220.7	
Wt. of Pycnometer + Water, gm (D)	211.8	208.0	
Specific Gravity = (B-A)/((D-A)-(C-B))	2.632	2.740	
Average Value	2.686		

Tested By :

Verified By:

TRACEABLE MEASUREMENTS

Geotechnical Engineer, Traceable Measurements
MSc. Virginia Tech

TRACEABLE MEASUREMENTS PVT. LTD.
www.traceablemeasurements.com

PARTICLE SIZE ANALYSIS ASTM D-6913

Project Information

Project Name:	MCA-Nepal
Project Number:	
Location:	T240N

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:	0-1.5m
Sample type:	
Sampled by:	

Laboratory Comments/Observations

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

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)	334.10
Mass of washed soil (g)	
Mass loss in wash (g)	

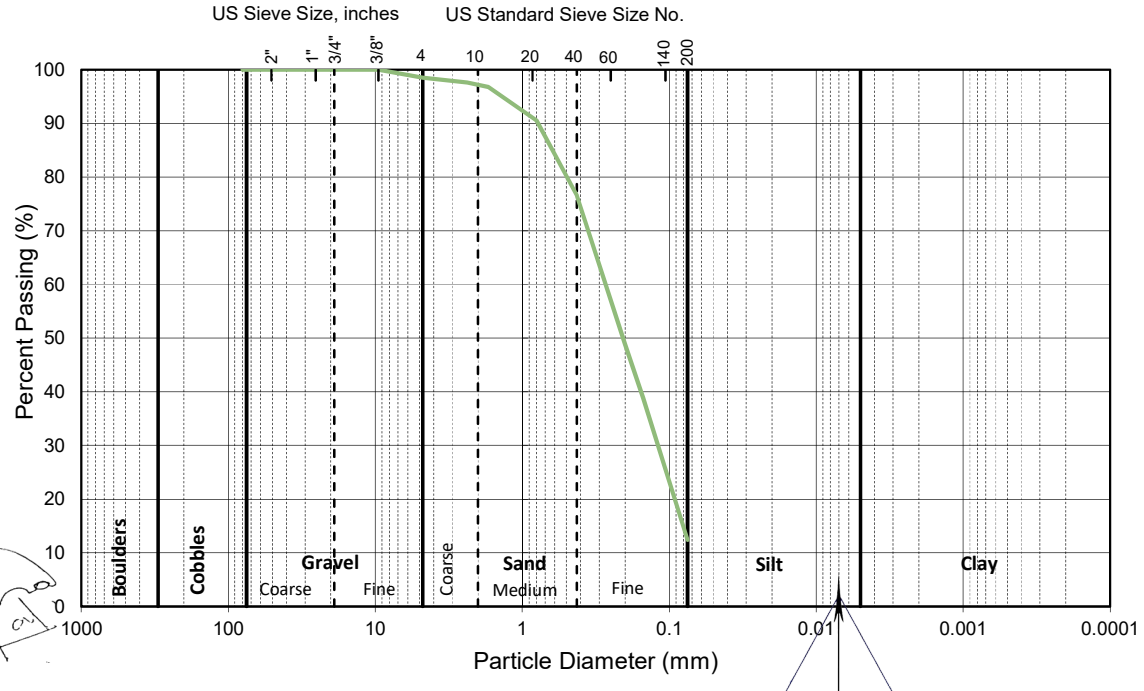
Summary Parameter

Coarser than Gravel%	0
Gravel%	2
Sand%	85
Fines%	12
D60, mm:	0.27
D30, mm:	0.12
D10, mm:	
Cc:	
Cu:	

S.N	(mm)	Wt Ret	% Ret	Cum % Ret	% Pass
1	80	0.00	0.00	0.00	100.00
2	38.1	0.00	0.00	0.00	100.00
3	25.4	0.00	0.00	0.00	100.00
4	19.1	0.00	0.00	0.00	100.00
5	9.5	0.00	0.00	0.00	100.00
6	4.75	4.90	1.47	1.47	98.53
7	2.36	3.0	0.90	2.36	97.64
8	1.70	2.8	0.84	3.20	96.80
9	0.8	20.8	6.23	9.43	90.57
10	0.425	46.9	14.04	23.47	76.53
11	0.20	92.2	27.60	51.06	48.94
12	0.15	33.8	10.12	61.18	38.82
13	0.075	88.3	26.43	87.61	12.39
Pan		41.4			
Tot Pan		41.40	12.39	100.00	0.00
Fineness Mod.				1.52	

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

Poorly Graded Sand with Silt



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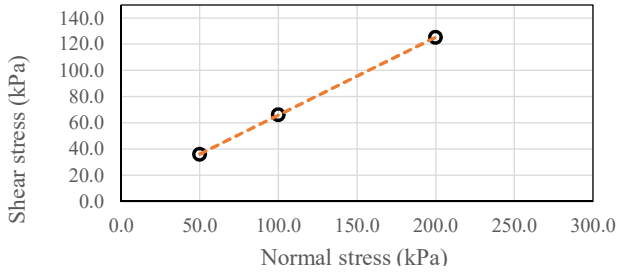
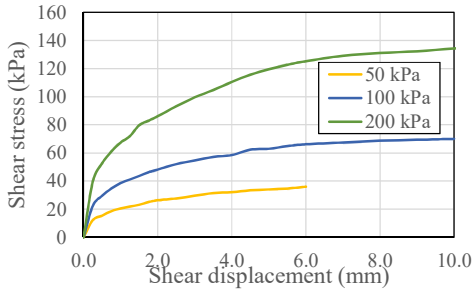
PAN: 604248398, Reg. No. 148209/72/073
TRACEABLE MEASUREMENTS PVT. LTD.
Tel. 01-5413270; Sanepa, Lalitpur.

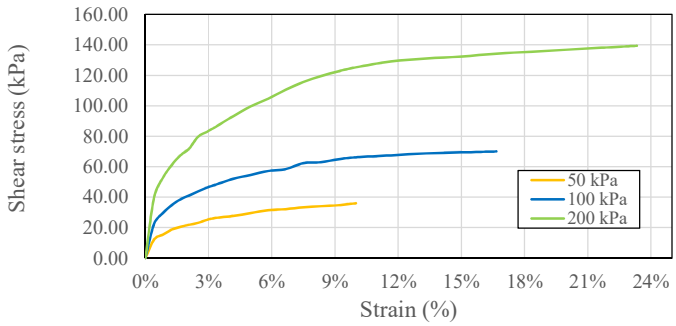
Direct Shear Test

Project Name	:	**MCA-Nepal**		
Location	:	**T240N**		
Bore Hole No	:	**1**	**PRG factor:**	**0.002312**
Bore Hole Depth	:	**1.5m**	**Area:**	**0.0036**

Hz Dial Gauge reading (x 0.01mm)	Normal Strain (%)	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	0.00	0	0.00	0	0.00	
25	0.4%	19	12.20	35	22.48	62	39.82	
50	0.8%	24	15.41	46	29.54	82	52.66	
75	1%	29	18.62	54	34.68	95	61.01	
100	1.7%	32	20.55	60	38.53	105	67.43	
125	2.1%	34	21.84	64	41.10	112	71.93	
150	3%	36	23.12	68	43.67	124	79.64	
175	2.9%	39	25.05	72	46.24	129	82.85	
200	3.3%	41	26.33	75	48.17	134	86.06	
250	4%	43	27.62	81	52.02	145	93.12	
300	5.0%	46	29.54	85	54.59	155	99.54	
350	5.8%	49	31.47	89	57.16	163	104.68	
400	7%	50	32.11	91	58.44	172	110.46	
450	7.5%	52	33.40	97	62.30	180	115.60	
500	8.3%	53	34.04	98	62.94	186	119.45	
550	9.2%	54	34.68	101	64.86	191	122.66	
600	10%	56	35.96	103	66.15	195	125.23	
700	11.7%			105	67.43	201	129.09	
800	13.3%			107	68.72	204	131.01	
900	15%			108	69.36	206	132.30	
1000	16.7%			109	70.00	209	134.22	
1100	18.3%					211	135.51	
1200	20%					213	136.79	
1300	21.7%					215	138.08	
1400	23.3%					217	139.36	
1500	25%							
1600	26.7%							







ϕ'	**31**	Degree
c'	**6.40**	kN/m^2

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Soil Investigation Works of Services & updated line Design for 30 km of Changes in 400kv Transmission Line Route Aligment of MCA-Nepal
Bearing capacity analysis of the Mat foundation

This calculation is based on the SPT N-value.

Bore Hole No. - T240N **Safe Settlement Bearing Pressure kN/m^2 (IS:6403-65 mm Settlement)**

Depth of Foundation, D_f (m)	1	3	4	6	7	9	10	12
SPT N Value	21	100	95	100	125	83	100	100
Unit wt of soil kN/m3	18	19	19	19	19	19	19	19
Water Reduction Factor Wγ	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

Depth of Foundation, D_f (m)	1.0	3.0	4.0	6.0	7.0	9.0	10.0	12.0
Safe Settlement Bearing Pressure, kN/m^2	229	1232	1168	1232	1549	1016	1232	1232
Modulus of Subgrade Reaction, Ks (kN/m^3)	18288	98552	93472	98552	123952	81280	98552	98552

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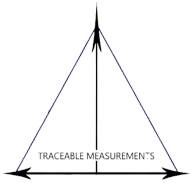


Prepared By: Manab Rijal

Traceable Measurement (P) Ltd.

Soil Investigation Works of Consulting Services & updated line Design for 30 km of Changes in 400kv Transmission Line Route Aligment of MCA-Nepal

Bearing capacity analysis of the Shallow Foundation

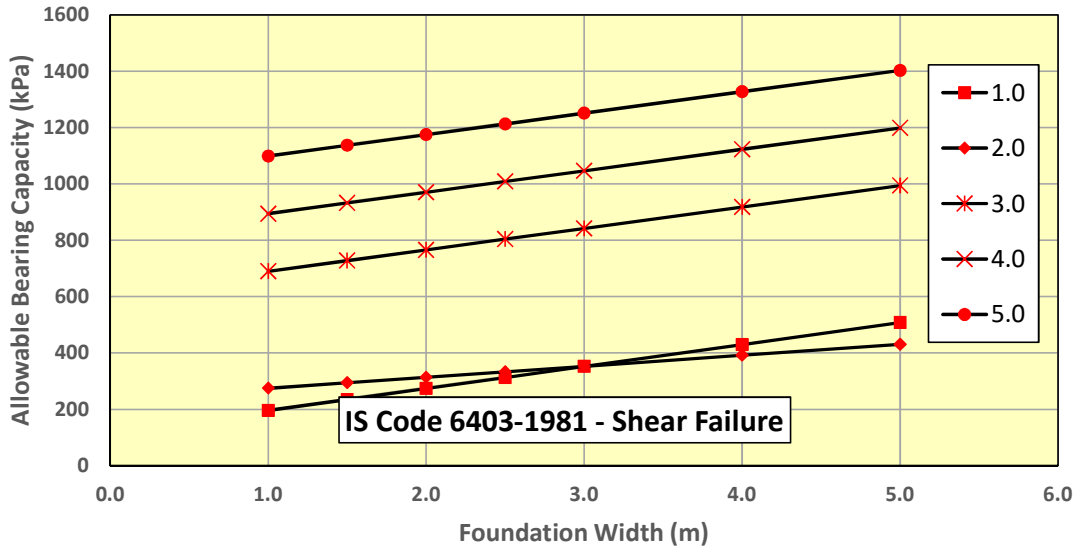
This calculation based on the IS:6403-1981. The allowable bearing capacity is based on the shear failure of soil. The effective internal angle of friction is adopted either from direct shear test result or empirical correlation or approximated using engineering judgement and experience between SPT N value and angle of friction.

New Damauli-Ratamate 400 kV D/C TL

Bore Hole No. - T240N

Depth of Foundation, D_f (m)	1.0	2.0	3.0	4.0	5.0
Friction angle	31	31	35	35	35
SPT N Value	21	21	100	95	95
Unit wt. of soil, kN/m^3	18	18	19	19	19
Buoyant Unit wt. of soil. kN/m^3	8	8	9	9	9
Cohesion. kN/m^2	0	0	0	0	0
Water Reduction Factor W_γ	1	0.5	0.5	0.5	0.5
N_q	20.63	20.63	33.30	33.30	33.30
N_c	32.67	32.67	46.12	46.12	46.12
N_γ	25.99	25.99	48.03	48.03	48.03

	Net Allowable Bearing, kN/m^2 (IS: 6403-1981 Shear Failure)				
Depth of Foundation, D_f (m)	1.0	2.0	3.0	4.0	5.0
Width of foundation, B (m)					
1.0	196	275	690	894	1099
1.5	235	294	728	932	1137
2.0	274	314	766	970	1175
2.5	313	333	804	1008	1213
3.0	352	353	842	1046	1251
4.0	430	392	918	1122	1327
5.0	508	431	994	1198	1403



Note: For footing size greater than 2 m bearing capacity is usually governed by settlement criterion. Please refer to bearing capacity evaluated based on settlement criterion.

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Soil Investigation Works of Consulting Services & updated line Design for 30 km of Changes in 400kv Transmission Line Route Aligment of MCA-Nepal

Bearing capacity analysis of the Shallow Foundation

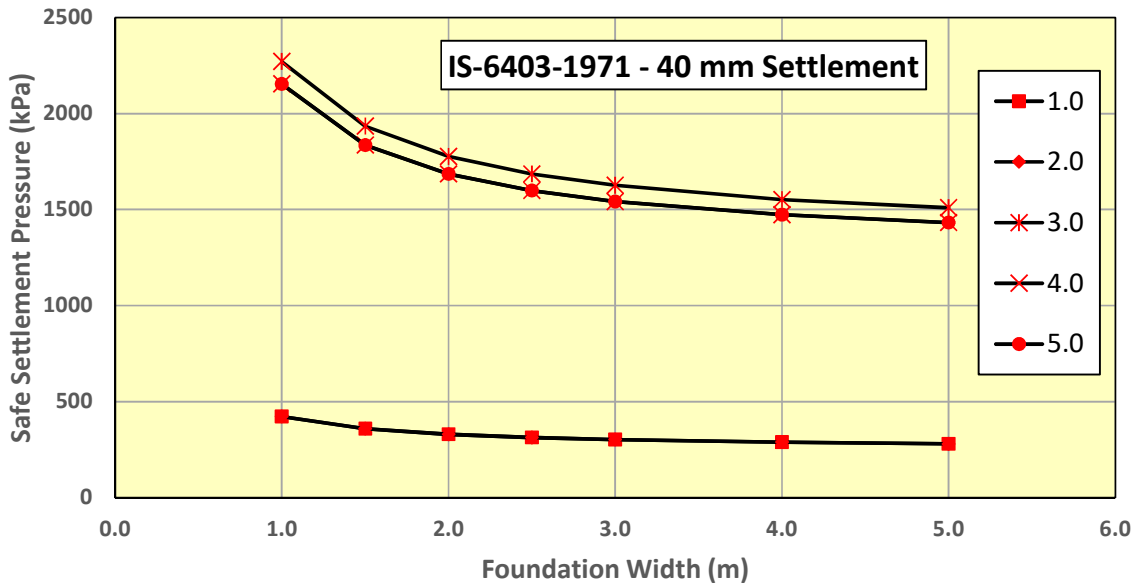
This calculation based on the IS:6403-1971. The allowable bearing capacity is based on the settlement of 40 mm. The effective internal angle of friction is adopted either from direct shear test result or empirical correlation or approximated using engineering judgement and experience between SPT N value and angle of friction.

ɪmauli-Ratamate 400 kV D/C TL

Bore Hole No. - T240N

Depth of Foundation, D_f (m)	1.0	2.0	3.0	4.0	5.0
Friction angle	31	31	35	35	35
SPT N Value	21	21	100	95	95
Unit wt of soil kN/m3	18	19	19	19	19
Water Reduction Factor Wγ	1	0.5	0.5	0.5	0.5

	Net Allowable Bearing, kN/m^2 (IS:6403-1971-40 mm Settlement)				
Depth of Foundation, D_f (m)	1.0	2.0	3.0	4.0	5.0
Width of foundation, B (m)					
1.0	421	421	2270	2153	2153
1.5	359	359	1935	1835	1835
2.0	330	330	1777	1685	1685
2.5	313	313	1685	1598	1598
3.0	302	302	1626	1542	1542
4.0	288	288	1553	1472	1472
5.0	280	280	1510	1432	1432



Note: For footing size greater than 2 m bearing capacity is usually governed by settlement criterion.

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TRACEABLE MEASUREMENTS

Soil Investigation Works of Services & updated line Design for 30 km of Changes in 400kv Transmission Line Route Aligment of MCA-Nepal

New Damauli-Ratamate 400 kV D/C TL

Depth to GW	4.5	m
PGA	0.3	g
Mw	7.8	
P_a	101.3	kPA

Borehole -T240N

Input

NE: Water Table not Encountered

Depth (m)	N_{field}	Total unit wt. γ_t (KN/m^3)	Fines content	σ (kN/m^2)	u (kN/m^2)	σ' (kN/m^2)	α(z)	β(z)	r_d	MSF	$N_{1,60}$	ΔN1,60	$N_{1,60cs}$	$CSR_{M7.5}$	$CRR_{M7.5}$	C_σ	k_σ	FS
1.0	33	18.0	12	18	0	18	-0.03	0.00	1.00	0.92	47	2.07	49	0.21	0.60	0.30	1.10	NL
3.0	43	19.0	12	56	0	56	-0.13	0.02	0.99	0.92	42	2.07	44	0.21	0.60	0.30	1.10	NL
4.0	50	19.0	12	75	0	75	-0.20	0.02	0.98	0.92	45	2.07	47	0.21	0.60	0.30	1.09	NL
6.0	86	19.0	12	113	59	54	-0.34	0.04	0.96	0.92	84	2.07	86	0.42	0.60	-0.21	0.87	NL
7.0	100	19.0	12	132	69	63	-0.42	0.05	0.95	0.92	94	2.07	96	0.42	0.60	-0.16	0.92	NL
9.0	94	19.0	12	170	88	82	-0.59	0.07	0.93	0.92	82	2.07	84	0.41	0.60	-0.22	0.95	NL
10.0	83	19.0	12	189	98	91	-0.68	0.08	0.92	0.92	71	2.07	73	0.40	0.60	-0.34	0.96	NL

Notes: 1) If above the water table, not subject to liquefaction

2) Fines content > 35%; Liquid Limit (LL) > 35%; and natural moisture content within 90% of the LL (i.e., 'Chinese Criteria'), not subject to liquefaction

3) Cyclical Resistance Ratio (CRR) equal to or greater than 0.5, not subject to liquefaction.

4) Clean sand $(N1)_{60}$ equivalent equal to or greater than 34, not subject to liquefaction.

5) Fines content 50% or greater, not subject to liquefaction.

6) NL = Non-Liquefiable.

7) FS<1 indicates liquifiable soils.

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APPENDIX-E

Laboratory Data and Detail Analysis of Ratamate-New Hetauda 400 kV D/C TL (T138N)

Traceable Measurement Pvt. Ltd.

Drilling Log

Project:	Soil Investigation Works of Consulting Services for Detailed Survey and Updated Line Design for 30 km of Changes in 400kV Transmission Line Route Alignment		
Location:	Ratamate New Heatuda 400 kV D/C TL	Position Cordinate	
Client:	MCA-N	Easting (m)	Northing (m)
Borehole No:	T138N	304271	3035190
Dates	Started: 09/09/2079		
	Finished: 12/09/2079		
Method:	**DCPT**	Water Table :-	7.3m
Hammer Type:	Monkey Hammer		

Material Description	Symbol	Depth, m	Sample No. &Type	No. of blows 10 cm	10 cm	10 cm	N-Value	Ncr-Value
Gravel and Boulder with sand		- 1	DCPT	4	11	7		22
		- 2						
		- 3	DCPT					50/9
		- 4	DCPT					50/12
		- 5						
		- 6	DCPT					50/6
		- 7	DCPT					50/12
		- 8						
		- 9	DCPT					50/13
		- 10	DCPT					50/7
		- 11						
		- 12	DCPT					50/9

N-Value SPT DCPT

End Depth * **Completed at 12.00m** **Ground: Dry**

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

Notes:

1. Bottom of Boring at 20.0 m.
2. Boring terminated at selected depth.
3. Boring backfilled with auger cuttings upon completion.
4. Emperical Relation Between DCPT (Ncr) and SPT (N) values:

Ncr = 1.5 N for depths upto 3.00 m
Ncr = 1.75 N for depths 3.00 m to 6.00 m
Ncr = 2.00 N for depths greater than 6.00 m
Where,
Ncr = recorded DCPT values
N = SPT values

TRACEABLE MEASUREMENTS

Geotechnical Engineer, Traceable Measurements
MSc. Virginia Tech

Soil Investigation Works of Consulting Services & updated line Design for 30 km of Changes in 400kv Transmission Line Route Aligment of MCA-Nepal

Bearing capacity analysis of the Shallow Foundation

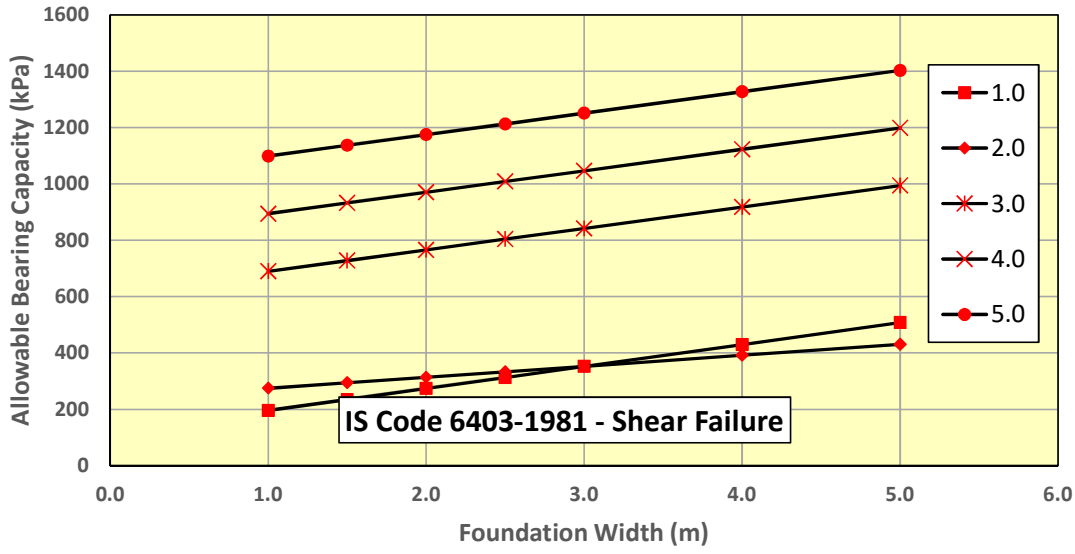
This calculation based on the IS:6403-1981. The allowable bearing capacity is based on the shear failure of soil. The effective internal angle of friction is adopted either from direct shear test result or empirical correlation or approximated using engineering judgement and experience between SPT N value and angle of friction.

Ratamate New Heatuda 400 kV D/C TL

Bore Hole No. - T138N

Depth of Foundation, D_f (m)	1.0	2.0	3.0	4.0	5.0
Friction angle	31	31	35	35	35
SPT N Value	14	14	100	71	71
Unit wt. of soil, kN/m^3	18	18	19	19	19
Buoyant Unit wt. of soil. kN/m^3	8	8	9	9	9
Cohesion. kN/m^2	0	0	0	0	0
Water Reduction Factor W_γ	1	0.5	0.5	0.5	0.5
N_q	20.63	20.63	33.30	33.30	33.30
N_c	32.67	32.67	46.12	46.12	46.12
N_γ	25.99	25.99	48.03	48.03	48.03

	Net Allowable Bearing, kN/m^2 (IS: 6403-1981 Shear Failure)				
Depth of Foundation, D_f (m)	1.0	2.0	3.0	4.0	5.0
Width of foundation, B (m)					
1.0	196	275	690	894	1099
1.5	235	294	728	932	1137
2.0	274	314	766	970	1175
2.5	313	333	804	1008	1213
3.0	352	353	842	1046	1251
4.0	430	392	918	1122	1327
5.0	508	431	994	1198	1403



Note: For footing size greater than 2 m bearing capacity is usually governed by settlement criterion. Please refer to bearing capacity evaluated based on settlement criterion.

TRACEABLE MEASUREMENTS

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MSc. Virginia Tech

Soil Investigation Works of Consulting Services & updated line Design for 30 km of Changes in 400kv Transmission Line Route Aligment of MCA-Nepal

Bearing capacity analysis of the Shallow Foundation

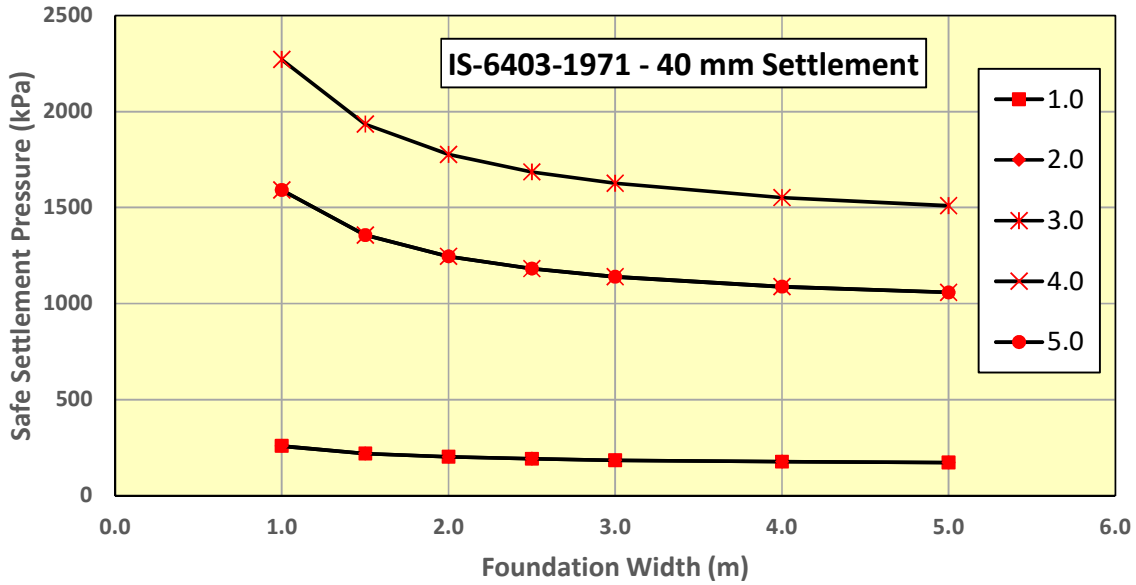
This calculation based on the IS:6403-1971. The allowable bearing capacity is based on the settlement of 40 mm. The effective internal angle of friction is adopted either from direct shear test result or empirical correlation or approximated using engineering judgement and experience between SPT N value and angle of friction.

Ratamate New Heatuda 400 kV D/C TL

Bore Hole No. - T138N

Depth of Foundation, D_f (m)	1.0	2.0	3.0	4.0	5.0
Friction angle	31	31	35	35	35
SPT N Value	14	14	100	71	71
Unit wt of soil kN/m3	18	19	19	19	19
Water Reduction Factor Wγ	1	0.5	0.5	0.5	0.5

	Net Allowable Bearing, kN/m^2 (IS:6403-1971-40 mm Settlement)				
Depth of Foundation, D_f (m)	1.0	2.0	3.0	4.0	5.0
Width of foundation, B (m)					
1.0	257	257	2270	1592	1592
1.5	219	219	1935	1356	1356
2.0	201	201	1777	1246	1246
2.5	191	191	1685	1181	1181
3.0	184	184	1626	1140	1140
4.0	176	176	1553	1088	1088
5.0	171	171	1510	1058	1058



Note: For footing size greater than 2 m bearing capacity is usually governed by settlement criterion.

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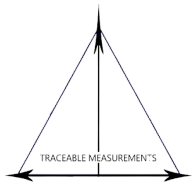
Soil Investigation Works of Services & updated line Design for 30 km of Changes in 400kv Transmission Line Route Aligment of MCA-Nepal
Bearing capacity analysis of the Mat foundation

This calculation is based on the SPT N-value.

Bore Hole No. - T138N **Safe Settlement Bearing Pressure kN/m^2 (IS:6403-65 mm Settlement)**

Depth of Foundation, D_f (m)	1	3	4	6	7	9	10	12
SPT N Value	14	100	71	100	62	57	100	83
Unit wt of soil kN/m3	18	19	19	19	19	19	19	19
Water Reduction Factor Wγ	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

Depth of Foundation, D_f (m)	1.0	3.0	4.0	6.0	7.0	9.0	10.0	12.0
Safe Settlement Bearing Pressure, kN/m^2	140	1232	864	1232	749	686	1232	1016
Modulus of Subgrade Reaction, Ks (kN/m^3)	11176	98552	69088	98552	59944	54864	98552	81280



Geotechnical Engineer, Traceable Measurements
MSc. Virginia Tech

Prepared By: Manab Rijal

Traceable Measurement (P) Ltd.

APPENDIX-F

Laboratory Data and Detail Analysis of Ratamate-New Hetauda 400 kV D/C TL (T140N)

Traceable Measurement Pvt. Ltd.

Drilling Log

Project:	Soil Investigation Works of Consulting Services for Detailed Survey and Updated Line Design for 30 km of Changes in 400kV Transmission Line Route Alignment		
Location:	Ratamate New Heatuda 400 kV D/C TL	Position Cordinate	
Client:	MCA-N	Easting (m)	Northing (m)
Borehole No:	T140N	303560	3035120
Dates	Started: 14/09/2079		
	Finished: 15/09/2079		
Method:	DCPT	Water Table :-	Dry
Hammer Type:	Monkey Hammer		

Material Description	Symbol	Depth, m	Sample No. &Type	No. of blows 10 cm	10 cm	10 cm	N-Value	Ncr-Value
Gravel and Boulder with sand		1	DCPT					50/12
		2						
		3	DCPT					50/15
		4						
		5	DCPT					50/10
		6	DCPT					50/9
		7						
		8	DCPT					50/13
		9	DCPT					50/11
		10						
		11	DCPT					50/14
		12	DCPT					50/8

N-Value SPT DCPT

End Depth * Completed at 12.00m **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

Notes:

1. Bottom of Boring at 20.0 m.
2. Boring terminated at selected depth.
3. Boring backfilled with auger cuttings upon completion.
4. Emperical Relation Between DCPT (Ncr) and SPT (N) values:

Ncr = 1.5 N for depths upto 3.00 m
Ncr = 1.75 N for depths 3.00 m to 6.00 m
Ncr = 2.00 N for depths greater than 6.00 m
Where,
Ncr = recorded DCPT values
N = SPT values

TRACEABLE MEASUREMENTS

Geotechnical Engineer, Traceable Measurements
MSc. Virginia Tech

Soil Investigation Works of Consulting Services & updated line Design for 30 km of Changes in 400kv Transmission Line Route Aligment of MCA-Nepal

Bearing capacity analysis of the Shallow Foundation

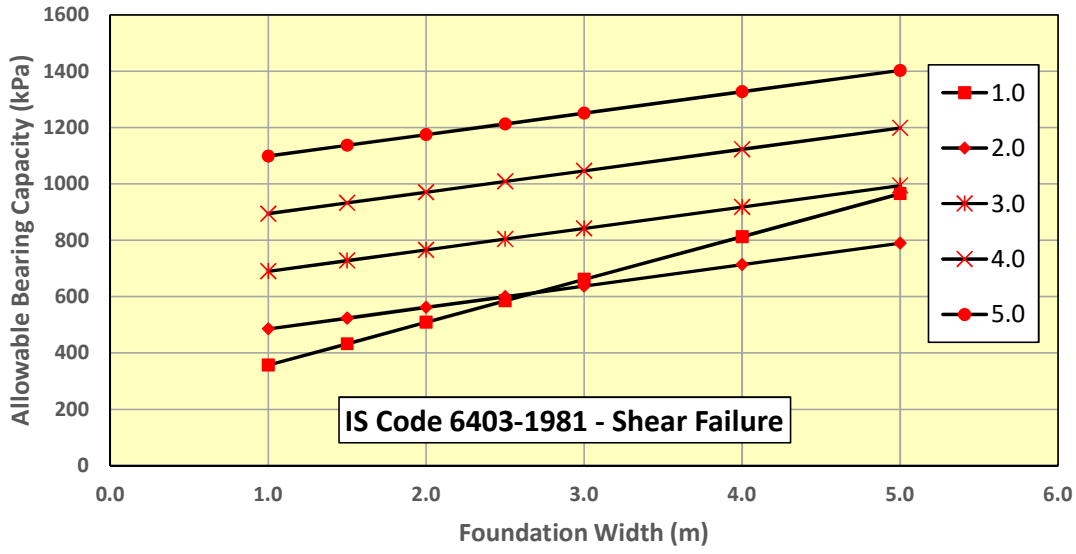
This calculation based on the IS:6403-1981. The allowable bearing capacity is based on the shear failure of soil. The effective internal angle of friction is adopted either from direct shear test result or empirical correlation or approximated using engineering judgement and experience between SPT N value and angle of friction.

Ratamate New Heatuda 400 kV D/C TL

Bore Hole No. - T140N

Depth of Foundation, D_f (m)	1.0	2.0	3.0	4.0	5.0
Friction angle	35	35	35	35	35
SPT N Value	83	83	63	85	85
Unit wt. of soil, kN/m^3	19	19	19	19	19
Buoyant Unit wt. of soil. kN/m^3	9	9	9	9	9
Cohesion. kN/m^2	0	0	0	0	0
Water Reduction Factor W_γ	1	0.5	0.5	0.5	0.5
N_q	33.30	33.30	33.30	33.30	33.30
N_c	46.12	46.12	46.12	46.12	46.12
N_γ	48.03	48.03	48.03	48.03	48.03

	Net Allowable Bearing, kN/m^2 (IS: 6403-1981 Shear Failure)				
Depth of Foundation, D_f (m)	1.0	2.0	3.0	4.0	5.0
Width of foundation, B (m)					
1.0	357	485	690	894	1099
1.5	433	523	728	932	1137
2.0	509	561	766	970	1175
2.5	585	599	804	1008	1213
3.0	661	637	842	1046	1251
4.0	813	713	918	1122	1327
5.0	965	789	994	1198	1403



Note: For footing size greater than 2 m bearing capacity is usually governed by settlement criterion. Please refer to bearing capacity evaluated based on settlement criterion.

TRACEABLE MEASUREMENTS

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Soil Investigation Works of Consulting Services & updated line Design for 30 km of Changes in 400kv Transmission Line Route Aligment of MCA-Nepal

Bearing capacity analysis of the Shallow Foundation

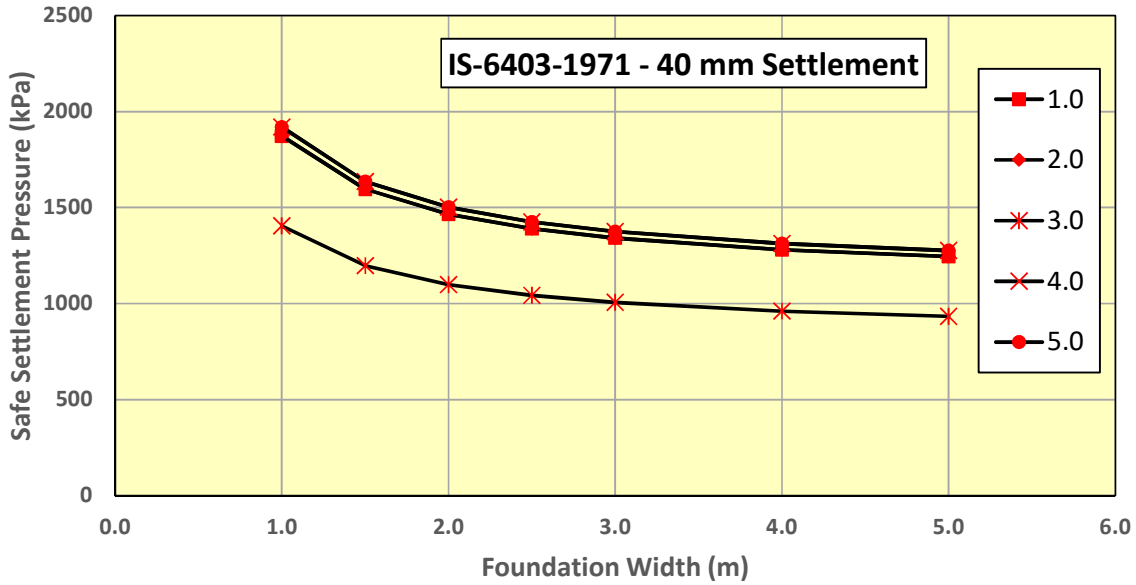
This calculation based on the IS:6403-1971. The allowable bearing capacity is based on the settlement of 40 mm. The effective internal angle of friction is adopted either from direct shear test result or empirical correlation or approximated using engineering judgement and experience between SPT N value and angle of friction.

Ratamate New Heatuda 400 kV D/C TL

Bore Hole No. - T140N

Depth of Foundation, D_f (m)	1.0	2.0	3.0	4.0	5.0
Friction angle	35	35	35	35	35
SPT N Value	83	83	63	85	85
Unit wt of soil kN/m3	18	19	19	19	19
Water Reduction Factor Wγ	1	0.5	0.5	0.5	0.5

	Net Allowable Bearing, kN/m^2 (IS:6403-1971-40 mm Settlement)				
Depth of Foundation, D_f (m)	1.0	2.0	3.0	4.0	5.0
Width of foundation, B (m)					
1.0	1873	1873	1404	1919	1919
1.5	1596	1596	1197	1635	1635
2.0	1465	1465	1099	1502	1502
2.5	1390	1390	1042	1425	1425
3.0	1341	1341	1006	1374	1374
4.0	1280	1280	960	1312	1312
5.0	1245	1245	934	1276	1276



Note: For footing size greater than 2 m bearing capacity is usually governed by settlement criterion.

TRACEABLE MEASUREMENTS

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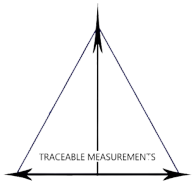
Soil Investigation Works of Services & updated line Design for 30 km of Changes in 400kv Transmission Line Route Aligment of MCA-Nepal
Bearing capacity analysis of the Mat foundation

This calculation is based on the SPT N-value.

Bore Hole No. - T140N **Safe Settlement Bearing Pressure kN/m^2 (IS:6403-65 mm Settlement)**

Depth of Foundation, D_f (m)	1	3	4	6	7	9	10	12
SPT N Value	83	66	85	95	57	68	53	93
Unit wt of soil kN/m3	19	19	19	19	19	19	19	19
Water Reduction Factor Wγ	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

Depth of Foundation, D_f (m)	1.0	3.0	4.0	6.0	7.0	9.0	10.0	12.0
Safe Settlement Bearing Pressure, kN/m^2	1016	800	1041	1168	686	826	635	1143
Modulus of Subgrade Reaction, Ks (kN/m^3)	81280	64008	83312	93472	54864	66040	50800	91440



Geotechnical Engineer, Traceable Measurements
MSc. Virginia Tech

Prepared By: Manab Rijal

Traceable Measurement (P) Ltd.

APPENDIX-G

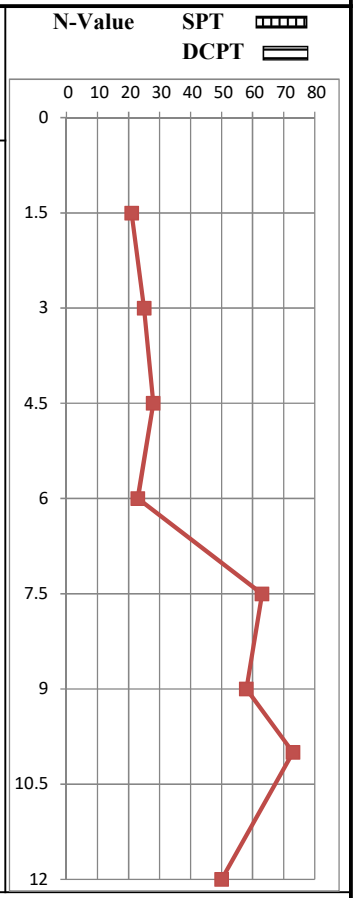
Laboratory Data and Detail Analysis of Indo Nepal Border-New Butwal 400 kV D/C TL (T17/1N)

Traceable Measurement Pvt. Ltd.

Drilling Log

Project:	Soil Investigation Works of Consulting Services for Detailed Survey and Updated Line Design for 30 km of Changes in 400kV Transmission Line Route Alignment		
Location:	Indo Nepal Border - New Butwal 400 kV D/C TL	Position Cordinate	
Client:	MCA-N	Easting (m)	Northing (m)
Borehole No:	T17/1N	173344	3043566
Dates	Started: 17/09/2079		
	Finished: 20/09/2079		
Method:	**Rotary Boring**	Water Table :-	6m
Hammer Type:	Monkey Hammer		

Material Description	Symbol	Depth, m	Sample No. &Type	No. of blows 15 cm	15 cm	15 cm	Nc-Value	N-Value
Clayey Sand; wet, grey, fine to coarse grained sand	SC	1	SPT	8	10	11		21
Poorly Graded Sand with Fat Clay ; wet, grey, fine to coarse grained sand	(SP-SC)	2						
		3	SPT	10	14	11		25
		4	SPT	9	13	15		28
Poorly Graded Sand with Elastic Silt; moist, brown, contains root, fine to coarse grained sand	SP-SM	5						
		6	SPT	8	11	12		23
Poorly Graded Sand; moist, brown, fine to coarse grained sand	SP	7	SPT	20	28	35		63
Clayey Sand with Gravel; moist, brown, fine to coarse grained sand	SP	8						
		9	SPT	15	25	33		58
Poorly Graded Sand with Clay; moist, brown, fine to coarse grained sand	(SP-SC)	10						
		11	SPT	22	33	40		73
		12	SPT	35	50/5			50



End Depth * **Completed at 12.00m** **Ground: Dry**

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

Notes:

1. Bottom of Boring at 20.0 m. SPT was conducted upto depth of 12 m.
2. Boring terminated at selected depth.
3. Boring backfilled with auger cuttings upon completion.
4. Emperical Relation Between DCPT (Ncr) and SPT (N) values:

Ncr = 1.5 N for depths upto 3.00 m
Ncr = 1.75 N for depths 3.00 m to 6.00 m
Ncr = 2.00 N for depths greater than 6.00 m
Where,
Ncr = recorded DCPT values
N = SPT values

TRACEABLE MEASUREMENTS

Geotechnical Engineer, Traceable Measurements
MSc. Virginia Tech

Traceable Measurements Pvt. Ltd

Lalitpur-2, Sanepa, Nepal

Determination of Moisture Content

Project	:	Soil Investigation Works of Services & updated line Design for 30 km of Changes in 400kv Transmission Line Route Aligment of MCA-Nepal		
Location	:	T17/1N		
Sample Description	:	SPT Sample		
Bore Hole No	:	1	**Date Of Sampling**	17/09/2079
Lab Ref No.	:		**Date Of Test**	05/10/2079

NATURAL MOISTURE CONTENT

Depth m.	0-1.5m			1.5m - 4.5m		
Container No.	109	76	104	7	51	78
Weight of Wet Soil + Container,g	25.1	25.6	26.7	40.7	41.6	40.6
Weight of Dry Soil + Container,g	22.3	23.0	23.7	36.1	35.4	35.0
Weight of Water, g	2.8	2.6	3.0	4.6	6.2	5.6
Weight of container, g	12.2	13.1	12.5	17.7	13.0	11.7
Weight of Dry Soil, g	10.1	9.9	11.2	18.4	22.4	23.3
Water Content, W %	27.7	26.3	26.8	25.0	27.7	24.0
Average Water Content, W %	26.9			25.6		

Bore Hole No :-01

Depth m.	4.5m-6m			6m-7.5m		
Container No.	48	117	0	203	57	15
Weight of Wet Soil + Container,g	32.4	31.1	32.9	31.5	33.4	33.5
Weight of Dry Soil + Container,g	28.2	27.5	29.0	27.8	29.9	30.1
Weight of Water, g	4.2	3.6	3.9	3.7	3.5	3.4
Weight of container, g	11.3	13.2	14.1	11.0	14.9	14.4
Weight of Dry Soil, g	16.9	14.3	14.9	16.8	15.0	15.7
Water Content, W %	24.9	25.2	26.2	22.0	23.3	21.7
Average Water Content, W %	25.4			22.3		

Bore Hole No :-01

Depth m.	7.5m-9m			12m		
Container No.	43	45	68	64	26	218
Weight of Wet Soil + Container,g	30.4	31.6	31.6	45.0	46.6	46.6
Weight of Dry Soil + Container,g	27.3	27.9	29.0	38.8	39.4	40.2
Weight of Water, g	3.1	3.7	2.6	6.2	7.2	6.4
Weight of container, g	12.4	12.7	12.5	11.6	12.5	12.6
Weight of Dry Soil, g	14.9	15.2	16.5	27.2	26.9	27.6
Water Content, W %	20.8	24.3	15.8	22.8	26.8	23.2
Average Water Content, W %	20.3			24.2		

Tested By:	Verified By:
TRACEABLE MEASUREMENTS	Geotechnical Engineer, Traceable Measurements MSc. Virginia Tech

Traceable Measurements Pvt. Ltd

Lalitpur-2, Sanepa, Nepal

TEST FOR SPECIFIC GRAVITY OF SOIL

Project : Soil Investigation Works of Services & updated line Design for 30 km of Changes in 400kv Transmission Line Route Aligment of MCA-Nepal

Client Name : MCA-N

Borehole No: : T17/1N

SAMPLE LABEL INFORMATION

Date of Sampling : 17/09/2079

Date of Testing :- 06/10/2079

Description of Sample
100 % pass through 4.75 mm

Depth 0-1.5m

Test No	1	2	
Wt. of Pycnometer, gm (A)	96.5	100.4	
Wt. of Pycnometer + Sample, gm (B)	116.5	120.4	
Wt. of Pycnometer + Sample + Water, gm (C)	220.6	224.6	
Wt. of Pycnometer + Water, gm (D)	208.5	212.6	
Specific Gravity = (B-A)/((D-A)-(C-B))	2.532	2.500	
Average Value	2.516		

TEST FOR SPECIFIC GRAVITY OF SOIL

Project : Soil Investigation Works of Services & updated line Design for 30 km of Changes in 400kv Transmission Line Route Aligment of MCA-Nepal

Client Name : MCA-N

Borehole No: : T17/1N

SAMPLE LABEL INFORMATION

Date of Sampling : 17/09/2079

Date of Testing :- 06/10/2079

Description of Sample
100 % pass through 4.75 mm

Depth 1.5m - 4.5m

Test No	1	2	
Wt. of Pycnometer, gm (A)	96.4	101	
Wt. of Pycnometer + Sample, gm (B)	116.4	121.0	
Wt. of Pycnometer + Sample + Water, gm (C)	220.4	224.5	
Wt. of Pycnometer + Water, gm (D)	208.4	212.7	
Specific Gravity = (B-A)/((D-A)-(C-B))	2.500	2.439	
Average Value	2.470		

Tested By :	Verified By:
TRACEABLE MEASUREMENTS	Geotechnical Engineer, Traceable Measurements MSc. Virginia Tech

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Lalitpur-2, Sanepa, Nepal

TEST FOR SPECIFIC GRAVITY OF SOIL

Project : Soil Investigation Works of Services & updated line Design for 30 km of Changes in 400kv Transmission Line Route Aligment of MCA-Nepal

Client Name : MCA-N

Borehole No: : T17/1N

SAMPLE LABEL INFORMATION

Date of Sampling : 17/09/2079

Date of Testing :- 06/10/2079

Description of Sample
100 % pass through 4.75 mm

Depth 4.5m - 6m

Test No	1	2	
Wt. of Pycnometer, gm (A)	96.7	100.2	
Wt. of Pycnometer + Sample, gm (B)	116.7	120.2	
Wt. of Pycnometer + Sample + Water, gm (C)	220.6	224.3	
Wt. of Pycnometer + Water, gm (D)	208.4	211.8	
Specific Gravity = (B-A)/((D-A)-(C-B))	2.564	2.667	
Average Value	2.615		

Traceable Measurements Pvt. Ltd

Lalitpur-2, Sanepa, Nepal

TEST FOR SPECIFIC GRAVITY OF SOIL

Project : Soil Investigation Works of Services & updated line Design for 30 km of Changes in 400kv Transmission Line Route Aligment of MCA-Nepal

Client Name : MCA-N

Borehole No: : T17/1N

SAMPLE LABEL INFORMATION

Date of Sampling : 17/09/2079

Date of Testing :- 06/10/2079

Description of Sample
100 % pass through 4.75 mm

Depth 6m - 7.5m

Test No	1	2	
Wt. of Pycnometer, gm (A)	96.7	100.1	
Wt. of Pycnometer + Sample, gm (B)	116.7	120.0	
Wt. of Pycnometer + Sample + Water, gm (C)	220.6	224.1	
Wt. of Pycnometer + Water, gm (D)	208.2	211.7	
Specific Gravity = (B-A)/((D-A)-(C-B))	2.632	2.653	
Average Value	2.642		

Tested By :	Verified By:
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MSc. Virginia Tech

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TEST FOR SPECIFIC GRAVITY OF SOIL

Project : Soil Investigation Works of Services & updated line Design for 30 km of Changes in 400kv Transmission Line Route Aligment of MCA-Nepal

Client Name : MCA-N

Borehole No: : T17/1N

SAMPLE LABEL INFORMATION

Date of Sampling : 17/09/2079

Date of Testing :- 06/10/2079

Description of Sample
100 % pass through 4.75 mm

Depth 7.5 m - 9m

Test No	1	2	
Wt. of Pycnometer, gm (A)	100.1	96.7	
Wt. of Pycnometer + Sample, gm (B)	120.0	116.7	
Wt. of Pycnometer + Sample + Water, gm (C)	224.0	220.6	
Wt. of Pycnometer + Water, gm (D)	211.5	208.1	
Specific Gravity = (B-A)/((D-A)-(C-B))	2.689	2.667	
Average Value	2.678		

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TEST FOR SPECIFIC GRAVITY OF SOIL

Project : Soil Investigation Works of Services & updated line Design for 30 km of Changes in 400kv Transmission Line Route Aligment of MCA-Nepal

Client Name : MCA-N

Borehole No: : T17/1N

SAMPLE LABEL INFORMATION

Date of Sampling : 17/09/2079

Date of Testing :- 06/10/2079

Description of Sample
100 % pass through 4.75 mm

Depth 9m - 12m

Test No	1	2	
Wt. of Pycnometer, gm (A)	96.7	100.2	
Wt. of Pycnometer + Sample, gm (B)	116.9	120.0	
Wt. of Pycnometer + Sample + Water, gm (C)	220.6	224.0	
Wt. of Pycnometer + Water, gm (D)	208.0	211.5	
Specific Gravity = (B-A)/((D-A)-(C-B))	2.658	2.712	
Average Value	2.685		

Tested By :	Verified By:
TRACEABLE MEASUREMENTS	Geotechnical Engineer, Traceable Measurements MSc. Virginia Tech

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PARTICLE SIZE ANALYSIS ASTM D-6913

Project Information

Project Name:	MCA-Nepal
Project Number:	
Location:	T17/1N

Sample Information

Borehole/Test Pit:	BH-01
Sample #:	
Depth:	0-1.5m
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)	263.60
Mass of washed soil (g)	
Mass loss in wash (g)	

Summary Parameter

Coarser than Gravel%	0
Gravel%	0
Sand%	84
Fines%	16
D60, mm:	0.23
D30, mm:	0.10
D10, mm:	
Cc:	
Cu:	

Laboratory Information

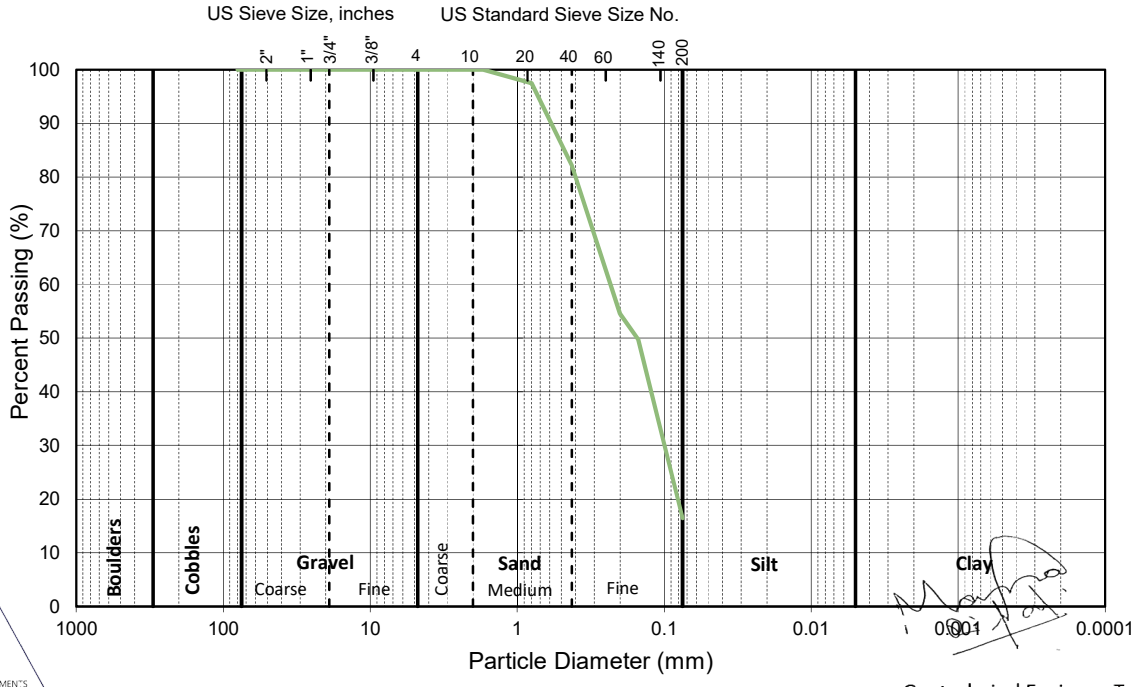
Lab Name:	Traceable Measurement Pvt. Ltd.
Tested By:	
Reviewed By:	
Test Date:	7/10/2079
Report Date:	

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

S.N	(mm)	Wt Ret	% Ret	Cum % Ret	% Pass
1	80	0.00	0.00	0.00	100.00
2	38.1	0.00	0.00	0.00	100.00
3	25.4	0.00	0.00	0.00	100.00
4	19.1	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	0.0	0.00	0.00	100.00
8	1.70	0.0	0.00	0.00	100.00
9	0.8	6.6	2.50	2.50	97.50
10	0.425	40.3	15.29	17.79	82.21
11	0.20	73.0	27.69	45.49	54.51
12	0.15	12.5	4.74	50.23	49.77
13	0.075	87.8	33.31	83.54	16.46
Pan		43.4			
Tot Pan		43.40	16.46	100.00	0.00
Fineness Mod.				1.16	

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

Clayey Sand (SC)



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MSc. Virginia Tech

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PARTICLE SIZE ANALYSIS ASTM D-6913

Project Information

Project Name:	MCA-Nepal
Project Number:	
Location:	T17/1N

Sample Information

Borehole/Test Pit:	BH-01
Sample #:	
Depth:	1.5m - 4.5m
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)	329.30
Mass of washed soil (g)	
Mass loss in wash (g)	

Summary Parameter

Coarser than Gravel%	0
Gravel%	0
Sand%	89
Fines%	11
D60, mm:	0.36
D30, mm:	0.22
D10, mm:	
Cc:	
Cu:	

Laboratory Information

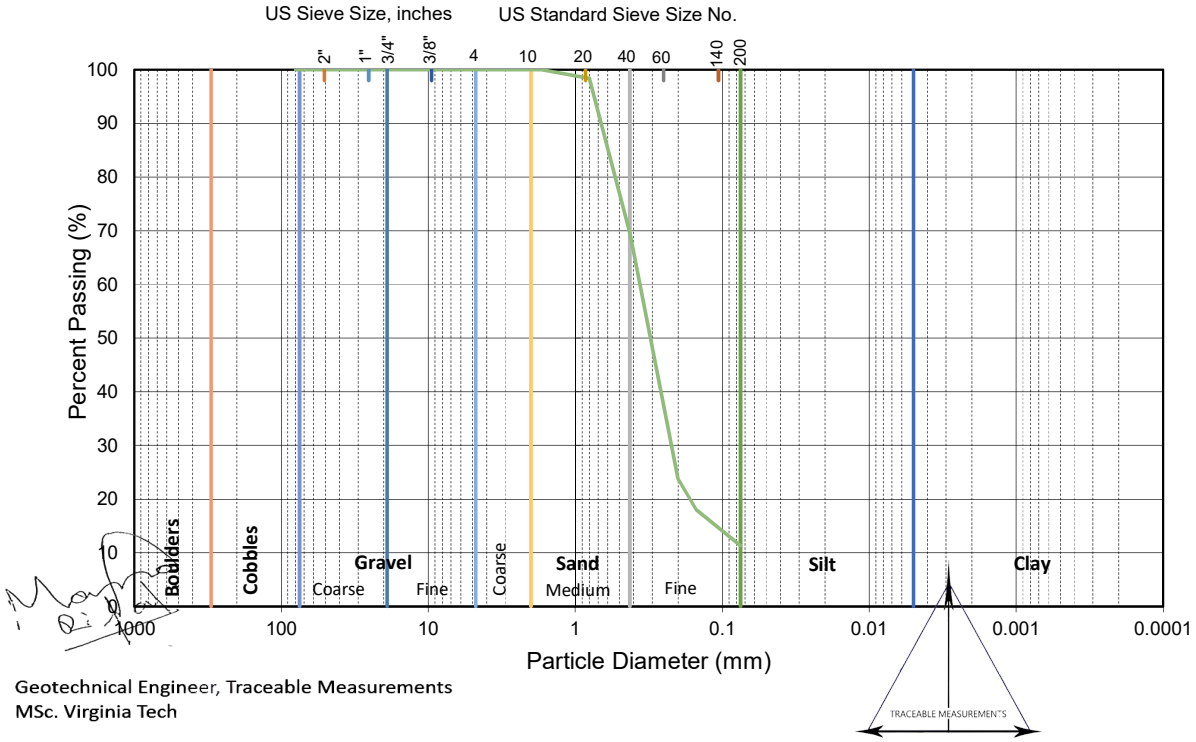
Lab Name:	Traceable Measurement Pvt. Ltd.
Tested By:	
Reviewed By:	
Test Date:	07/10/2079
Report Date:	

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

S.N	(mm)	Wt Ret	% Ret	Cum % Ret	% Pass
1	80	0.0	0.00	0.00	100.00
2	38.1	0.0	0.00	0.00	100.00
3	25.4	0.0	0.00	0.00	100.00
4	19.1	0.0	0.00	0.00	100.00
5	9.5	0.0	0.00	0.00	100.00
6	4.75	0.0	0.00	0.00	100.00
7	2.36	0.000	0.00	0.00	100.00
8	1.70	0.000	0.00	0.00	100.00
9	0.8	5.200	1.58	1.58	98.42
10	0.425	95.300	28.94	30.52	69.48
11	0.20	150.300	45.64	76.16	23.84
12	0.15	19.200	5.83	81.99	18.01
13	0.075	21.900	6.65	88.64	11.36
Pan		37.400			
Tot Pan		37.40	11.36	100.00	0.00
Fineness Mod.				1.90	

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

Poorly Graded Sand with Fat Clay (SP-SC)



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PARTICLE SIZE ANALYSIS ASTM D-6913

Project Information

Project Name:	MCA-Nepal
Project Number:	
Location:	T17/1N

Sample Information

Borehole/Test Pit:	BH-01
Sample #:	
Depth:	4.5m-6m
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)	314.70
Mass of washed soil (g)	
Mass loss in wash (g)	

Summary Parameter

Coarser than Gravel%	0
Gravel%	0
Sand%	86
Fines%	14
D60, mm:	0.32
D30, mm:	0.14
D10, mm:	
Cc:	
Cu:	

Laboratory Information

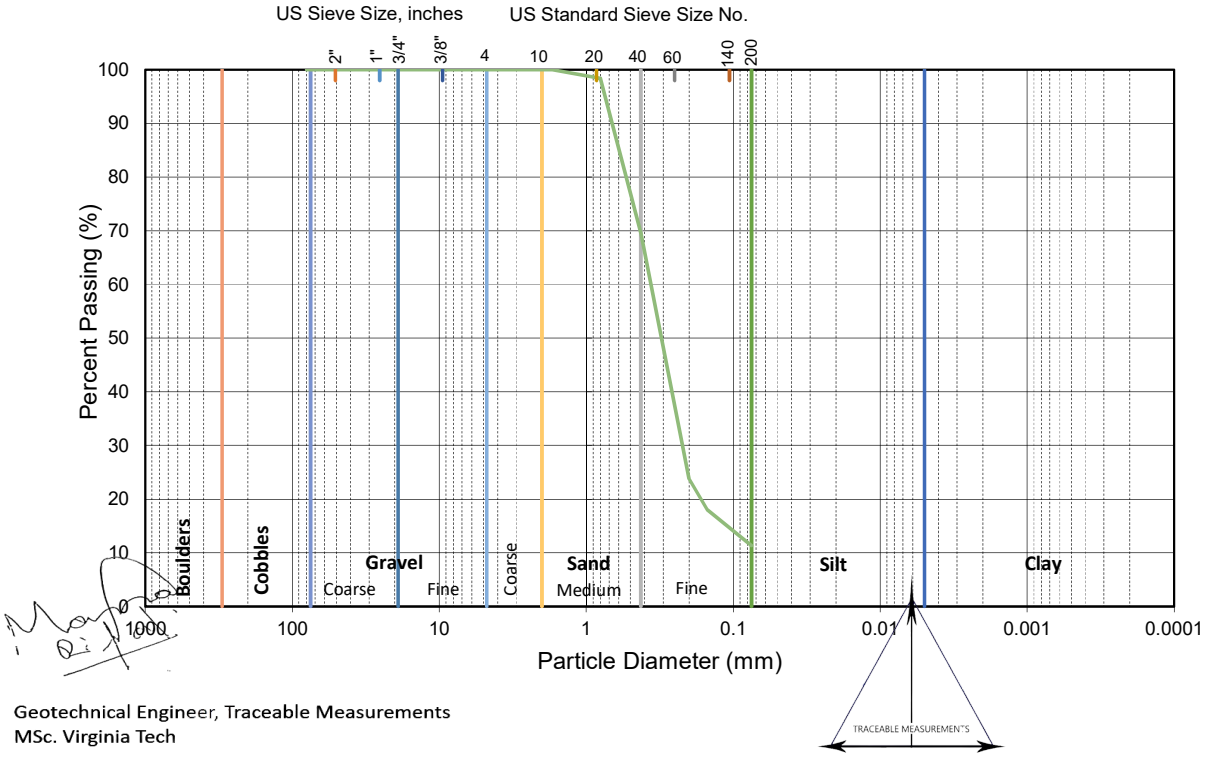
Lab Name:	Traceable Measurement Pvt. Ltd.
Tested By:	
Reviewed By:	
Test Date:	07/10/2079
Report Date:	

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

S.N	(mm)	Wt Ret	% Ret	Cum % Ret	% Pass
1	80	0.0	0.00	0.00	100.00
2	38.1	0.0	0.00	0.00	100.00
3	25.4	0.0	0.00	0.00	100.00
4	19.1	0.0	0.00	0.00	100.00
5	9.5	0.0	0.00	0.00	100.00
6	4.75	0.0	0.00	0.00	100.00
7	2.36	0.000	0.00	0.00	100.00
8	1.70	0.100	0.03	0.03	99.97
9	0.8	8.600	2.73	2.76	97.24
10	0.425	75.100	23.86	26.63	73.37
11	0.20	106.600	33.87	60.50	39.50
12	0.15	21.400	6.80	67.30	32.70
13	0.075	60.300	19.16	86.46	13.54
Pan		42.600			
Tot Pan		42.60	13.54	100.00	0.00
Fineness Mod.				1.57	

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

Poorly Graded Sand with Elastic Silt (SP-SM)



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MSc. Virginia Tech

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PARTICLE SIZE ANALYSIS ASTM D-6913

Project Information

Project Name:	MCA-Nepal
Project Number:	
Location:	T17/1N

Sample Information

Borehole/Test Pit:	BH-01
Sample #:	
Depth:	6m-7.5m
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)	269.60
Mass of washed soil (g)	
Mass loss in wash (g)	

Summary Parameter

Coarser than Gravel%	0
Gravel%	0
Sand%	100
Fines%	0
D60, mm:	0.31
D30, mm:	0.24
D10, mm:	0.20
Cc:	0.92
Cu:	1.55

Laboratory Information

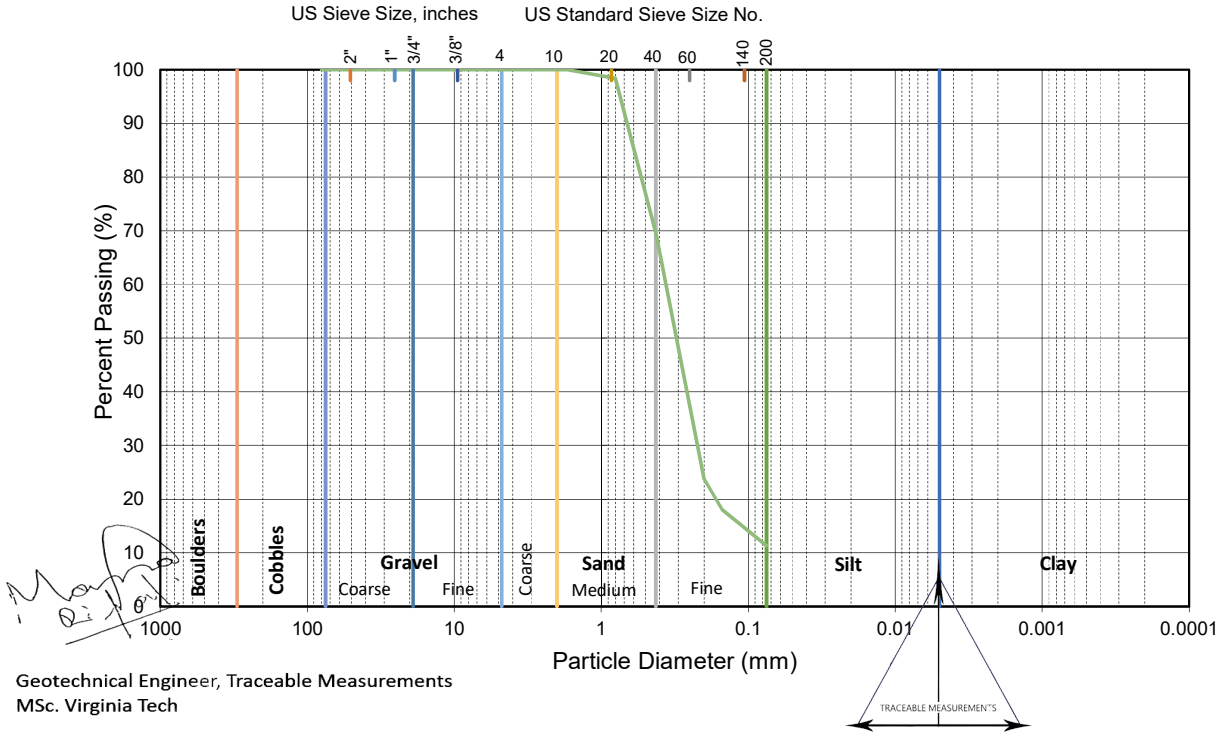
Lab Name:	Traceable Measurement Pvt. Ltd.
Tested By:	
Reviewed By:	
Test Date:	07/10/2079
Report Date:	

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

S.N	(mm)	Wt Ret	% Ret	Cum % Ret	% Pass
1	80	0.0	0.00	0.00	100.00
2	38.1	0.0	0.00	0.00	100.00
3	25.4	0.0	0.00	0.00	100.00
4	19.1	0.0	0.00	0.00	100.00
5	9.5	0.0	0.00	0.00	100.00
6	4.75	0.0	0.00	0.00	100.00
7	2.36	0.000	0.00	0.00	100.00
8	1.70	0.200	0.07	0.07	99.93
9	0.8	1.100	0.41	0.48	99.52
10	0.425	10.900	4.04	4.53	95.47
11	0.20	230.500	85.50	90.02	9.98
12	0.15	21.100	7.83	97.85	2.15
13	0.075	4.600	1.71	99.55	0.45
Pan		1.200			
Tot Pan		1.20	0.45	100.00	0.00
Fineness Mod.				1.93	

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

Poorly Graded Sand (SP)



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PARTICLE SIZE ANALYSIS ASTM D-6913

Project Information

Project Name:	MCA-Nepal
Project Number:	
Location:	T17/1N

Sample Information

Borehole/Test Pit:	BH-01
Sample #:	
Depth:	7.5m - 9m
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)	166.70
Mass of washed soil (g)	
Mass loss in wash (g)	

Summary Parameter

Coarser than Gravel%	0
Gravel%	13
Sand%	63
Fines%	24
D60, mm:	0.15
D30, mm:	0.08
D10, mm:	#VALUE!
Cc:	#VALUE!
Cu:	#VALUE!

Laboratory Information

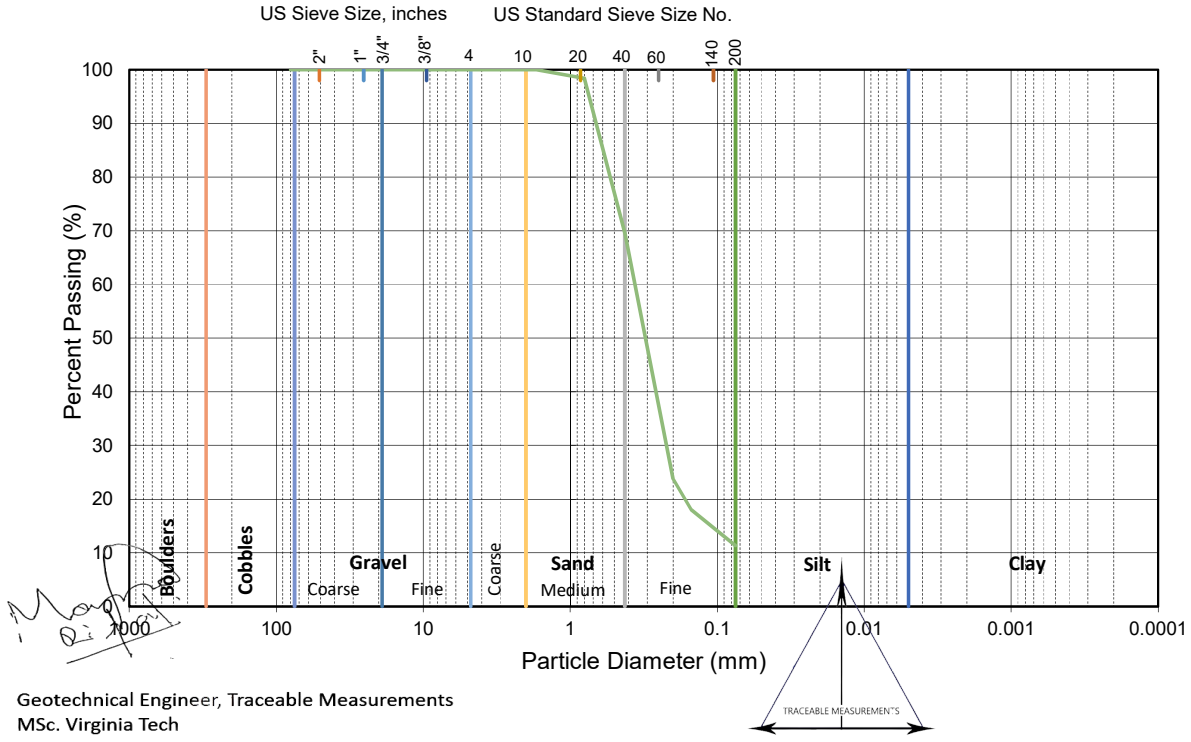
Lab Name:	Traceable Measurement Pvt. Ltd.
Tested By:	
Reviewed By:	
Test Date:	07/10/2079
Report Date:	

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

S.N	(mm)	Wt Ret	% Ret	Cum % Ret	% Pass
1	80	0.0	0.00	0.00	100.00
2	38.1	0.0	0.00	0.00	100.00
3	25.4	0.0	0.00	0.00	100.00
4	19.1	0.0	0.00	0.00	100.00
5	9.5	0.0	0.00	0.00	100.00
6	4.75	6.9	4.14	4.14	95.86
7	2.36	14.900	8.94	13.08	86.92
8	1.70	5.500	3.30	16.38	83.62
9	0.8	13.000	7.80	24.18	75.82
10	0.425	7.200	4.32	28.49	71.51
11	0.20	10.900	6.54	35.03	64.97
12	0.15	6.500	3.90	38.93	61.07
13	0.075	61.200	36.71	75.64	24.36
Pan		40.600			
Tot Pan		40.60	24.36	100.00	0.00
Fineness Mod.				1.60	

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

Clayey Sand with Gravel (SC)



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PARTICLE SIZE ANALYSIS ASTM D-6913

Project Information

Project Name:	MCA-Nepal
Project Number:	
Location:	T17/1N

Sample Information

Borehole/Test Pit:	BH-01
Sample #:	
Depth:	9m - 12m
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)	161.90
Mass of washed soil (g)	
Mass loss in wash (g)	

Summary Parameter

Coarser than Gravel%	0
Gravel%	0
Sand%	92
Fines%	8
D60, mm:	0.27
D30, mm:	0.18
D10, mm:	0.08
Cc:	1.39
Cu:	3.22

Laboratory Information

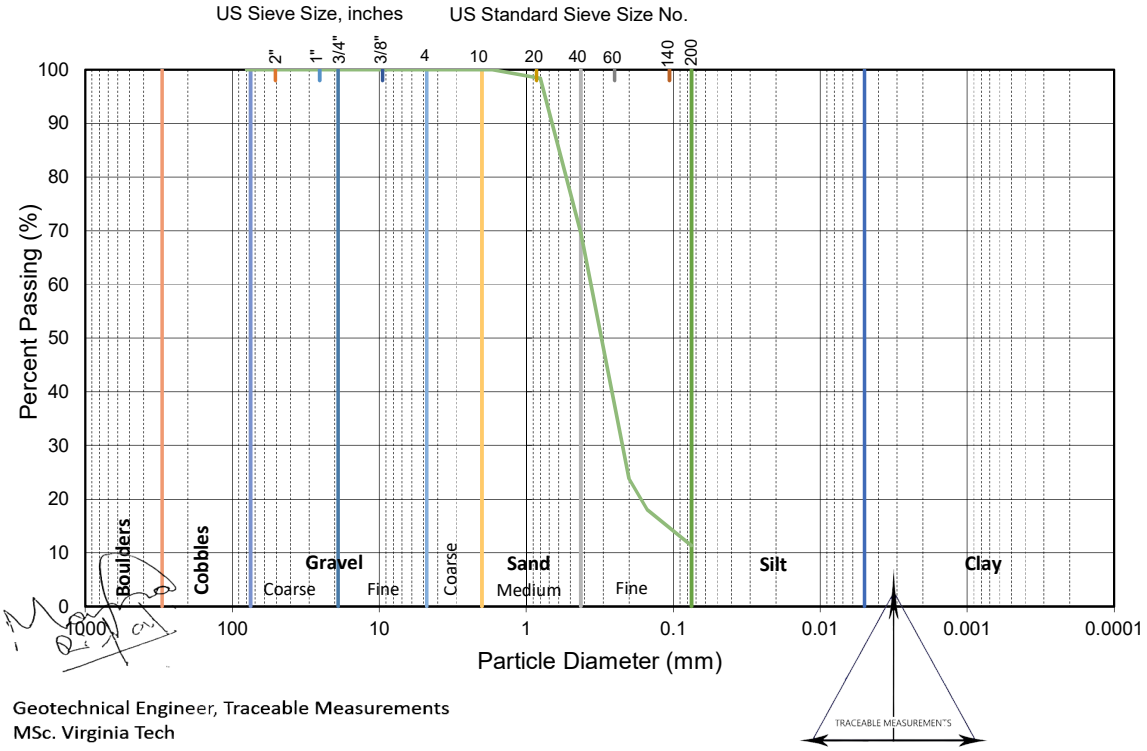
Lab Name:	Traceable Measurement Pvt. Ltd.
Tested By:	
Reviewed By:	
Test Date:	07/10/2079
Report Date:	

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

S.N	(mm)	Wt Ret	% Ret	Cum % Ret	% Pass
1	80	0.0	0.00	0.00	100.00
2	38.1	0.0	0.00	0.00	100.00
3	25.4	0.0	0.00	0.00	100.00
4	19.1	0.0	0.00	0.00	100.00
5	9.5	0.0	0.00	0.00	100.00
6	4.75	0.0	0.00	0.00	100.00
7	2.36	0.400	0.25	0.25	99.75
8	1.70	0.100	0.06	0.31	99.69
9	0.8	0.900	0.56	0.86	99.14
10	0.425	7.800	4.82	5.68	94.32
11	0.20	94.700	58.49	64.18	35.82
12	0.15	25.000	15.44	79.62	20.38
13	0.075	20.400	12.60	92.22	7.78
Pan		12.600			
Tot Pan		12.60	7.78	100.00	0.00
Fineness Mod.				1.51	

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

Poorly Graded Sand with Clay (SP-SC)



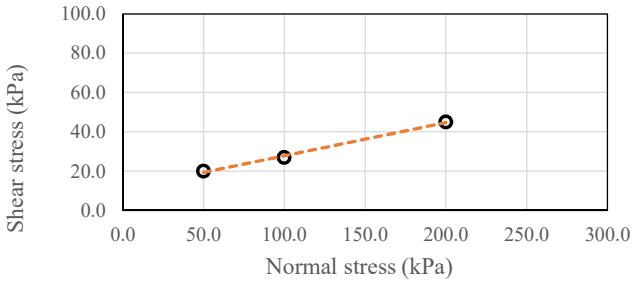
Geotechnical Engineer, Traceable Measurements
MSc. Virginia Tech

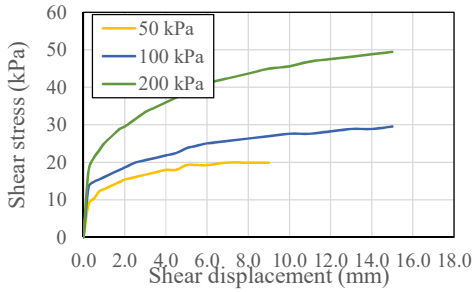
PAN: 604248398, Reg. No. 148209/72/073
TRACEABLE MEASUREMENTS PVT. LTD.
Tel. 01-5413270; Sanepa, Lalitpur.

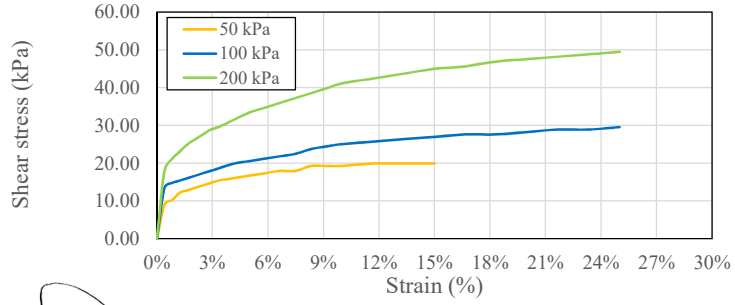
Direct Shear Test

Project Name	:	**MCA-Nepal**		
Location	:	**T17/1N**		
Bore Hole No	:	**1**	**PRG factor:**	**0.002312**
Bore Hole Depth	:	**0-1.5m**	**Area:**	**0.0036**

Hz Dial Gauge reading (x 0.01mm)	Normal Strain (%)	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	0.00	0	0.00	0	0.00	
25	0.4%	14	8.99	21	13.49	28	17.98	
50	0.8%	16	10.28	23	14.77	33	21.19	
75	1%	19	12.20	24	15.41	36	23.12	
100	1.7%	20	12.84	25	16.06	39	25.05	
125	2.1%	21	13.49	26	16.70	41	26.33	
150	3%	22	14.13	27	17.34	43	27.62	
175	2.9%	23	14.77	28	17.98	45	28.90	
200	3.3%	24	15.41	29	18.62	46	29.54	
250	4%	25	16.06	31	19.91	49	31.47	
300	5.0%	26	16.70	32	20.55	52	33.40	
350	5.8%	27	17.34	33	21.19	54	34.68	
400	7%	28	17.98	34	21.84	56	35.96	
450	7.5%	28	17.98	35	22.48	58	37.25	
500	8.3%	30	19.27	37	23.76	60	38.53	
550	9.2%	30	19.27	38	24.40	62	39.82	
600	10%	30	19.27	39	25.05	64	41.10	
700	11.7%	31	19.91	40	25.69	66	42.39	
800	13.3%	31	19.91	41	26.33	68	43.67	
900	15%	31	19.91	42	26.97	70	44.96	
1000	16.7%			43	27.62	71	45.60	
1100	18.3%			43	27.62	73	46.88	
1200	20%			44	28.26	74	47.52	
1300	21.7%			45	28.90	75	48.17	
1400	23.3%			45	28.90	76	48.81	
1500	25%			46	29.54	77	49.45	
1600	26.7%							







ϕ'	**14**	Degree
c'	**10.28**	kN/m^2

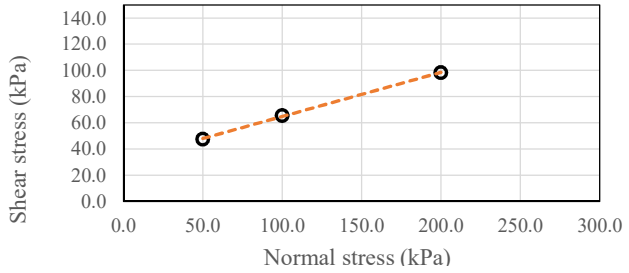
Geotechnical Engineer, Traceable Measurements
MSc. Virginia Tech

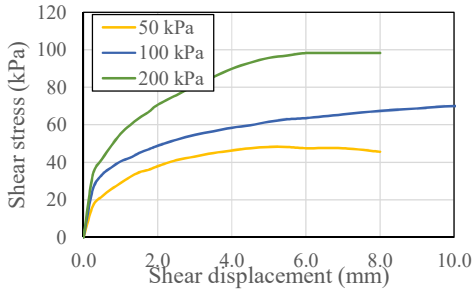
PAN: 604248398, Reg. No. 148209/72/073
TRACEABLE MEASUREMENTS PVT. LTD.
Tel. 01-5413270; Sanepa, Lalitpur.

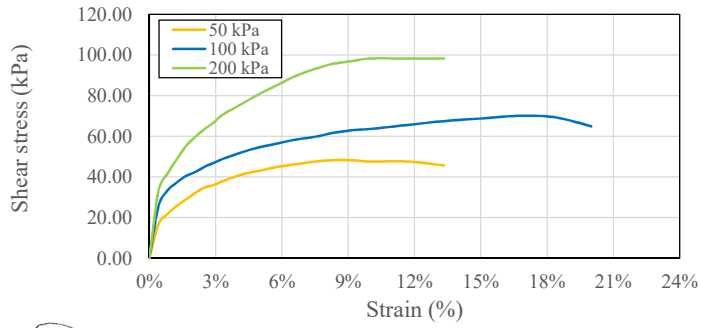
Direct Shear Test

Project Name	:	**MCA-Nepal**		
Location	:	**T17/1N**		
Bore Hole No	:	**1**	**PRG factor:**	**0.002312**
Bore Hole Depth	:	**1.5m - 4.5m**	**Area:**	**0.0036**

Hz Dial Gauge reading (x 0.01mm)	Normal Strain (%)	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	0.00	0	0.00	0	0.00	
25	0.4%	26	16.70	40	25.69	52	33.40	
50	0.8%	34	21.84	52	33.40	65	41.74	
75	1%	40	25.69	58	37.25	76	48.81	
100	1.7%	45	28.90	63	40.46	86	55.23	
125	2.1%	50	32.11	66	42.39	93	59.73	
150	3%	54	34.68	70	44.96	99	63.58	
175	2.9%	56	35.96	73	46.88	104	66.79	
200	3.3%	59	37.89	76	48.81	110	70.64	
250	4%	64	41.10	81	52.02	118	75.78	
300	5.0%	67	43.03	85	54.59	126	80.92	
350	5.8%	70	44.96	88	56.52	133	85.42	
400	7%	72	46.24	91	58.44	140	89.91	
450	7.5%	74	47.52	93	59.73	145	93.12	
500	8.3%	75	48.17	96	61.65	149	95.69	
550	9.2%	75	48.17	98	62.94	151	96.98	
600	10%	74	47.52	99	63.58	153	98.26	
700	11.7%	74	47.52	102	65.51	153	98.26	
800	13.3%	71	45.60	105	67.43	153	98.26	
900	15%			107	68.72			
1000	16.7%			109	70.00			
1100	18.3%			108	69.36			
1200	20%			101	64.86			
1300	21.7%							
1400	23.3%							
1500	25%							
1600	26.7%							







ϕ'	**19**	Degree
c'	**31.14**	kN/m^2

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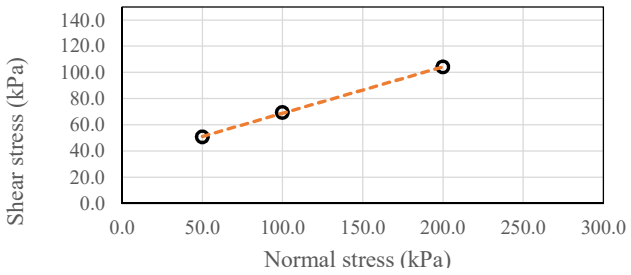
MSc. Virginia Tech

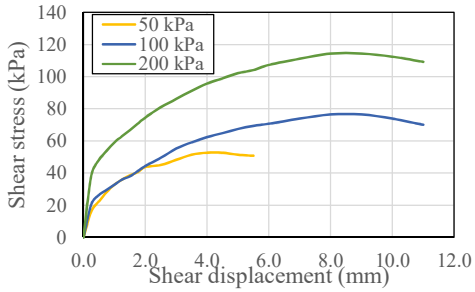
PAN: 604248398, Reg. No. 148209/72/073
TRACEABLE MEASUREMENTS PVT. LTD.
Tel. 01-5413270; Sanepa, Lalitpur.

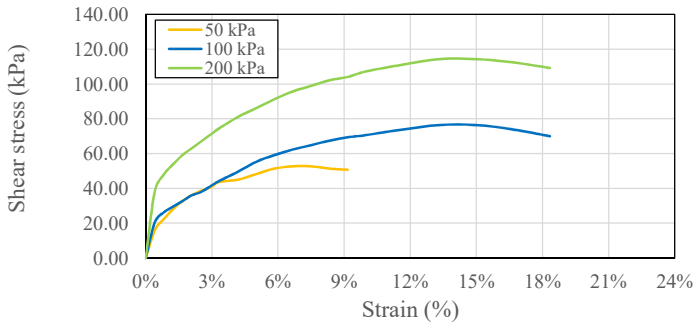
Direct Shear Test

Project Name	:	**MCA-Nepal**		
Location	:	**T17/1N**		
Bore Hole No	:	**1**	**PRG factor:**	**0.002312**
Bore Hole Depth	:	**4.5m - 6m**	**Area:**	**0.0036**

Hz Dial Gauge reading (x 0.01mm)	Normal Strain (%)	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	0.00	0	0.00	0	0.00	
25	0.4%	25	16.06	32	20.55	60	38.53	
50	0.8%	35	22.48	41	26.33	75	48.17	
75	1%	44	28.26	46	29.54	84	53.95	
100	1.7%	51	32.75	51	32.75	92	59.08	
125	2.1%	56	35.96	56	35.96	98	62.94	
150	3%	60	38.53	59	37.89	104	66.79	
175	2.9%	63	40.46	64	41.10	110	70.64	
200	3.3%	68	43.67	69	44.31	116	74.50	
250	4%	70	44.96	77	49.45	126	80.92	
300	5.0%	75	48.17	86	55.23	134	86.06	
350	5.8%	80	51.38	92	59.08	142	91.20	
400	7%	82	52.66	97	62.30	149	95.69	
450	7.5%	82	52.66	101	64.86	154	98.90	
500	8.3%	80	51.38	105	67.43	159	102.11	
550	9.2%	79	50.74	108	69.36	162	104.04	
600	10%			110	70.64	167	107.25	
700	11.7%			115	73.86	173	111.10	
800	13.3%			119	76.42	178	114.32	
900	15%			119	76.42	178	114.32	
1000	16.7%			115	73.86	175	112.39	
1100	18.3%			109	70.00	170	109.18	
1200	20%							
1300	21.7%							
1400	23.3%							
1500	25%							
1600	26.7%							







ϕ'	**19**	Degree
c'	**33.31**	kN/m^2

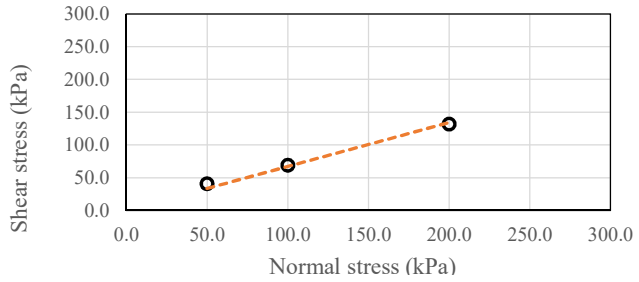
Geotechnical Engineer, Traceable Measurements
MSc. Virginia Tech

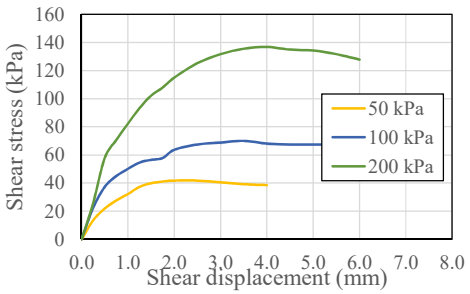
PAN: 604248398, Reg. No. 148209/72/073
TRACEABLE MEASUREMENTS PVT. LTD.
Tel. 01-5413270; Sanepa, Lalitpur.

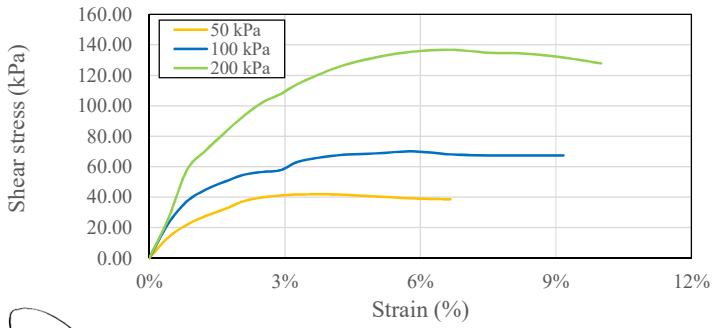
Direct Shear Test

Project Name	:	**MCA-Nepal**		
Location	:	**T17/1N**		
Bore Hole No	:	**1**	**PRG factor:**	**0.002312**
Bore Hole Depth	:	**6m - 7.5m**	**Area:**	**0.0036**

Hz Dial Gauge reading (x 0.01mm)	Normal Strain (%)	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	0.00	0	0.00	0	0.00	
25	0.4%	21	13.49	35	22.48	40	25.69	
50	0.8%	34	21.84	58	37.25	90	57.80	
75	1%	43	27.62	70	44.96	110	70.64	
100	1.7%	50	32.11	78	50.09	128	82.20	
125	2.1%	58	37.25	85	54.59	145	93.12	
150	3%	62	39.82	88	56.52	159	102.11	
175	2.9%	64	41.10	90	57.80	168	107.89	
200	3.3%	65	41.74	99	63.58	179	114.96	
250	4%	65	41.74	105	67.43	195	125.23	
300	5.0%	63	40.46	107	68.72	205	131.66	
350	5.8%	61	39.18	109	70.00	211	135.51	
400	7%	60	38.53	106	68.08	213	136.79	
450	7.5%			105	67.43	210	134.87	
500	8.3%			105	67.43	209	134.22	
550	9.2%			105	67.43	205	131.66	
600	10%					199	127.80	
700	11.7%							
800	13.3%							
900	15%							
1000	16.7%							
1100	18.3%							
1200	20%							
1300	21.7%							
1400	23.3%							
1500	25%							
1600	26.7%							







ϕ'	**34**	Degree
c'	**0.00**	kN/m^2

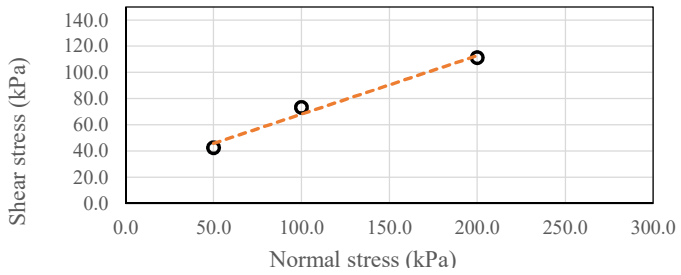
Geotechnical Engineer, Traceable Measurements
MSc. Virginia Tech

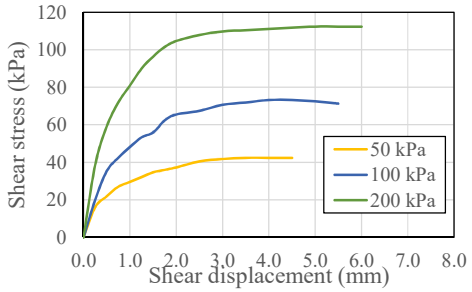
PAN: 604248398, Reg. No. 148209/72/073
TRACEABLE MEASUREMENTS PVT. LTD.
Tel. 01-5413270; Sanepa, Lalitpur.

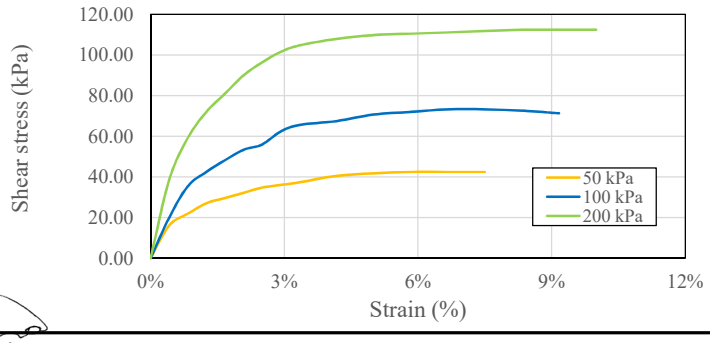
Direct Shear Test

Project Name	:	**MCA-Nepal**		
Location	:	**T17/1N**		
Bore Hole No	:	**1**	**PRG factor:**	**0.002312**
Bore Hole Depth	:	**7.5m - 9m**	**Area:**	**0.0036**

Hz Dial Gauge reading (x 0.01mm)	Normal Strain (%)	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	0.00	0	0.00	0	0.00	
25	0.4%	25	16.06	31	19.91	60	38.53	
50	0.8%	34	21.84	55	35.32	92	59.08	
75	1%	42	26.97	66	42.39	112	71.93	
100	1.7%	46	29.54	75	48.17	126	80.92	
125	2.1%	50	32.11	83	53.30	140	89.91	
150	3%	54	34.68	87	55.87	150	96.33	
175	2.9%	56	35.96	97	62.30	158	101.47	
200	3.3%	58	37.25	102	65.51	163	104.68	
250	4%	63	40.46	105	67.43	168	107.89	
300	5.0%	65	41.74	110	70.64	171	109.82	
350	5.8%	66	42.39	112	71.93	172	110.46	
400	7%	66	42.39	114	73.21	173	111.10	
450	7.5%	66	42.39	114	73.21	174	111.75	
500	8.3%			113	72.57	175	112.39	
550	9.2%			111	71.29	175	112.39	
600	10%					175	112.39	
700	11.7%							
800	13.3%							
900	15%							
1000	16.7%							
1100	18.3%							
1200	20%							
1300	21.7%							
1400	23.3%							
1500	25%							
1600	26.7%							







ϕ'	**24**	Degree
c'	**23.00**	kN/m^2

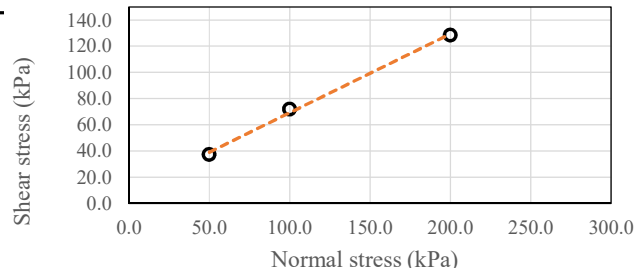
Geotechnical Engineer, Traceable Measurements
MSc. Virginia Tech

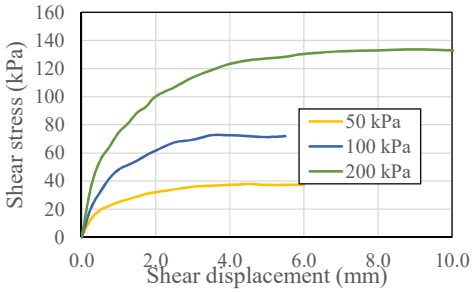
PAN: 604248398, Reg. No. 148209/72/073
TRACEABLE MEASUREMENTS PVT. LTD.
Tel. 01-5413270; Sanepa, Lalitpur.

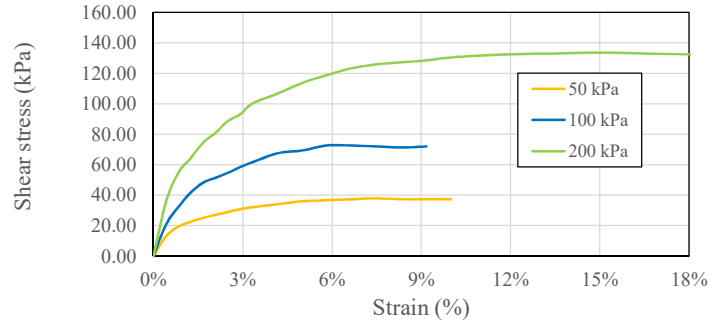
Direct Shear Test

Project Name	:	**MCA-Nepal**		
Location	:	**T17/1N**		
Bore Hole No	:	**1**	**PRG factor:**	**0.002312**
Bore Hole Depth	:	**9m - 12m**	**Area:**	**0.0036**

Hz Dial Gauge reading (x 0.01mm)	Normal Strain (%)	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	0.00	0	0.00	0	0.00	
25	0.4%	20	12.84	32	20.55	55	35.32	
50	0.8%	30	19.27	50	32.11	85	54.59	
75	1%	35	22.48	65	41.74	100	64.22	
100	1.7%	39	25.05	75	48.17	116	74.50	
125	2.1%	42	26.97	80	51.38	126	80.92	
150	3%	45	28.90	85	54.59	138	88.63	
175	2.9%	48	30.83	91	58.44	145	93.12	
200	3.3%	50	32.11	96	61.65	156	100.19	
250	4%	53	34.04	105	67.43	166	106.61	
300	5.0%	56	35.96	108	69.36	177	113.67	
350	5.8%	57	36.61	113	72.57	185	118.81	
400	7%	58	37.25	113	72.57	192	123.31	
450	7.5%	59	37.89	112	71.93	196	125.88	
500	8.3%	58	37.25	111	71.29	198	127.16	
550	9.2%	58	37.25	112	71.93	200	128.44	
600	10%	58	37.25			203	130.37	
700	11.7%					206	132.30	
800	13.3%					207	132.94	
900	15%					208	133.58	
1000	16.7%					207	132.94	
1100	18.3%					206	132.30	
1200	20%					206	132.30	
1300	21.7%					206	132.30	
1400	23.3%							
1500	25%							
1600	26.7%							







ϕ'	**31**	Degree
c'	**9.00**	kN/m^2

Geotechnical Engineer, Traceable Measurements
MSc. Virginia Tech

ATTERBERG LIMITS ASTM D4318-17 Method A

TRACEABLE MEASUREMENTS PVT. LTD.
www.traceablemeasurements.com.np

Project Information

Project Name:	MCC
Location:	T17/1N
Client Name:	

Sample Information

Borehole/Test Pit:	1
Sample #:	
Depth:	1.5m
Sample Type:	
Sampled By:	

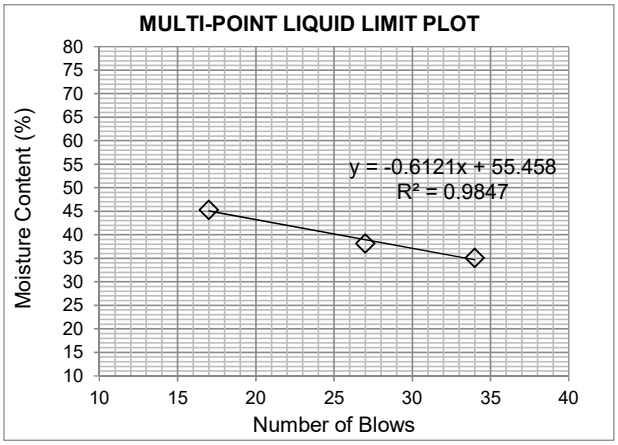
Laboratory Information

Lab Name:	
Tested By:	
Checked By:	
Approved By:	
Test Date:	

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

Liquid Limit

Sample Number	1	2	3	4
(I) No. of Blows	34	27	17	
(II) Tin ID	0	102	117	
(III) Mass of Tin + Moist Soil, g	21.70	19.70	27.30	
(IV) Mass of Tin + Dry Soil, g	19.70	17.60	22.90	
(V) Mass of Water, g = (C-D)	2.00	2.10	4.40	
(VI) Mass of Tin, g	14.00	12.10	13.20	
(VII) Mass of Dry Soil, g = (D-F)	5.70	5.50	9.70	
(VII) Moisture Content, % = (E/G)	35.09	38.18	45.36	

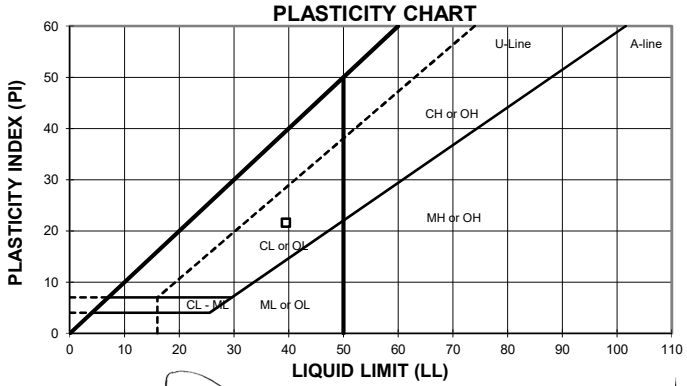


Plastic Limit

Sample Number	1	2	3	4
(IX) Tin ID	19	50	58	
(X) Mass of Tin + Moist Soil, g	16.60	17.40	17.90	
(XI) Mass of Tin + Dry Soil, g	16.00	17.00	17.20	
(XII) Mass of Water, g = (J-K)	0.60	0.40	0.70	
(XII) Mass of Tin, g	13.20	13.90	13.60	
(XIV) Mass of Dry Soil, g = (K-M)	2.80	3.10	3.60	
(XV) Moisture Content, % = (L/N)	21.43	12.90	19.44	
(XVI) Average Moisture Content, %	17.93			

Visual Description

USCS Group Symbol (ASTM D2487-17)
CL



Liquid Limit (%): 40
Plastic Limit (%): 18
Plasticity Index (%) 22

Report Date:	

Geotechnical Engineer, Traceable Measurements
MSc. Virginia Tech

TRACEABLE MEASUREMENTS

ATTERBERG LIMITS ASTM D4318-17 Method A

TRACEABLE MEASUREMENTS PVT. LTD.
www.traceablemeasurements.com.np

Project Information

Project Name:	MCC
Location:	T17/1N
Client Name:	

Sample Information

Borehole/Test Pit:	1
Sample #:	
Depth:	1.5m-4.5m
Sample Type:	
Sampled By:	

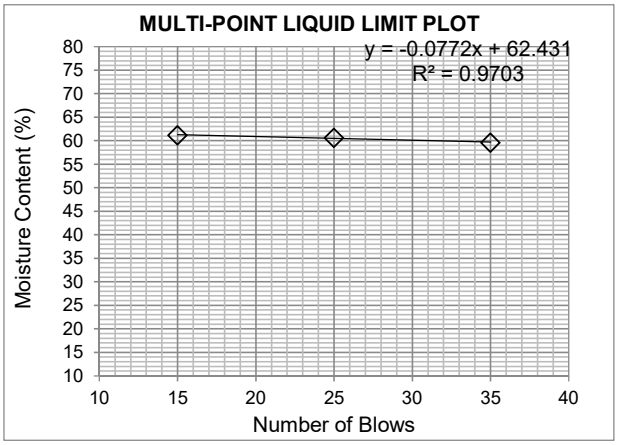
Laboratory Information

Lab Name:	
Tested By:	
Checked By:	
Approved By:	
Test Date:	

Preparation Method: Wet Preparation ☐ Oven Dry [X] Air Dry ☐

Liquid Limit

Sample Number	1	2	3	4
(I) No. of Blows	35	25	15	
(II) Tin ID	76	26	73	
(III) Mass of Tin + Moist Soil, g	22.20	22.20	33.00	
(IV) Mass of Tin + Dry Soil, g	18.80	18.50	24.80	
(V) Mass of Water, g = (C-D)	3.40	3.70	8.20	
(VI) Mass of Tin, g	13.10	12.40	11.40	
(VII) Mass of Dry Soil, g = (D-F)	5.70	6.10	13.40	
(VII) Moisture Content, % = (E/G)	59.65	60.66	61.19	

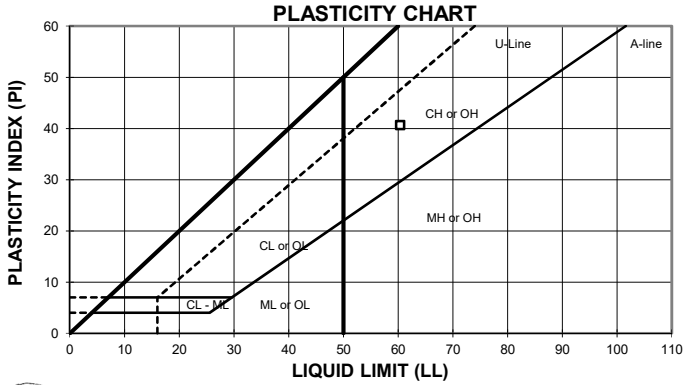


Plastic Limit

Sample Number	1	2	3	4
(IX) Tin ID	17	34	75	
(X) Mass of Tin + Moist Soil, g	17.10	15.70	17.40	
(XI) Mass of Tin + Dry Soil, g	16.40	15.10	16.70	
(XII) Mass of Water, g = (J-K)	0.70	0.60	0.70	
(XII) Mass of Tin, g	12.10	12.70	12.80	
(XIV) Mass of Dry Soil, g = (K-M)	4.30	2.40	3.90	
(XV) Moisture Content, % = (L/N)	16.28	25.00	17.95	
(XVI) Average Moisture Content, %	19.74			

Visual Description

USCS Group Symbol (ASTM D2487-17)
CH



Liquid Limit (%): 60
Plastic Limit (%): 20
Plasticity Index (%) 41

Report Date:	

Geotechnical Engineer, Traceable Measurements
MSc. Virginia Tech

TRACEABLE MEASUREMENTS

ATTERBERG LIMITS ASTM D4318-17 Method A

TRACEABLE MEASUREMENTS PVT. LTD.
www.traceablemeasurements.com.np

Project Information

Project Name:	MCC
Location:	T17/1N
Client Name:	

Sample Information

Borehole/Test Pit:	1
Sample #:	
Depth:	6m
Sample Type:	
Sampled By:	

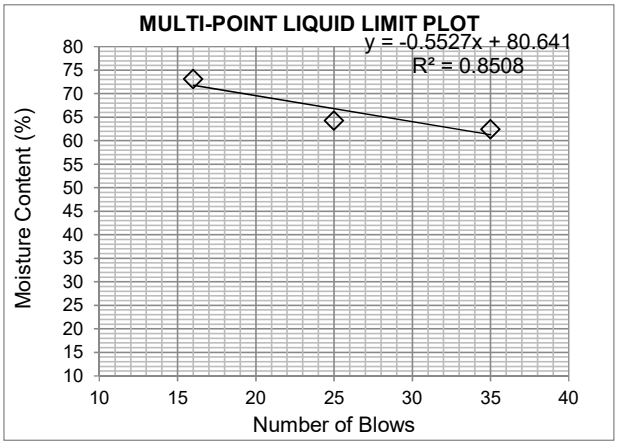
Laboratory Information

Lab Name:	
Tested By:	
Checked By:	
Approved By:	
Test Date:	

Preparation Method: Wet Preparation ☐ Oven Dry [X] Air Dry ☐

Liquid Limit

Sample Number	1	2	3	4
(I) No. of Blows	25	35	16	
(II) Tin ID	78	104	45	
(III) Mass of Tin + Moist Soil, g	16.30	21.60	24.40	
(IV) Mass of Tin + Dry Soil, g	14.50	18.10	19.50	
(V) Mass of Water, g = (C-D)	1.80	3.50	4.90	
(VI) Mass of Tin, g	11.70	12.50	12.80	
(VII) Mass of Dry Soil, g = (D-F)	2.80	5.60	6.70	
(VII) Moisture Content, % = (E/G)	64.29	62.50	73.13	

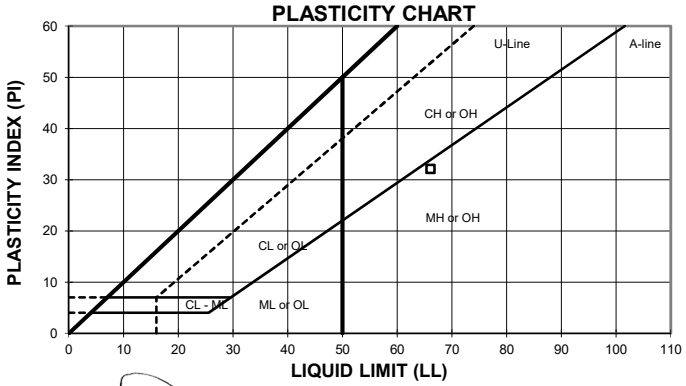


Plastic Limit

Sample Number	1	2	3	4
(IX) Tin ID	75	57	48	
(X) Mass of Tin + Moist Soil, g	16.40	18.70	14.70	
(XI) Mass of Tin + Dry Soil, g	15.40	17.80	13.90	
(XII) Mass of Water, g = (J-K)	1.00	0.90	0.80	
(XII) Mass of Tin, g	12.90	14.80	11.40	
(XIV) Mass of Dry Soil, g = (K-M)	2.50	3.00	2.50	
(XV) Moisture Content, % = (L/N)	40.00	30.00	32.00	
(XVI) Average Moisture Content, %	34.00			

Visual Description

USCS Group Symbol (ASTM D2487-17)
MH



Liquid Limit (%): 66
Plastic Limit (%): 34
Plasticity Index (%) 32

Report Date:	

Geotechnical Engineer, Traceable Measurements
MSc. Virginia Tech

TRACEABLE MEASUREMENTS

PAN: 604248398, Reg. No. 148209/72/073
TRACEABLE MEASUREMENTS PVT. LTD.
Tel. 01-5413270; Sanepa, Lalitpur.

CIVIL ENGINEERING LAB REPORT

Project Name	:	Soil Investigation Works of Services & updated line Design for 30 km of Changes in 400kv Transmission Line Route Aligment of	
Client Name	:	MCA-N	Date Sampled: 17/09/2079
Consultant	:		Date Tested: 13/10/2079
Location	:	T17/1N	
Borehole No.	:	1	
Borehole Depth	:	1.5m	

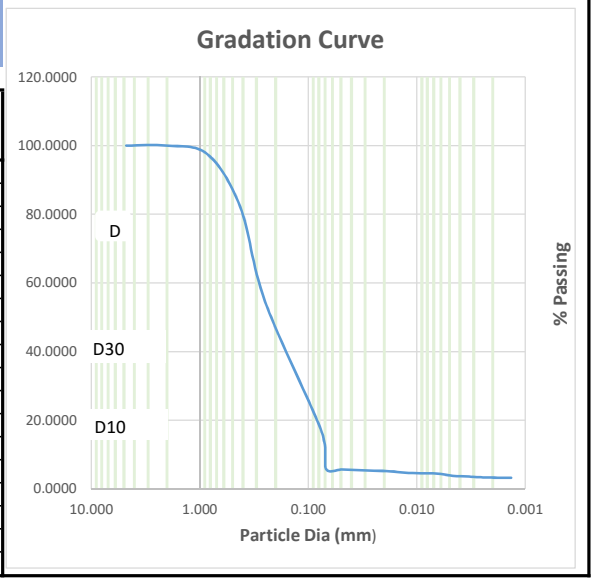
Hydrometer Test
(IS:2720-4-1985)

Input Parameters		
Viscosity of water at 25 C temperature	9.220E-06	g s/cm2
Specific gravity of soil	2.516	
Weight of dry soil	50	g
Zero Correction	2.5	
Miniscous Correction	0.5	

Time (MIN)	Ra	T	Tc=-4.85+0.25T	Rc=Ra-Zc+Tc	% finer = (Rcxa)/Ws	Rcorrected for miniscous	L=16.3-0.164Ra	K	D (mm)	Actual % finer wrt to total fines in soil mass
0.5	19.5	24	1.15	18.15	36.3	20	13.102	0.01351	0.0691	5.977
1	18.5	24	1.15	17.15	34.3	19	13.266	0.01351	0.0492	5.647
2	18	24	1.15	16.65	33.3	18.5	13.348	0.01351	0.0349	5.483
4	17.5	24	1.15	16.15	32.3	18	13.43	0.01351	0.0248	5.318
8	17	24	1.15	15.65	31.3	17.5	13.512	0.01351	0.0176	5.153
15	15.5	25	1.4	14.4	28.8	16	13.758	0.01351	0.0129	4.742
30	15	25	1.4	13.9	27.8	15.5	13.84	0.01351	0.0092	4.577
60	14.5	26	1.65	13.65	27.3	15	13.922	0.01351	0.0065	4.495
120	12.5	26	1.65	11.65	23.3	13	14.25	0.01351	0.0047	3.836
240	12.5	23	0.9	10.9	21.8	13	14.25	0.01351	0.0033	3.589
480	12	22	0.65	10.15	20.3	12.5	14.332	0.01351	0.0023	3.342
1440	11	25	1.4	9.9	19.8	11.5	14.496	0.01351	0.0014	3.260

Sieve Analysis test calculations & Particle Size Distribution Curve

Sieve Number	Diameter (mm)	Soil Retained (g)	Accumulative Retain (gm)	% Mass Retain	% Passing
#4	4.750	0	0	0.0000	100.0000
#10	2.000	0	0	0.0000	100.0000
#20	0.850	6.6	6.6	2.5038	97.4962
#40	0.425	40.3	46.9	17.7921	82.2079
#60	0.250	73.0	119.9	45.4856	54.5144
#200	0.075	100.3	220.2	83.5357	16.4643
Hydrometer Analysis	0.0691	43.4	263.6		5.977
	0.0492				5.647
	0.0349				5.483
	0.0248				5.318
	0.0176				5.153
	0.0129				4.742
	0.0092				4.577
	0.0065				4.495
	0.0047				3.836
	0.0033				3.589
	0.0023				3.342
	0.0014				3.260



Geotechnical Engineer, Traceable Measurements
MSc. Virginia Tech

PAN: 604248398, Reg. No. 148209/72/073
TRACEABLE MEASUREMENTS PVT. LTD.
Tel. 01-5413270; Sanepa, Lalitpur.

CIVIL ENGINEERING LAB REPORT

Project Name	:	Soil Investigation Works of Services & updated line Design for 30 km of Changes in 400kv Transmission Line Route Aligment of	
Client Name	:	MCA-N	Date Sampled: 17/09/2079
Consultant	:		Date Tested: 13/10/2079
Location	:	T17/1N	
Borehole No.	:	1	
Borehole Depth	:	1.5m-4.5m	

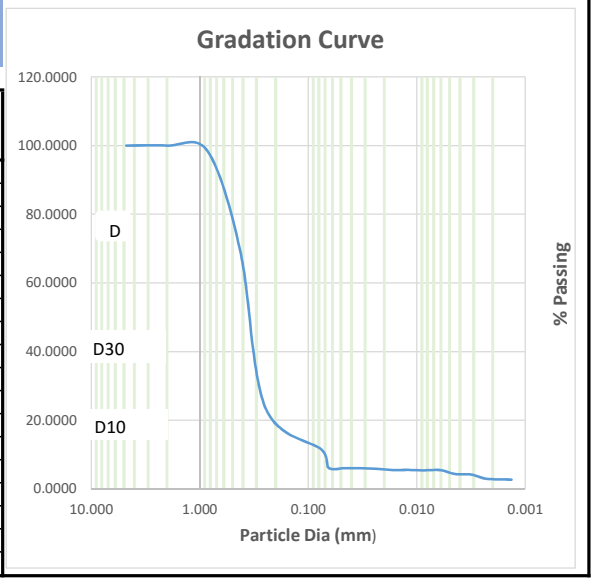
Hydrometer Test
(IS:2720-4-1985)

Input Parameters		
Viscosity of water at 25 C temperature	9.220E-06	g s/cm2
Specific gravity of soil	2.516	
Weight of dry soil	50	g
Zero Correction	2.5	
Miniscous Correction	0.5	

Time (MIN)	Ra	T	Tc=-4.85+0.25T	Rc=Ra-Zc+Tc	% finer = (Rcxa)/Ws	Rcorrected for miniscous	L=16.3-0.164Ra	K	D (mm)	Actual % finer wrt to total fines in soil mass
0.5	28.5	24	1.15	27.15	54.3	29	11.626	0.01351	0.0651	6.167
1	28	24	1.15	26.65	53.3	28.5	11.708	0.01351	0.0462	6.054
2	28	24	1.15	26.65	53.3	28.5	11.708	0.01351	0.0327	6.054
4	27	24	1.15	25.65	51.3	27.5	11.872	0.01351	0.0233	5.826
8	25.5	24	1.15	24.15	48.3	26	12.118	0.01351	0.0166	5.486
15	25.5	25	1.4	24.4	48.8	26	12.118	0.01351	0.0121	5.542
30	25	25	1.4	23.9	47.8	25.5	12.2	0.01351	0.0086	5.429
60	25	26	1.65	24.15	48.3	25.5	12.2	0.01351	0.0061	5.486
120	20	26	1.65	19.15	38.3	20.5	13.02	0.01351	0.0044	4.350
240	20	23	0.9	18.4	36.8	20.5	13.02	0.01351	0.0031	4.180
480	15	22	0.65	13.15	26.3	15.5	13.84	0.01351	0.0023	2.987
1440	13	25	1.4	11.9	23.8	13.5	14.168	0.01351	0.0013	2.703

Sieve Analysis test calculations & Particle Size Distribution Curve

Sieve Number	Diameter (mm)	Soil Retained (g)	Accumulative Retain (gm)	% Mass Retain	% Passing
#4	4.750	0	0	0.0000	100.0000
#10	2.000	0	0	0.0000	100.0000
#20	0.850	5.2	5.2	1.5791	98.4209
#40	0.425	95.3	100.5	30.5193	69.4807
#60	0.250	150.3	250.8	76.1616	23.8384
#200	0.075	41.1	291.9	88.6426	11.3574
Hydrometer Analysis	0.0651	37.4	329.3		6.167
	0.0462				6.054
	0.0327				6.054
	0.0233				5.826
	0.0166				5.486
	0.0121				5.542
	0.0086				5.429
	0.0061				5.486
	0.0044				4.350
	0.0031				4.180
	0.0023				2.987
	0.0013				2.703



Geotechnical Engineer, Traceable Measurements
MSc. Virginia Tech

PAN: 604248398, Reg. No. 148209/72/073
TRACEABLE MEASUREMENTS PVT. LTD.
Tel. 01-5413270; Sanepa, Lalitpur.

CIVIL ENGINEERING LAB REPORT

Project Name	:	Soil Investigation Works of Services & updated line Design for 30 km of Changes in 400kv Transmission Line Route Aligment of	
Client Name	:	MCA-N	Date Sampled: 17/09/2079
Consultant	:		Date Tested: 13/10/2079
Location	:	T17/1N	
Borehole No.	:	1	
Borehole Depth	:	6m	

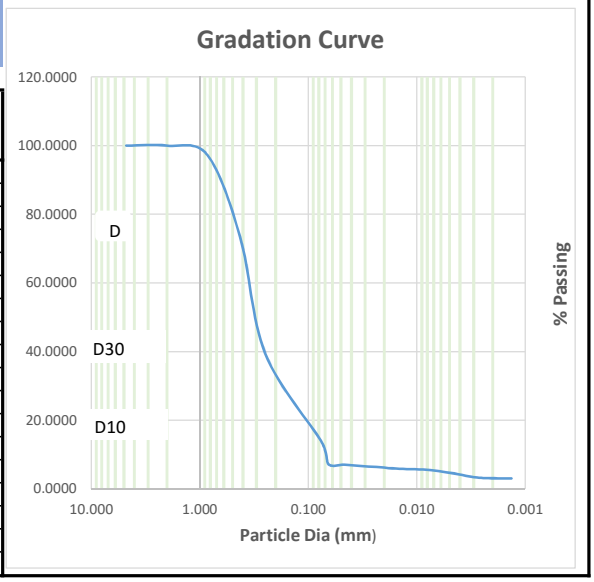
Hydrometer Test
(IS:2720-4-1985)

Input Parameters		
Viscosity of water at 25 C temperature	9.220E-06	g s/cm2
Specific gravity of soil	2.516	
Weight of dry soil	50	g
Zero Correction	2.5	
Miniscous Correction	0.5	

Time (MIN)	Ra	T	Tc=-4.85+0.25T	Rc=Ra-Zc+Tc	% finer = (Rcxa)/Ws	Rcorrected for miniscous	L=16.3-0.164Ra	K	D (mm)	Actual % finer wrt to total fines in soil mass
0.5	28	24	1.15	26.65	53.3	28.5	11.708	0.01351	0.0654	7.215
1	27.5	24	1.15	26.15	52.3	28	11.79	0.01351	0.0464	7.080
2	26	24	1.15	24.65	49.3	26.5	12.036	0.01351	0.0331	6.674
4	25	24	1.15	23.65	47.3	25.5	12.2	0.01351	0.0236	6.403
8	23.5	24	1.15	22.15	44.3	24	12.446	0.01351	0.0168	5.997
15	22.5	25	1.4	21.4	42.8	23	12.61	0.01351	0.0124	5.794
30	22	25	1.4	20.9	41.8	22.5	12.692	0.01351	0.0088	5.658
60	20	26	1.65	19.15	38.3	20.5	13.02	0.01351	0.0063	5.185
120	17.5	26	1.65	16.65	33.3	18	13.43	0.01351	0.0045	4.508
240	15	23	0.9	13.4	26.8	15.5	13.84	0.01351	0.0032	3.628
480	13.5	22	0.65	11.65	23.3	14	14.086	0.01351	0.0023	3.154
1440	12.5	25	1.4	11.4	22.8	13	14.25	0.01351	0.0013	3.086

Sieve Analysis test calculations & Particle Size Distribution Curve

Sieve Number	Diameter (mm)	Soil Retained (g)	Accumulative Retain (gm)	% Mass Retain	% Passing
#4	4.750	0	0	0.0000	100.0000
#10	2.000	0	0	0.0000	100.0000
#20	0.850	8.7	8.7	2.7645	97.2355
#40	0.425	75.1	83.8	26.6285	73.3715
#60	0.250	106.6	190.4	60.5021	39.4979
#200	0.075	81.7	272.1	86.4633	13.5367
Hydrometer Analysis	0.0654	42.6	314.7		7.215
	0.0464				7.080
	0.0331				6.674
	0.0236				6.403
	0.0168				5.997
	0.0124				5.794
	0.0088				5.658
	0.0063				5.185
	0.0045				4.508
	0.0032				3.628
	0.0023				3.154
	0.0013				3.086



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Soil Investigation Works of Consulting Services & updated line Design for 30 km of Changes in 400kv Transmission Line Route Aligment of MCA-Nepal

Bearing capacity analysis of the Shallow Foundation

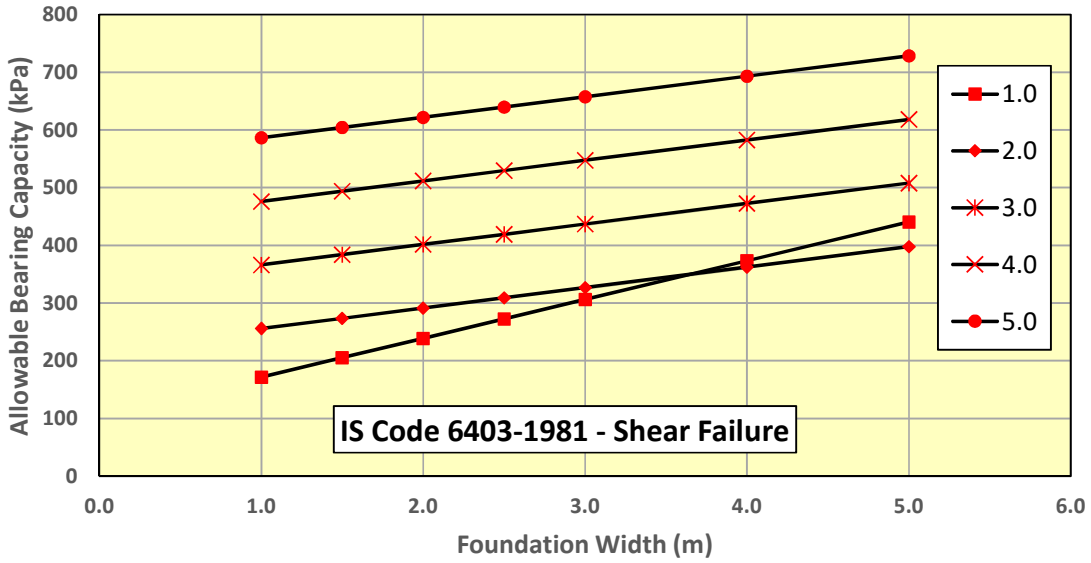
This calculation based on the IS:6403-1981. The allowable bearing capacity is based on the shear failure of soil. The effective internal angle of friction is adopted either from direct shear test result or empirical correlation or approximated using engineering judgement and experience between SPT N value and angle of friction.

Indo Nepal Border - New Butwal 400 kV D/C TL

Bore Hole No. - T17/1N

Depth of Foundation, D_f (m)	1.0	2.0	3.0	4.0	5.0
Friction angle	30	30	30	30	30
SPT N Value	21	21	25	28	28
Unit wt. of soil, kN/m^3	18	19	19	19	19
Buoyant Unit wt. of soil. kN/m^3	8	9	9	9	9
Cohesion. kN/m^2	0	0	0	0	0
Water Reduction Factor W_y	1	0.5	0.5	0.5	0.5
N_q	18.40	18.40	18.40	18.40	18.40
N_c	30.14	30.14	30.14	30.14	30.14
N_y	22.40	22.40	22.40	22.40	22.40

	Net Allowable Bearing, kN/m^2 (IS: 6403-1981 Shear Failure)				
Depth of Foundation, D_f (m)	1.0	2.0	3.0	4.0	5.0
Width of foundation, B (m)					
1.0	172	256	366	476	587
1.5	205	274	384	494	604
2.0	239	291	402	512	622
2.5	272	309	419	530	640
3.0	306	327	437	547	657
4.0	373	362	473	583	693
5.0	440	398	508	618	728



Note: For footing size greater than 2 m bearing capacity is usually governed by settlement criterion. Please refer to bearing capacity evaluated based on settlement criterion.

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Soil Investigation Works of Consulting Services & updated line Design for 30 km of Changes in 400kv Transmission Line Route Aligment of MCA-Nepal

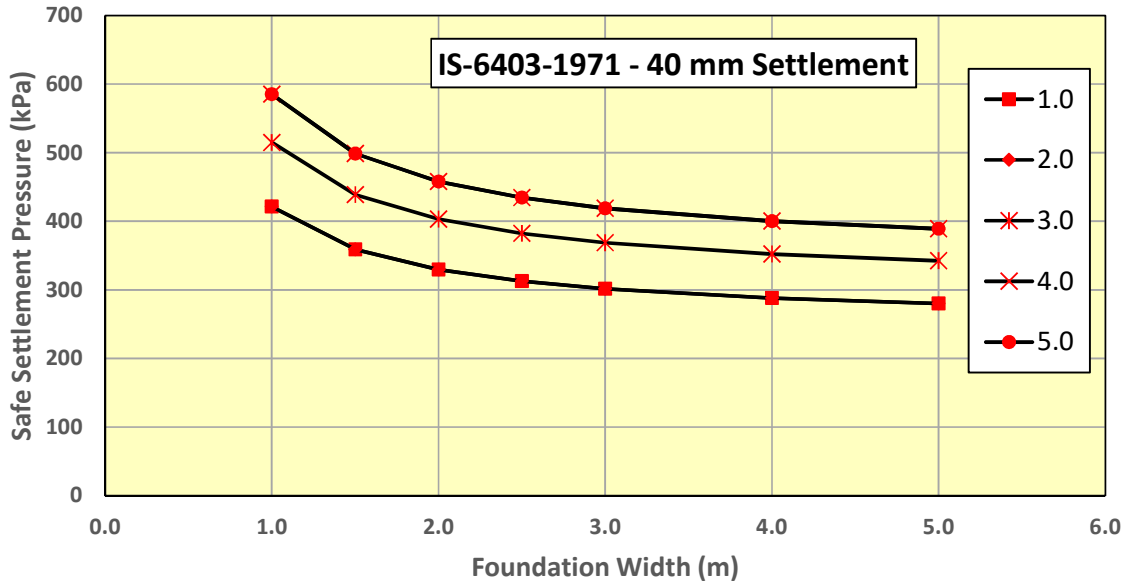
Bearing capacity analysis of the Shallow Foundation

This calculation based on the IS:6403-1971. The allowable bearing capacity is based on the settlement of 40 mm. The effective internal angle of friction is adopted either from direct shear test result or empirical correlation or approximated using engineering judgement and experience between SPT N value and angle of friction.

Indo Nepal Border - New Butwal 400 kV D/C TL

Bore Hole No. - T17/1N					
Depth of Foundation, D_f (m)	1.0	2.0	3.0	4.0	5.0
Friction angle	30	30	30	30	30
SPT N Value	21	21	25	28	28
Unit wt of soil kN/m3	18	19	19	19	19
Water Reduction Factor Wγ	1	0.5	0.5	0.5	0.5

	Net Allowable Bearing, kN/m^2 (IS:6403-1971-40 mm Settlement)				
Depth of Foundation, D_f (m)	1.0	2.0	3.0	4.0	5.0
Width of foundation, B (m)					
1.0	421	421	515	585	585
1.5	359	359	439	499	499
2.0	330	330	403	458	458
2.5	313	313	382	434	434
3.0	302	302	369	419	419
4.0	288	288	352	400	400
5.0	280	280	342	389	389



Note: For footing size greater than 2 m bearing capacity is usually governed by settlement criterion.

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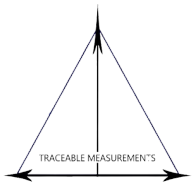
Soil Investigation Works of Services & updated line Design for 30 km of Changes in 400kv Transmission Line Route Aligment of MCA-Nepal
Bearing capacity analysis of the Mat foundation

This calculation is based on the SPT N-value.

Bore Hole No. -T17/1N **Safe Settlement Bearing Pressure kN/m^2 (IS:6403-50 mm Settlement)**

Depth of Foundation, D_f (m)	1	3	4	6	7	9	10	12
SPT N Value	21	25	28	23	63	58	73	50
Unit wt of soil kN/m3	18	18	18	18	19	19	19	19
Water Reduction Factor Wγ	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

Depth of Foundation, D_f (m)	1.0	3.0	4.0	6.0	7.0	9.0	10.0	12.0
Safe Settlement Bearing Pressure, (kN/m^2)	229	279	318	254	762	699	889	597
Modulus of Subgrade Reaction, Ks (kN/m^3)	18288	22352	25400	20320	60960	55880	71120	47752



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MSc. Virginia Tech

Prepared By: Manab Rijal

Traceable Measurement (P) Ltd.

Soil Investigation Works of Services & updated line Design for 30 km of Changes in 400kv Transmission Line Route Aligment of MCA-Nepal

Indo Nepal Border - New Butwal 400 kV D/C TL **Borehole -T17/1N**

Depth to GW	6	m
PGA	0.3	g
Mw	7.8	
P_a	101.3	kPA

Input

NE: Water Table not Encountered

Depth (m)	N_{field}	Total unit wt. γ_t (KN/m^3)	Fines content	σ (kN/m^2)	u (kN/m^2)	σ' (kN/m^2)	α(z)	β(z)	r_d	MSF	$N_{1,60}$	ΔN1,60	$N_{1,60cs}$	$CSR_{M7.5}$	$CRR_{M7.5}$	C_σ	k_σ	FS
1.0	21	18.0	16	18	0	18	-0.03	0.00	1.00	0.92	30	3.58	33	0.21	0.60	0.24	1.10	NL
3.0	25	18.0	11	54	0	54	-0.13	0.02	0.99	0.92	27	1.61	28	0.21	0.40	0.19	1.10	NL
4.0	28	18.0	11	72	0	72	-0.20	0.02	0.98	0.92	26	1.61	28	0.21	0.39	0.19	1.06	NL
6.0	23	18.0	14	108	0	108	-0.34	0.04	0.96	0.92	19	2.91	21	0.20	0.23	0.14	0.99	1.1
7.0	63	19.0	0	127	69	58	-0.42	0.05	0.95	0.92	60	0.00	60	0.44	0.60	-1.08	0.41	NL
9.0	58	19.0	24	165	88	77	-0.59	0.07	0.93	0.92	52	4.98	57	0.42	0.60	-3.18	0.12	NL
10.0	73	19.0	24	184	98	86	-0.68	0.08	0.92	0.92	63	4.98	68	0.41	0.60	-0.46	0.92	NL

Notes: 1) If above the water table, not subject to liquefaction

2) Fines content > 35%; Liquid Limit (LL) > 35%; and natural moisture content within 90% of the LL (i.e., 'Chinese Criteria'), not subject to liquefaction

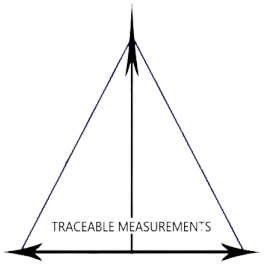
3) Cyclical Resistance Ratio (CRR) equal to or greater than 0.5, not subject to liquefaction.

4) Clean sand $(N1)_{60}$ equivalent equal to or greater than 34, not subject to liquefaction.

5) Fines content 50% or greater, not subject to liquefaction.

6) NL = Non-Liquefiable.

7) FS<1 indicates liquifiable soils.



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APPENDIX-H

Laboratory Data and Detail Analysis of New Butwal-New Damauli 400 kV D/C TL (TW198)

Traceable Measurement Pvt. Ltd.

Drilling Log

Project:	Soil Investigation Works of Consulting Services for Detailed Survey and Updated Line Design for 30 km of Changes in 400kV Transmission Line Route Alignment		
Location:	New Butwal - New Damauli 400 kV D/C TL	Position Cordinate	
Client:	MCA-N	Easting (m)	Northing (m)
Borehole No:	TW-198	218356	3092898
Dates	Started: 24/09/2079		
	Finished: 27/09/2079		
Method:	**Rotary Boring**	Water Table :-	
Hammer Type:	Monkey Hammer		

Material Description	Symbol	Depth, m	Sample No. &Type	No. of blows 15/10 cm	15/10 cm	15/10 cm	N-Value	Ncr-Value
Well Graded Gravel with Sand; moist, brown, fine to coarse grained sand	GW	1	SPT	10	15	18	33	
		2						
		3	SPT	12	18	25	43	
		4	SPT	15	15	35	50	
Well Graded Gravel with Silt and Sand; moist, brown, fine to coarse grained sand	GW GM	5						
		6	DCPT	50/10			50/10	
Well Graded Gravel with Sand; moist, brown, fine to coarse grained sand	GW	7	DCPT	50/5			50/5	
		8						
		9	DCPT	50/8			50/8	
Well Graded Gravel with Silt and Sand; moist, brown, fine to coarse grained sand	GW GM	10	DCPT	50/9			50/9	
Well Graded Gravel with Silt and Sand; moist, brown, fine to coarse grained sand	GW	11						
		12	DCPT	50/7			50/7	

N-Value SPT DCPT

End Depth *** Completed at 12.00m** **Ground: Dry**

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

Notes:

1. Bottom of Boring at 20.0 m. SPT was conducted upto depth of 4.5 m and DCPT was conducted from 3m to 12 m.
2. Boring terminated at selected depth.
3. Boring backfilled with auger cuttings upon completion.
4. Emperical Relation Between DCPT (Ncr) and SPT (N) values:

Ncr = 1.5 N for depths upto 3.00 m
Ncr = 1.75 N for depths 3.00 m to 6.00 m
Ncr = 2.00 N for depths greater than 6.00 m
Where,
Ncr = recorded DCPT values
N = SPT values

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Lalitpur-2, Sanepa, Nepal

Determination of Moisture Content

Project	:	Soil Investigation Works of Services & updated line Design for 30 km of Changes in 400kv Transmission Line Route Aligment of MCA-Nepal
Location	:	TW-198
Sample Description	:	SPT Sample
Bore Hole No	:	1 **Date Of Sampling**
Lab Ref No.	:	**Date Of Test**

NATURAL MOISTURE CONTENT

Depth m.	**0 - 1.5m**			**1.5m - 4.5m**		
Container No.	**15**	**20**	**46**	**218**	**209**	**62**
Weight of Wet Soil + Container,g	**56.0**	**59.6**	**63.4**	**79.9**	**100.9**	**90.3**
Weight of Dry Soil + Container,g	**50.0**	**54.2**	**54.9**	**72.5**	**90.0**	**80.2**
Weight of Water, g	**6.0**	**5.4**	**8.5**	**7.4**	**10.9**	**10.1**
Weight of container, g	**14.5**	**13.8**	**13.2**	**12.6**	**12.6**	**11.4**
Weight of Dry Soil, g	**35.5**	**40.4**	**41.7**	**59.9**	**77.4**	**68.8**
Water Content, W %	**16.9**	**13.4**	**20.4**	**12.4**	**14.1**	**14.7**
Average Water Content, W %	**16.9**			**13.7**		

Bore Hole No :-01

Depth m.	**4.5m - 6m**			**7.5m - 9m**		
Container No.	**51**	**70**	**210**	**217**	**10**	**38**
Weight of Wet Soil + Container,g	**62.7**	**66.8**	**80.4**	**87.2**	**91.3**	**97.0**
Weight of Dry Soil + Container,g	**57.9**	**61.8**	**73.7**	**79.0**	**83.9**	**88.5**
Weight of Water, g	**4.8**	**5.0**	**6.7**	**8.2**	**7.4**	**8.5**
Weight of container, g	**13.0**	**12.5**	**13.6**	**13.1**	**20.3**	**12.7**
Weight of Dry Soil, g	**44.9**	**49.3**	**60.1**	**65.9**	**63.6**	**75.8**
Water Content, W %	**10.7**	**10.1**	**11.1**	**12.4**	**11.6**	**11.2**
Average Water Content, W %	**10.7**			**11.8**		

Bore Hole No :-01

Depth m.	**10m**			**12m**		
Container No.	**0**	**6**	**114**	**29**	**72**	**109**
Weight of Wet Soil + Container,g	**98.0**	**93.2**	**95.3**	**51.8**	**69.8**	**73.9**
Weight of Dry Soil + Container,g	**87.4**	**84.1**	**84.5**	**51.6**	**69.3**	**73.6**
Weight of Water, g	**10.6**	**9.1**	**10.8**	**0.2**	**0.5**	**0.3**
Weight of container, g	**11.8**	**13.1**	**12.2**	**12.6**	**12.6**	**12.3**
Weight of Dry Soil, g	**75.6**	**71.0**	**72.3**	**39.0**	**56.7**	**61.3**
Water Content, W %	**14.0**	**12.8**	**14.9**	**0.5**	**0.9**	**0.5**
Average Water Content, W %	**13.9**			**0.6**		

Tested By:	Verified By:
TRACEABLE MEASUREMENTS	Geotechnical Engineer, Traceable Measurements MSc. Virginia Tech

Traceable Measurements Pvt. Ltd

Lalitpur-2, Sanepa, Nepal

TEST FOR SPECIFIC GRAVITY OF SOIL

Project : Soil Investigation Works of Services & updated line Design for 30 km of Changes in 400kv Transmission Line Route Aligment of MCA-Nepal

Client Name : MCA-Nepal

Location : TW-198

SAMPLE LABEL INFORMATION

Date of Sampling :

Date of Testing :-

D H # BH01

Depth 0-1.5m

Description of Sample
100 % pass through 4.75 mm

Test No	1	2	
Wt. of Pycnometer, gm (A)	96.4	100.8	
Wt. of Pycnometer + Sample, gm (B)	116.3	120.6	
Wt. of Pycnometer + Sample + Water, gm (C)	220.4	224.3	
Wt. of Pycnometer + Water, gm (D)	208.1	212.0	
Specific Gravity = (B-A)/((D-A)-(C-B))	2.618	2.640	
Average Value	2.629		

Tested By :	Verified By:
TRACEABLE MEASUREMENTS	

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Lalitpur-2, Sanepa, Nepal

TEST FOR SPECIFIC GRAVITY OF SOIL

Project : Soil Investigation Works of Services & updated line Design for 30 km of Changes in 400kv Transmission Line Route Aligment of MCA-Nepal

Client Name : MCA-Nepal

Angle Point : TW-198

SAMPLE LABEL INFORMATION

Date of Sampling :

Date of Testing :-

D H # BH01

Depth 1.5m - 4.5m

Description of Sample
100 % pass through 4.75 mm

Test No	1	2	
Wt. of Pycnometer, gm (A)	96.4	101.3	
Wt. of Pycnometer + Sample, gm (B)	116.4	121.3	
Wt. of Pycnometer + Sample + Water, gm (C)	220.4	225.0	
Wt. of Pycnometer + Water, gm (D)	208.3	212.2	
Specific Gravity = (B-A)/((D-A)-(C-B))	2.532	2.778	
Average Value	2.655		

Tested By :	Verified By:
TRACEABLE MEASUREMENTS	

Geotechnical Engineer, Traceable Measurements
MSc. Virginia Tech

Traceable Measurements Pvt. Ltd

Lalitpur-2, Sanepa, Nepal

TEST FOR SPECIFIC GRAVITY OF SOIL

Project : Soil Investigation Works of Services & updated line Design for 30 km of Changes in 400kv Transmission Line Route Aligment of MCA-Nepal

Client Name : MCA-Nepal

Angle Point : TW-198

SAMPLE LABEL INFORMATION

Date of Sampling :

Date of Testing :-

Description of Sample

100 % pass through 4.75 mm

D H # BH01

Depth 4.5m-6m

Test No	1	2	
Wt. of Pycnometer, gm (A)	96.9	100.3	
Wt. of Pycnometer + Sample, gm (B)	116.9	120.3	
Wt. of Pycnometer + Sample + Water, gm (C)	220.6	224.1	
Wt. of Pycnometer + Water, gm (D)	208.5	211.5	
Specific Gravity = (B-A)/((D-A)-(C-B))	2.532	2.703	
Average Value	2.617		

Tested By :

Verified By:

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Lalitpur-2, Sanepa, Nepal

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MSc. Virginia Tech

TEST FOR SPECIFIC GRAVITY OF SOIL

Project : Soil Investigation Works of Services & updated line Design for 30 km of Changes in 400kv Transmission Line Route Aligment of MCA-Nepal

Client Name : MCA-Nepal

Angle Point : TW-198

SAMPLE LABEL INFORMATION

Date of Sampling :

Date of Testing :-

Description of Sample

100 % pass through 4.75 mm

D H # BH01

Depth 6m-9m

Test No	1	2	
Wt. of Pycnometer, gm (A)	97	100.5	
Wt. of Pycnometer + Sample, gm (B)	117.0	120.4	
Wt. of Pycnometer + Sample + Water, gm (C)	208.2	211.5	
Wt. of Pycnometer + Water, gm (D)	208.5	211.5	
Specific Gravity = (B-A)/((D-A)-(C-B))	0.985	1.000	
Average Value	0.993		

Tested By :

Verified By:

Geotechnical Engineer, Traceable Measurements
MSc. Virginia Tech

Traceable Measurements Pvt. Ltd

Lalitpur-2, Sanepa, Nepal

TEST FOR SPECIFIC GRAVITY OF SOIL

Project : Soil Investigation Works of Services & updated line Design for 30 km of Changes in 400kv Transmission Line Route Aligment of MCA-Nepal

Client Name : MCA-Nepal

Angle Point : TW-198

SAMPLE LABEL INFORMATION

Date of Sampling :

Date of Testing :-

Description of Sample

100 % pass through 4.75 mm

D H # BH01

Depth 9m-10m

Test No	1	2	
Wt. of Pycnometer, gm (A)	96.7	100.6	
Wt. of Pycnometer + Sample, gm (B)	116.7	220.6	
Wt. of Pycnometer + Sample + Water, gm (C)	220.5	224.4	
Wt. of Pycnometer + Water, gm (D)	208.6	211.5	
Specific Gravity = (B-A)/((D-A)-(C-B))	2.469	1.120	
Average Value	1.795		

Tested By :	Verified By:
TRACEABLE MEASUREMENTS	

Traceable Measurements Pvt. Ltd

Lalitpur-2, Sanepa, Nepal

Geotechnical Engineer, Traceable Measurements
MSc. Virginia Tech

TEST FOR SPECIFIC GRAVITY OF SOIL

Project : Soil Investigation Works of Services & updated line Design for 30 km of Changes in 400kv Transmission Line Route Aligment of MCA-Nepal

Client Name : MCA-Nepal

Angle Point : TW-198

SAMPLE LABEL INFORMATION

Date of Sampling :

Date of Testing :-

Description of Sample

100 % pass through 4.75 mm

D H # BH01

Depth 10m-12m

Test No	1	2	
Wt. of Pycnometer, gm (A)	96.8	100.2	
Wt. of Pycnometer + Sample, gm (B)	116.8	120.2	
Wt. of Pycnometer + Sample + Water, gm (C)	220.6	224.2	
Wt. of Pycnometer + Water, gm (D)	208.3	211.7	
Specific Gravity = (B-A)/((D-A)-(C-B))	2.597	2.667	
Average Value	2.632		

Tested By :	Verified By:
TRACEABLE MEASUREMENTS	

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PARTICLE SIZE ANALYSIS ASTM D-6913

Project Information

Project Name:	MCA-Nepal
Project Number:	
Location:	TW-198

Sample Information

Borehole/Test Pit:	BH-01
Sample #:	
Depth:	0-1.5m
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)	477.00
Mass of washed soil (g)	
Mass loss in wash (g)	

Summary Parameter

Coarser than Gravel%	0
Gravel%	69
Sand%	29
Fines%	2
D60, mm:	7.19
D30, mm:	3.22
D10, mm:	0.82
Cc:	1.75
Cu:	8.72

Laboratory Information

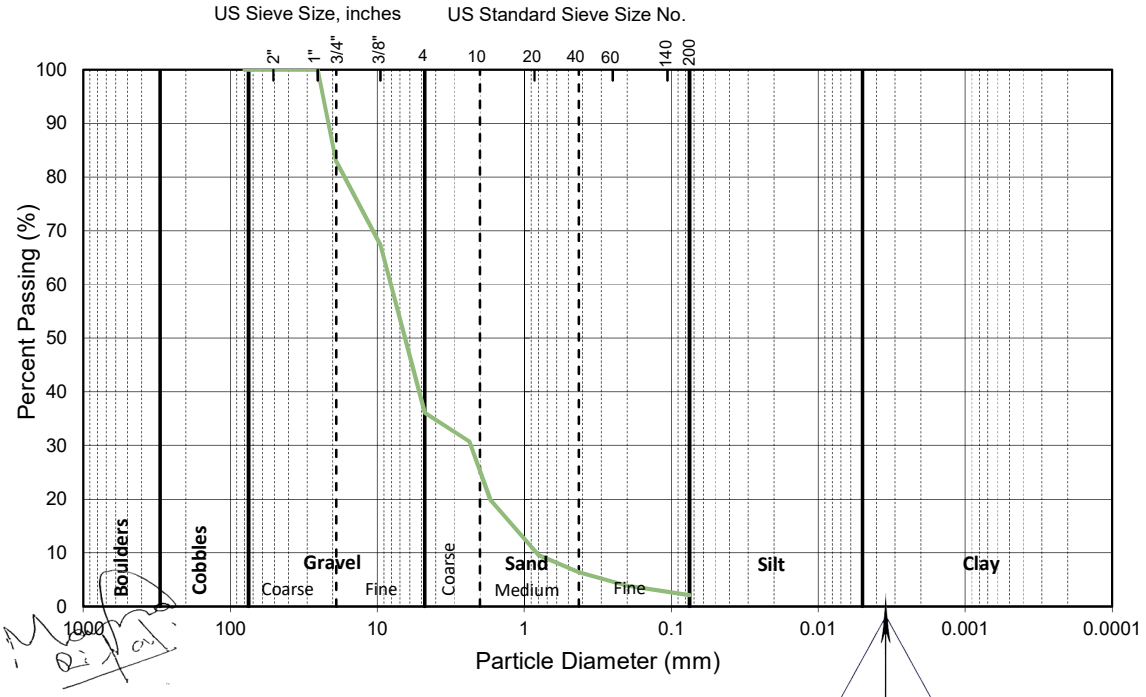
Lab Name:	Traceable Measurement Pvt. Ltd.
Tested By:	
Reviewed By:	
Test Date:	
Report Date:	

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

S.N	(mm)	Wt Ret	% Ret	Cum % Ret	% Pass
1	80	0.00	0.00	0.00	100.00
2	38.1	0.00	0.00	0.00	100.00
3	25.4	0.00	0.00	0.00	100.00
4	19.1	81.00	16.98	16.98	83.02
5	9.5	74.70	15.66	32.64	67.36
6	4.75	148.90	31.22	63.86	36.14
7	2.36	25.7	5.39	69.25	30.75
8	1.70	51.8	10.86	80.10	19.90
9	0.8	49.2	10.31	90.42	9.58
10	0.425	15.4	3.23	93.65	6.35
11	0.20	11.9	2.49	96.14	3.86
12	0.15	2.2	0.46	96.60	3.40
13	0.075	6.1	1.28	97.88	2.12
Pan		10.1			
Tot Pan		10.10	2.12	100.00	0.00
Fineness Mod.				6.40	

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

Well Graded Gravel with Sand



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PARTICLE SIZE ANALYSIS ASTM D-6913

Project Information

Project Name:	MCA-Nepal
Project Number:	
Location:	TW-198

Sample Information

Borehole/Test Pit:	BH-01
Sample #:	
Depth:	1.5m - 4.5m
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)	899.40
Mass of washed soil (g)	
Mass loss in wash (g)	

Summary Parameter

Coarser than Gravel%	0
Gravel%	55
Sand%	43
Fines%	2
D60, mm:	3.73
D30, mm:	1.12
D10, mm:	0.21
Cc:	1.64
Cu:	18.16

Laboratory Information

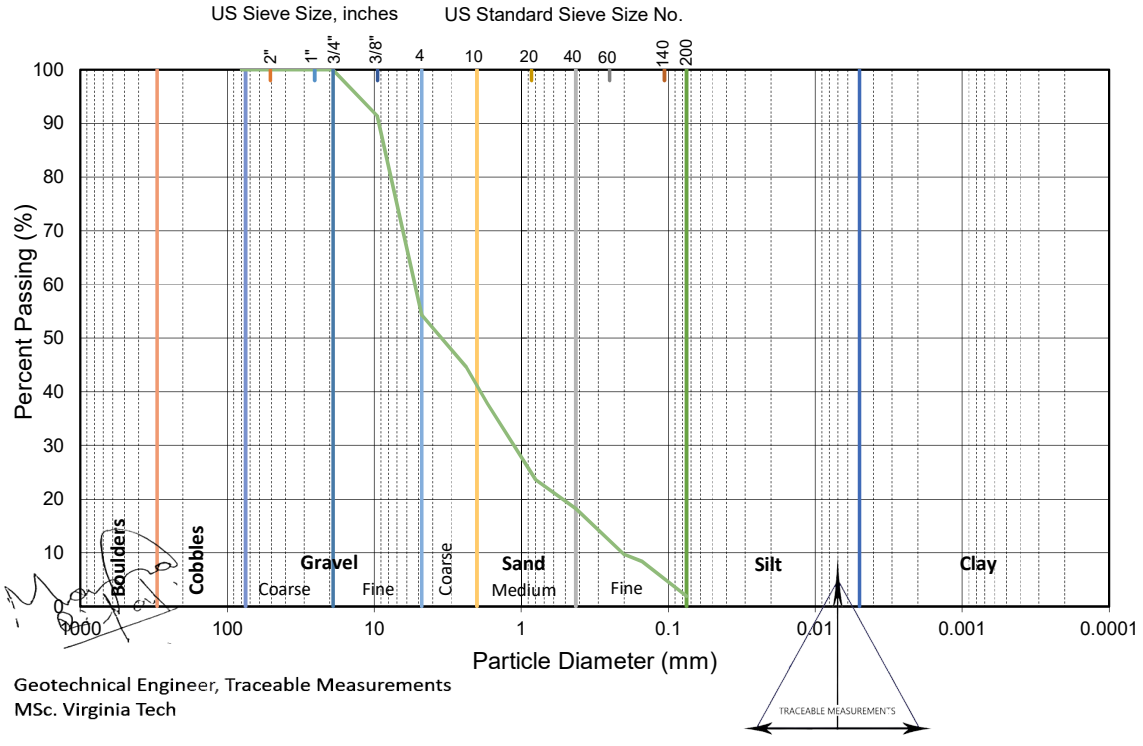
Lab Name:	Traceable Measurement Pvt. Ltd.
Tested By:	
Reviewed By:	
Test Date:	
Report Date:	

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

S.N	(mm)	Wt Ret	% Ret	Cum % Ret	% Pass
1	80	0.0	0.00	0.00	100.00
2	38.1	0.0	0.00	0.00	100.00
3	25.4	0.0	0.00	0.00	100.00
4	19.1	0.0	0.00	0.00	100.00
5	9.5	77.9	8.66	8.66	91.34
6	4.75	333.3	37.06	45.72	54.28
7	2.36	86.800	9.65	55.37	44.63
8	1.70	61.300	6.82	62.19	37.81
9	0.8	127.200	14.14	76.33	23.67
10	0.425	49.400	5.49	81.82	18.18
11	0.20	76.400	8.49	90.32	9.68
12	0.15	12.000	1.33	91.65	8.35
13	0.075	57.900	6.44	98.09	1.91
Pan		17.200			
Tot Pan		17.20	1.91	100.00	0.00
Fineness Mod.				5.12	

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

Well Graded Gravel with Sand



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PARTICLE SIZE ANALYSIS ASTM D-6913

Project Information

Project Name:	MCA-Nepal
Project Number:	
Location:	TW-198

Sample Information

Borehole/Test Pit:	BH-01
Sample #:	
Depth:	4.5m-6m
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)	377.40
Mass of washed soil (g)	
Mass loss in wash (g)	

Summary Parameter

Coarser than Gravel%	0
Gravel%	67
Sand%	28
Fines%	5
D60, mm:	4.90
D30, mm:	2.32
D10, mm:	0.29
Cc:	3.74
Cu:	16.72

Laboratory Information

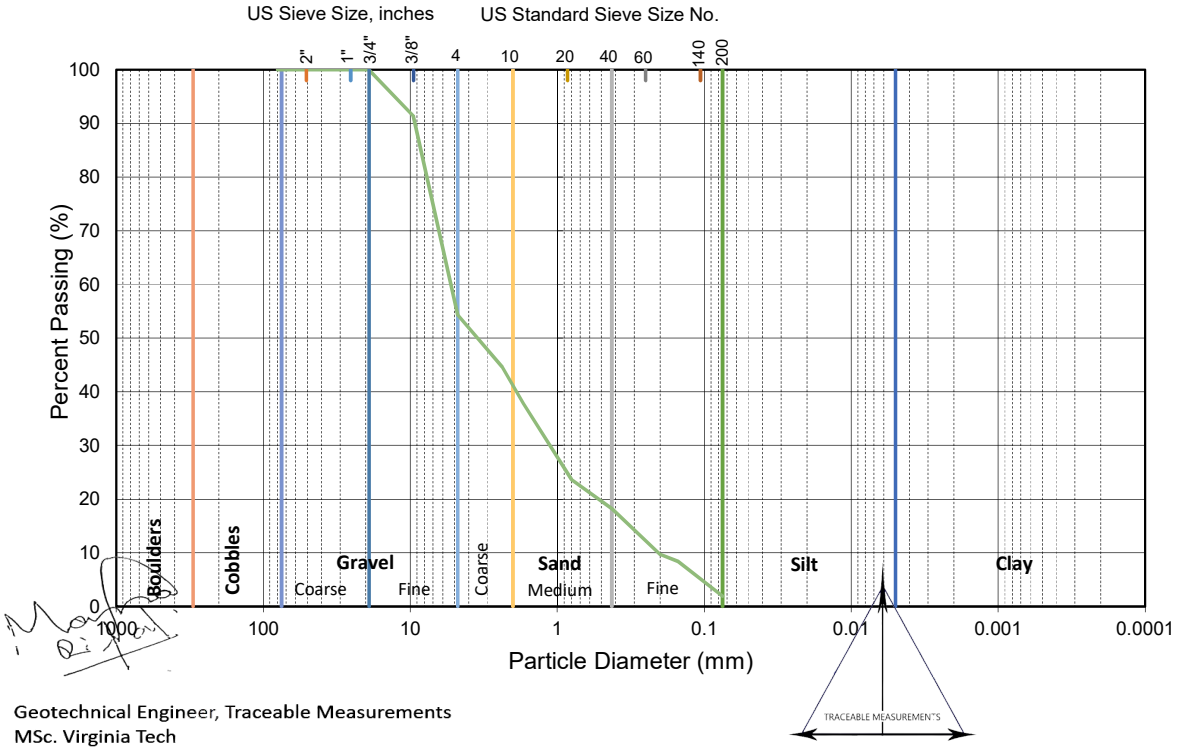
Lab Name:	Traceable Measurement Pvt. Ltd.
Tested By:	
Reviewed By:	
Test Date:	
Report Date:	

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

S.N	(mm)	Wt Ret	% Ret	Cum % Ret	% Pass
1	80	0.0	0.00	0.00	100.00
2	38.1	0.0	0.00	0.00	100.00
3	25.4	0.0	0.00	0.00	100.00
4	19.1	0.0	0.00	0.00	100.00
5	9.5	57.6	15.26	15.26	84.74
6	4.75	166.2	44.04	59.30	40.70
7	2.36	29.800	7.90	67.20	32.80
8	1.70	28.000	7.42	74.62	25.38
9	0.8	36.700	9.72	84.34	15.66
10	0.425	14.400	3.82	88.16	11.84
11	0.20	14.100	3.74	91.89	8.11
12	0.15	3.200	0.85	92.74	7.26
13	0.075	9.000	2.38	95.12	4.88
Pan		18.400			
Tot Pan		18.40	4.88	100.00	0.00
Fineness Mod.				5.74	

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

Well Graded Gravel with Silt and Sand



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PARTICLE SIZE ANALYSIS ASTM D-6913

Project Information

Project Name:	MCA-Nepal
Project Number:	
Location:	TW-198

Sample Information

Borehole/Test Pit:	BH-01
Sample #:	
Depth:	6m-9m
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)	1248.90
Mass of washed soil (g)	
Mass loss in wash (g)	

Summary Parameter

Coarser than Gravel%	0
Gravel%	61
Sand%	35
Fines%	4
D60, mm:	3.80
D30, mm:	1.37
D10, mm:	0.12
Cc:	3.98
Cu:	30.66

Laboratory Information

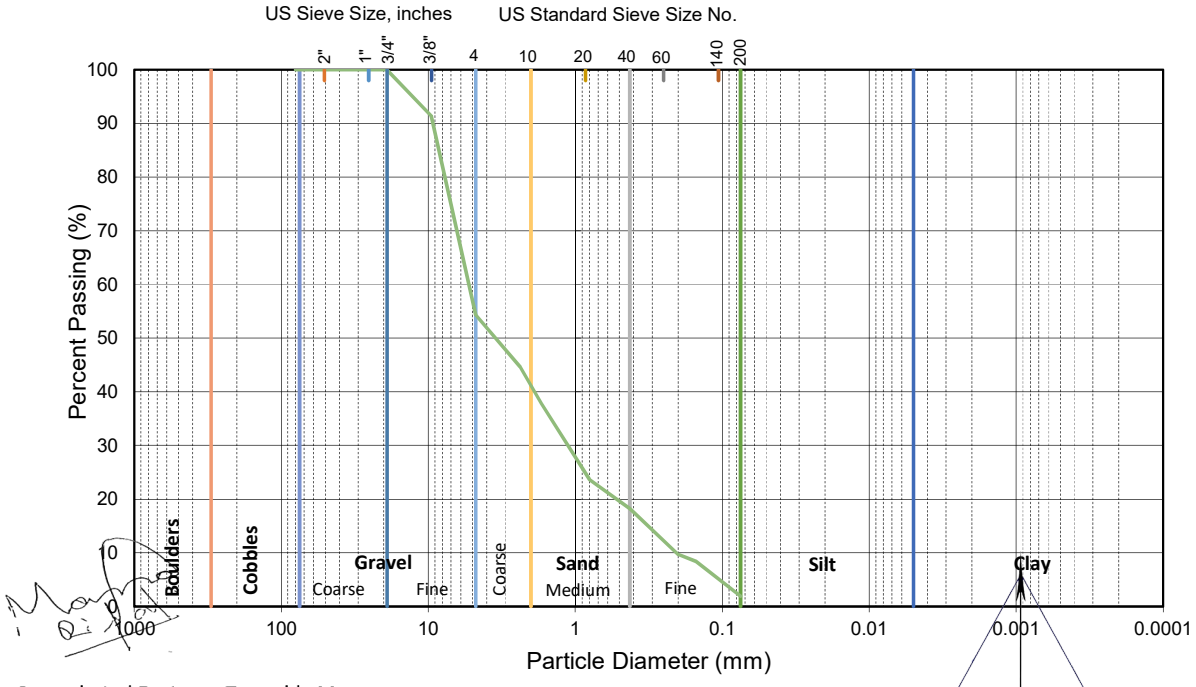
Lab Name:	Traceable Measurement Pvt. Ltd.
Tested By:	
Reviewed By:	
Test Date:	
Report Date:	

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

S.N	(mm)	Wt Ret	% Ret	Cum % Ret	% Pass
1	80	0.0	0.00	0.00	100.00
2	38.1	0.0	0.00	0.00	100.00
3	25.4	0.0	0.00	0.00	100.00
4	19.1	0.0	0.00	0.00	100.00
5	9.5	0.0	0.00	0.00	100.00
6	4.75	634.7	50.82	50.82	49.18
7	2.36	123.600	9.90	60.72	39.28
8	1.70	74.500	5.97	66.68	33.32
9	0.8	144.200	11.55	78.23	21.77
10	0.425	54.200	4.34	82.57	17.43
11	0.20	54.000	4.32	86.89	13.11
12	0.15	12.100	0.97	87.86	12.14
13	0.075	96.800	7.75	95.61	4.39
Pan		54.800			
Tot Pan		54.80	4.39	100.00	0.00
Fineness Mod.				5.14	

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

Well Graded Gravel with Sand



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PARTICLE SIZE ANALYSIS ASTM D-6913

Project Information

Project Name:	MCA-Nepal
Project Number:	
Location:	TW-198

Sample Information

Borehole/Test Pit:	BH-01
Sample #:	
Depth:	9m-10m
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)	594.30
Mass of washed soil (g)	
Mass loss in wash (g)	

Summary Parameter

Coarser than Gravel%	0
Gravel%	68
Sand%	27
Fines%	5
D60, mm:	4.46
D30, mm:	2.05
D10, mm:	0.29
Cc:	3.23
Cu:	15.34

Laboratory Information

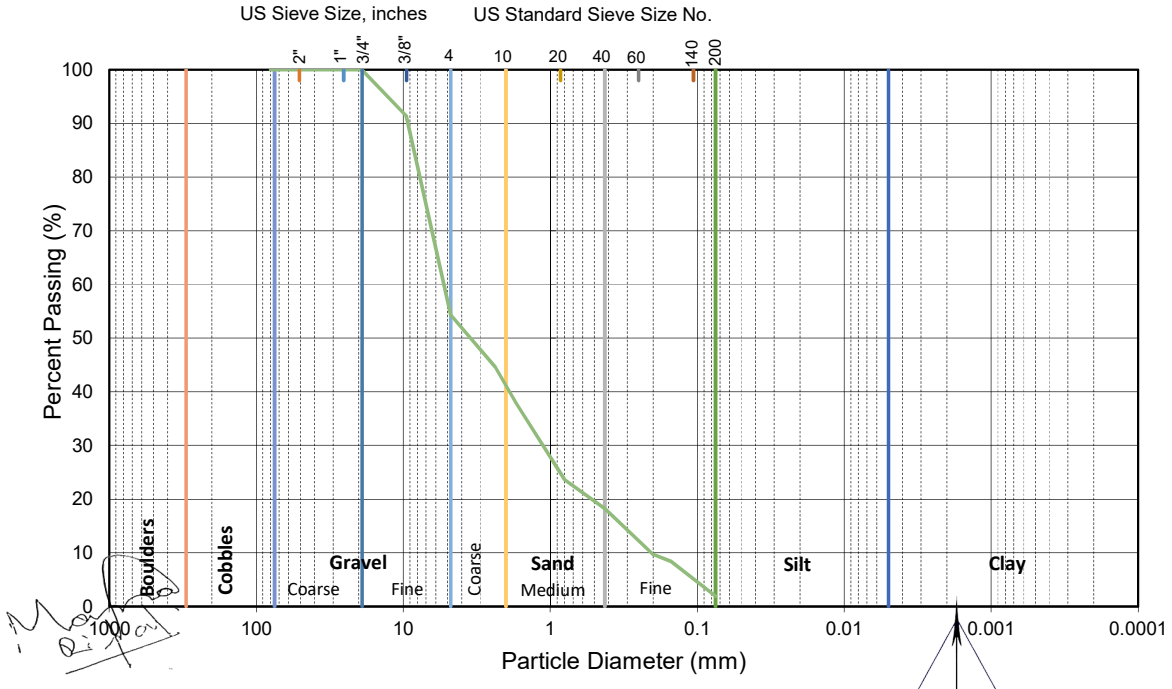
Lab Name:	Traceable Measurement Pvt. Ltd.
Tested By:	
Reviewed By:	
Test Date:	
Report Date:	

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

S.N	(mm)	Wt Ret	% Ret	Cum % Ret	% Pass
1	80	0.0	0.00	0.00	100.00
2	38.1	0.0	0.00	0.00	100.00
3	25.4	0.0	0.00	0.00	100.00
4	19.1	0.0	0.00	0.00	100.00
5	9.5	39.2	6.60	6.60	93.40
6	4.75	315.1	53.02	59.62	40.38
7	2.36	50.200	8.45	68.06	31.94
8	1.70	25.100	4.22	72.29	27.71
9	0.8	66.300	11.16	83.44	16.56
10	0.425	26.900	4.53	87.97	12.03
11	0.20	24.000	4.04	92.01	7.99
12	0.15	5.400	0.91	92.92	7.08
13	0.075	14.800	2.49	95.41	4.59
Pan		27.300			
Tot Pan		27.30	4.59	100.00	0.00
Fineness Mod.				5.63	

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

Well Graded Gravel with Silt and Sand



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PARTICLE SIZE ANALYSIS ASTM D-6913

Project Information

Project Name:	MCA-Nepal
Project Number:	
Location:	TW-198

Sample Information

Borehole/Test Pit:	BH-01
Sample #:	
Depth:	10m-12m
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)	393.00
Mass of washed soil (g)	
Mass loss in wash (g)	

Summary Parameter

Coarser than Gravel%	0
Gravel%	72
Sand%	24
Fines%	4
D60, mm:	5.01
D30, mm:	2.27
D10, mm:	0.33
Cc:	3.17
Cu:	15.34

Laboratory Information

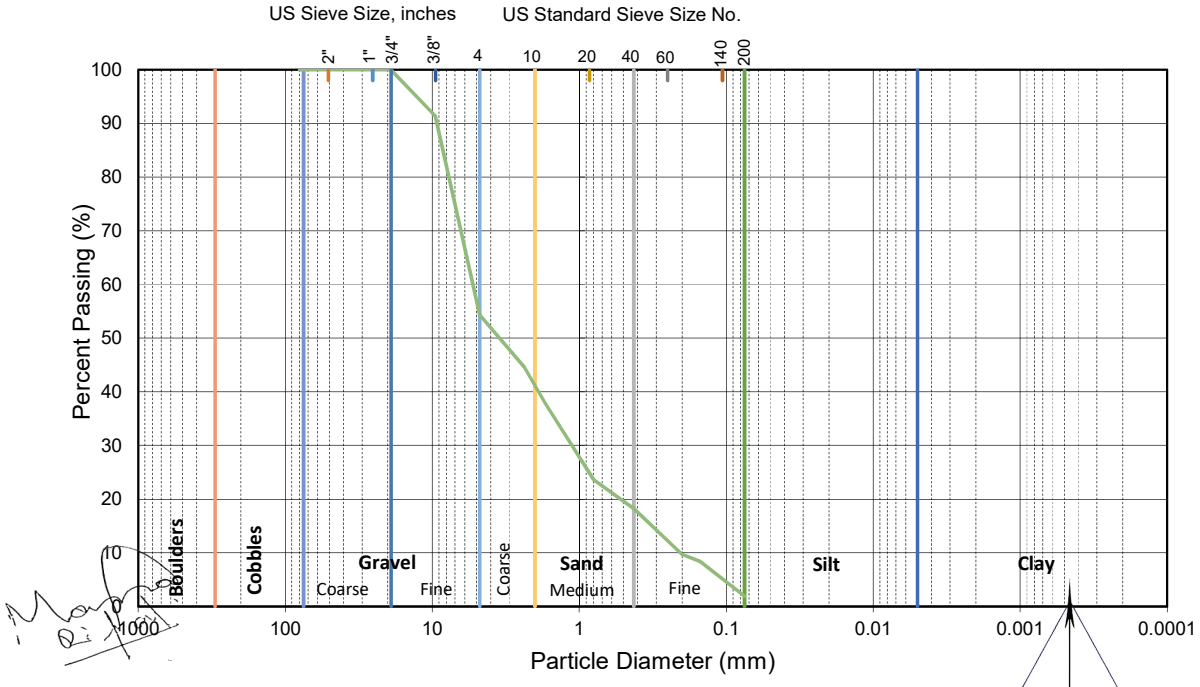
Lab Name:	Traceable Measurement Pvt. Ltd.
Tested By:	
Reviewed By:	
Test Date:	
Report Date:	

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

S.N	(mm)	Wt Ret	% Ret	Cum % Ret	% Pass
1	80	0.0	0.00	0.00	100.00
2	38.1	0.0	0.00	0.00	100.00
3	25.4	0.0	0.00	0.00	100.00
4	19.1	0.0	0.00	0.00	100.00
5	9.5	51.0	12.98	12.98	87.02
6	4.75	178.5	45.42	58.40	41.60
7	2.36	51.900	13.21	71.60	28.40
8	1.70	11.700	2.98	74.58	25.42
9	0.8	40.000	10.18	84.76	15.24
10	0.425	15.300	3.89	88.65	11.35
11	0.20	15.100	3.84	92.49	7.51
12	0.15	4.000	1.02	93.51	6.49
13	0.075	9.100	2.32	95.83	4.17
Pan		16.400			
Tot Pan		16.40	4.17	100.00	0.00
Fineness Mod.				5.77	

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

Well Graded Gravel with Sand



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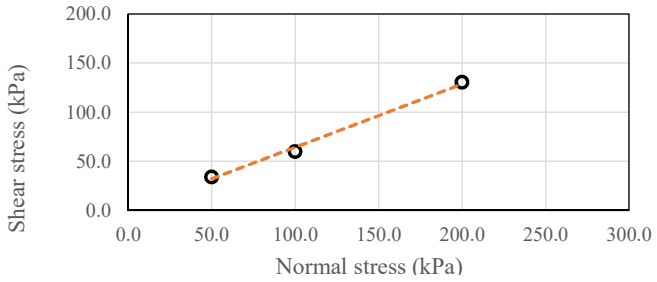
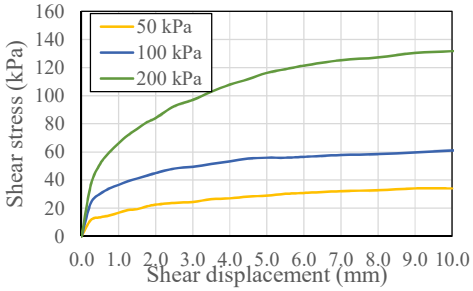
PAN: 604248398, Reg. No. 148209/72/073
TRACEABLE MEASUREMENTS PVT. LTD.
Tel. 01-5413270; Sanepa, Lalitpur.

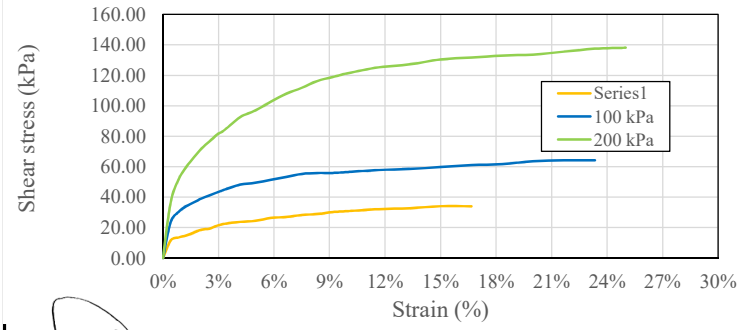
Direct Shear Test

Project Name	:	**MCA-Nepal**		
Location	:	**TW-198**		
Bore Hole No	:	**1**	**PRG factor:**	**0.002312**
Bore Hole Depth	:	**7.5m**	**Area:**	**0.0036**

Hz Dial Gauge reading (x 0.01mm)	Normal Strain (%)	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	0.00	0	0.00	0	0.00	
25	0.4%	18	11.56	37	23.76	57	36.61	
50	0.8%	21	13.49	47	30.18	80	51.38	
75	1%	23	14.77	53	34.04	93	59.73	
100	1.7%	26	16.70	57	36.61	103	66.15	
125	2.1%	29	18.62	61	39.18	112	71.93	
150	3%	30	19.27	64	41.10	119	76.42	
175	2.9%	33	21.19	67	43.03	126	80.92	
200	3.3%	35	22.48	70	44.96	131	84.13	
250	4%	37	23.76	75	48.17	144	92.48	
300	5.0%	38	24.40	77	49.45	151	96.98	
350	5.8%	41	26.33	80	51.38	160	102.76	
400	7%	42	26.97	83	53.30	168	107.89	
450	7.5%	44	28.26	86	55.23	174	111.75	
500	8.3%	45	28.90	87	55.87	181	116.24	
550	9.2%	47	30.18	87	55.87	185	118.81	
600	10%	48	30.83	88	56.52	189	121.38	
700	11.7%	50	32.11	90	57.80	195	125.23	
800	13.3%	51	32.75	91	58.44	198	127.16	
900	15%	53	34.04	93	59.73	203	130.37	
1000	16.7%	53	34.04	95	61.01	205	131.66	
1100	18.3%			96	61.65	207	132.94	
1200	20%			99	63.58	208	133.58	
1300	21.7%			100	64.22	211	135.51	
1400	23.3%			100	64.22	214	137.44	
1500	25%					215	138.08	
1600	26.7%							







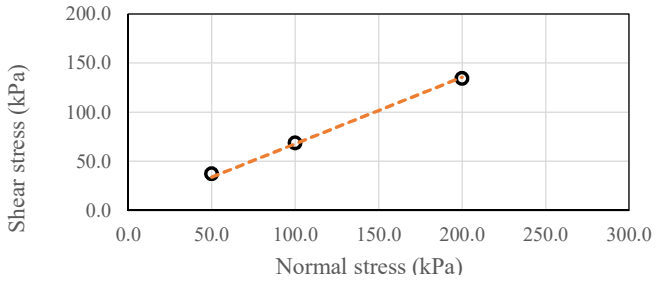
ϕ'	**33**	Degree
c'	**0.00**	kN/m^2

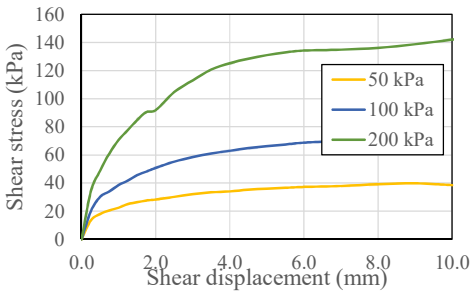
PAN: 604248398, Reg. No. 148209/72/073
TRACEABLE MEASUREMENTS PVT. LTD.
Tel. 01-5413270; Sanepa, Lalitpur.

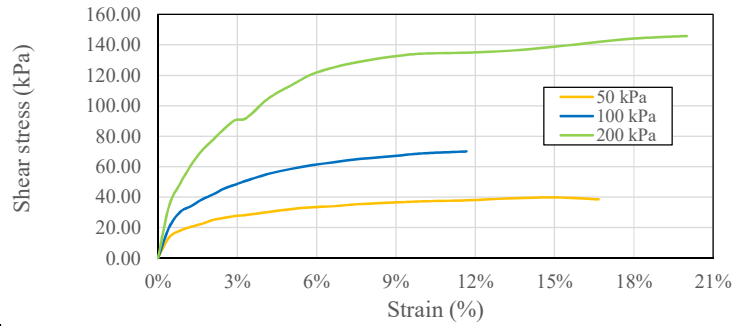
Direct Shear Test

Project Name	:	**MCA-Nepal**		
Location	:	**TW-198**		
Bore Hole No	:	**1**	**PRG factor:**	**0.002312**
Bore Hole Depth	:	**10m - 12m**	**Area:**	**0.0036**

Hz Dial Gauge reading (x 0.01mm)	Normal Strain (%)	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	0.00	0	0.00	0	0.00	
25	0.4%	21	13.49	31	19.91	53	34.04	
50	0.8%	28	17.98	47	30.18	76	48.81	
75	1%	32	20.55	53	34.04	95	61.01	
100	1.7%	35	22.48	60	38.53	110	70.64	
125	2.1%	39	25.05	65	41.74	121	77.71	
150	3%	41	26.33	71	45.60	132	84.77	
175	2.9%	43	27.62	75	48.17	141	90.55	
200	3.3%	44	28.26	79	50.74	143	91.84	
250	4%	47	30.18	86	55.23	163	104.68	
300	5.0%	50	32.11	91	58.44	176	113.03	
350	5.8%	52	33.40	95	61.01	188	120.74	
400	7%	53	34.04	98	62.94	195	125.23	
450	7.5%	55	35.32	101	64.86	200	128.44	
500	8.3%	56	35.96	103	66.15	204	131.01	
550	9.2%	57	36.61	105	67.43	207	132.94	
600	10%	58	37.25	107	68.72	209	134.22	
700	11.7%	59	37.89	109	70.00	210	134.87	
800	13.3%	61	39.18			212	136.15	
900	15%	62	39.82			216	138.72	
1000	16.7%	60	38.53			221	141.93	
1100	18.3%					225	144.50	
1200	20%					227	145.78	
1300	21.7%							
1400	23.3%							
1500	25%							
1600	26.7%							







ϕ'	**34**	Degree
c'	**0.00**	kN/m^2

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Soil Investigation Works of Consulting Services & updated line Design for 30 km of Changes in 400kv Transmission Line Route Aligment of MCA-Nepal

Bearing capacity analysis of the Shallow Foundation

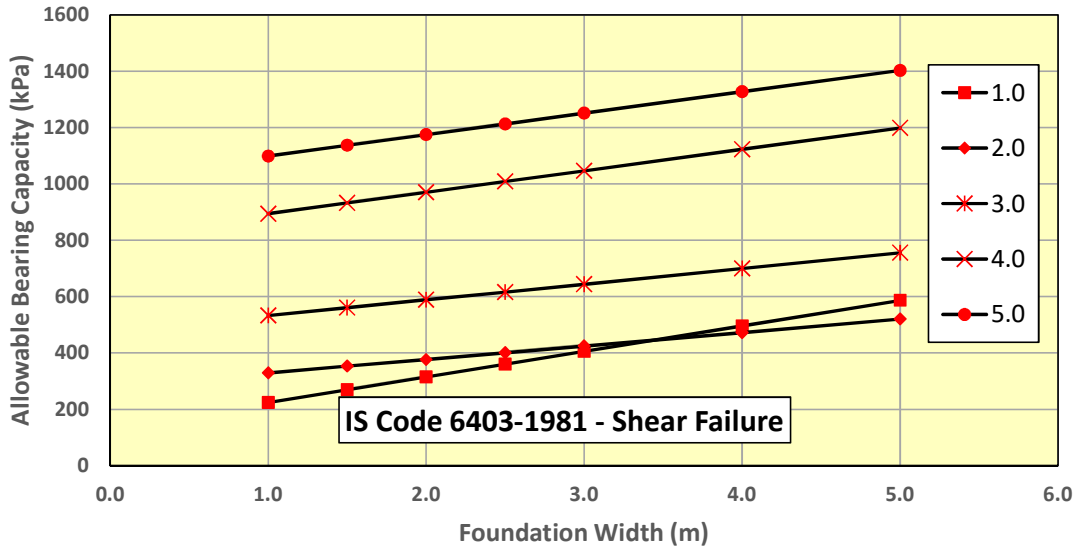
This calculation based on the IS:6403-1981. The allowable bearing capacity is based on the shear failure of soil. The effective internal angle of friction is adopted either from direct shear test result or empirical correlation or approximated using engineering judgement and experience between SPT N value and angle of friction.

New Butwal - New Damauli 400 kV D/C TL

Bore Hole No. - T198N

Depth of Foundation, D_f (m)	1.0	2.0	3.0	4.0	5.0
Friction angle	32	32	33	35	35
SPT N Value	33	33	43	50	50
Unit wt. of soil, kN/m^3	18	19	19	19	19
Buoyant Unit wt. of soil. kN/m^3	8	9	9	9	9
Cohesion. kN/m^2	0	0	0	0	0
Water Reduction Factor W_γ	1	0.5	0.5	0.5	0.5
N_q	23.18	23.18	26.09	33.30	33.30
N_c	35.49	35.49	38.64	46.12	46.12
N_γ	30.21	30.21	35.19	48.03	48.03

	Net Allowable Bearing, kN/m^2 (IS: 6403-1981 Shear Failure)				
Depth of Foundation, D_f (m)	1.0	2.0	3.0	4.0	5.0
Width of foundation, B (m)					
1.0	224	329	532	894	1099
1.5	269	353	560	932	1137
2.0	314	377	588	970	1175
2.5	360	401	616	1008	1213
3.0	405	424	644	1046	1251
4.0	496	472	700	1122	1327
5.0	586	520	755	1198	1403



Note: For footing size greater than 2 m bearing capacity is usually governed by settlement criterion. Please refer to bearing capacity evaluated based on settlement criterion.

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TRACEABLE MEASUREMENTS

Soil Investigation Works of Consulting Services & updated line Design for 30 km of Changes in 400kv Transmission Line Route Aligment of MCA-Nepal

Bearing capacity analysis of the Shallow Foundation

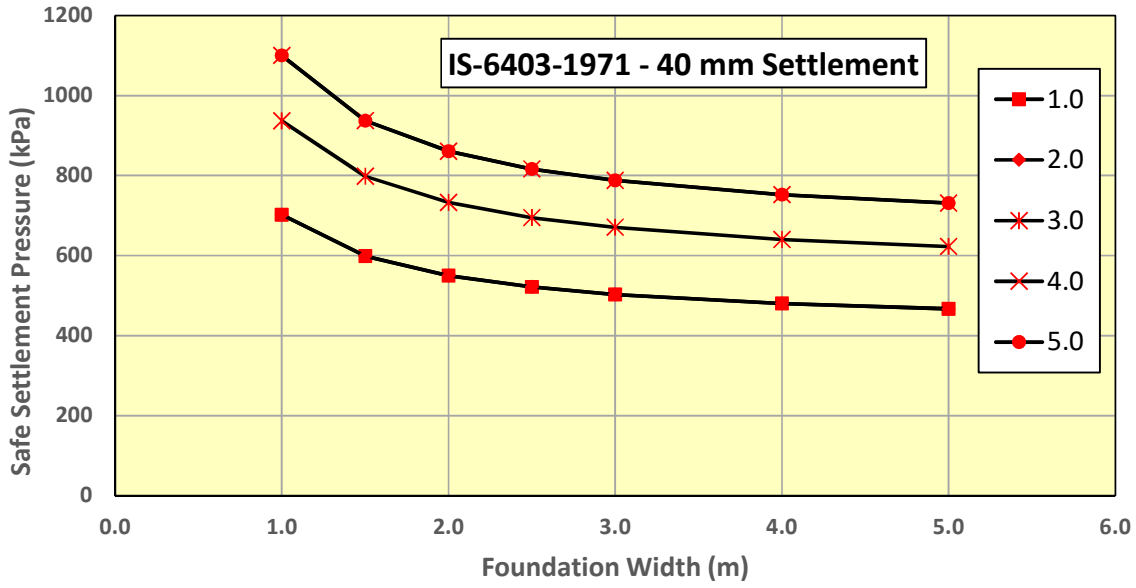
This calculation based on the IS:6403-1971. The allowable bearing capacity is based on the settlement of 40 mm. The effective internal angle of friction is adopted either from direct shear test result or empirical correlation or approximated using engineering judgement and experience between SPT N value and angle of friction.

New Butwal - New Damauli 400 kV D/C TL

Bore Hole No. - T198N

Depth of Foundation, D_f (m)	1.0	2.0	3.0	4.0	5.0
Friction angle	32	32	33	35	35
SPT N Value	33	33	43	50	50
Unit wt of soil kN/m3	18	19	19	19	19
Water Reduction Factor Wγ	1	0.5	0.5	0.5	0.5

	Net Allowable Bearing, kN/m^2 (IS:6403-1971-40 mm Settlement)				
Depth of Foundation, D_f (m)	1.0	2.0	3.0	4.0	5.0
Width of foundation, B (m)					
1.0	702	702	936	1100	1100
1.5	598	598	798	937	937
2.0	549	549	733	861	861
2.5	521	521	695	817	817
3.0	503	503	670	788	788
4.0	480	480	640	752	752
5.0	467	467	622	731	731



Note: For footing size greater than 2 m bearing capacity is usually governed by settlement criterion.

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TRACEABLE MEASUREMENTS

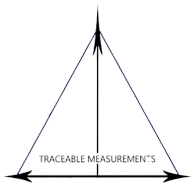
Soil Investigation Works of Services & updated line Design for 30 km of Changes in 400kv Transmission Line Route Aligment of MCA-Nepal
Bearing capacity analysis of the Mat foundation

This calculation is based on the SPT N-value.

Bore Hole No. - T198N **Safe Settlement Bearing Pressure kN/m^2 (IS:6403-65 mm Settlement)**

Depth of Foundation, D_f (m)	1	3	4	6	7	9	10	10
SPT N Value	33	43	50	86	100	94	83	100
Unit wt of soil kN/m3	18	19	19	19	19	19	19	19
Water Reduction Factor Wγ	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

Depth of Foundation, D_f (m)	1.0	3.0	4.0	6.0	7.0	9.0	10.0	10.0
Safe Settlement Bearing Pressure, kN/m^2	381	508	597	1054	1232	1156	1016	1232
Modulus of Subgrade Reaction, Ks (kN/m^3)	30480	40640	47752	84328	98552	92456	81280	98552



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Prepared By: Manab Rijal

Traceable Measurement (P) Ltd.

New Butwal - New Damauli 400 kV D/C TL **Borehole -TW-198**

Depth to GW	NE	m
PGA	0.3	g
Mw	7.8	
P_a	101.3	kPA

Input

NE: Water Table not Encountered

Depth (m)	N_{field}	Total unit wt. γ_t (KN/m^3)	Fines content	σ (kN/m^2)	u (kN/m^2)	σ' (kN/m^2)	α(z)	β(z)	r_d	MSF	$N_{1,60}$	ΔN1,60	$N_{1,60cs}$	$CSR_{M7.5}$	$CRR_{M7.5}$	C_σ	k_σ	FS
1.0	33	18.0	2	18	0	18	-0.03	0.00	1.00	0.92	47	0.00	47	0.21	0.60	0.30	1.10	NL-3
3.0	43	19.0	2	56	0	56	-0.13	0.02	0.99	0.92	42	0.00	42	0.21	0.60	0.30	1.10	NL-3
4.0	50	19.0	2	75	0	75	-0.20	0.02	0.98	0.92	45	0.00	45	0.21	0.60	0.30	1.09	NL-3
6.0	86	19.0	5	113	0	113	-0.34	0.04	0.96	0.92	69	0.00	69	0.20	0.60	-0.43	1.05	NL-3
7.0	100	19.0	4	132	0	132	-0.42	0.05	0.95	0.92	77	0.00	77	0.20	0.60	-0.28	1.07	NL-3
9.0	94	19.0	4	170	0	170	-0.59	0.07	0.93	0.92	68	0.00	68	0.20	0.60	-0.47	1.10	NL-3
10.0	83	19.0	5	189	0	189	-0.68	0.08	0.92	0.92	59	0.00	59	0.19	0.60	-1.57	1.10	NL-3

Notes: 1) If above the water table, not subject to liquefaction

2) Fines content > 35%; Liquid Limit (LL) > 35%; and natural moisture content within 90% of the LL (i.e., 'Chinese Criteria'), not subject to liquefaction

3) Cyclical Resistance Ratio (CRR) equal to or greater than 0.5, not subject to liquefaction.

4) Clean sand $(N1)_{60}$ equivalent equal to or greater than 34, not subject to liquefaction.

5) Fines content 50% or greater, not subject to liquefaction.

6) NL = Non-Liquefiable.

7) FS<1 indicates liquifiable soils.

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