TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
PULCHOWK CAMPUS
DEPARTMENT OF CIVIL ENGINEERING

Final Year Project Report

Bearing Capacity And Liquefaction Susceptibility Mapping Of Kathmandu Valley

Submitted By:

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April 23, 2021

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The undersigned certify that they have read and recommended to the Institute of Engineering for acceptance of a project entitled "Bearing Capacity and Liquefaction Susceptibility Mapping of Kathmandu Valley" submitted by Nitesh Bhandari, Puskar Gautam, Ribash Dahal, Rupak Bajgain, Samir Niraula and Suman Raj Regmi in partial fulfilment of the requirement of degree of Bachelors in Civil Engineering.

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C_B	:	Borehole diameter correction
C_S	:	Sample correction
C_R	:	Rod length correction
N_{60}	:	Corrected N value for field conditions
ϕ_{deg}	:	Internal angle of friction
γ_{sat}	:	Saturated unit weight of soil
E	:	Modulus of elasticity
Q_u	:	Ultimate Bearing Capacity of Soil
q_a	:	Allowable Capacity of Soil
q_{nu}	:	Net Ultimate Bearing Capacity of Soil
$q_{a(net)}$	:	Net Allowable Bearing Capacity of Soil
C	:	Cohesion for soil
q_0	:	Surcharge at that depth
γ	:	Unit weight of soil
N_c, N_q, N_γ	:	Constants for determining bearing capacity
S_c, S_q, S_γ	:	Shape factors
d_c, d_q, d_γ	:	Depth factors
i_c, i_q, i_γ	:	Inclination factors
B	:	Width of foundation
K_p	:	Passive earth pressure coefficient
R_{W1}, R_{W2}	:	Water table correction factors
D_{W1}	:	Depth of water table from ground level
D_{W2}	:	Depth of water table from footing
D_f	:	Depth of footing
ν	:	Poisson's ratio
K_σ	:	Correction factor for effective overburden
M_w	:	Magnitude of earthquake.
σ'_v	:	Vertical effective stress
σ_v	:	Total Vertical stress
P	:	Atmospheric pressure at location of site.
C_σ	:	Factor for calculating correlation factor for overburden
$(N_1)_{60cs}$	:	Corrected SPT value
N'_1	:	SPT value after dilatancy correction.
$(N_1)_{60}$	:	SPT value before fineness correction
N	:	Measured SPT value
C_N	:	Overburden correction factor
C_R	:	Rod length correction
E_H	:	Hammer energy ratio
C_B	:	Borehole Diameter ratio
C_S	:	Sampler correction
$\Delta(N_1)_{60}$	:	Correction for fineness content
a_{max}	:	Peak horizontal acceleration at surface

g	:	Acceleration due to gravity
r_d	:	Shear reduction factor
z	:	Depth of soil in m
E_r	:	Energy ratio of hammer

List of Abbreviations

WT	:	Water Table
SPT	:	Standard Penetration Test
FOS	:	Factor of Safety
GIS	:	Geographical Information Services
CSR	:	Cyclic Stress ratio of soil
CRR	:	Cyclic Resistance ratio of soil
FS	:	Factor of safety of soil
LPI	:	Liquefaction Potential Index
MSF	:	Magnitude Safety Factor
PGA	:	Peak Ground Acceleration
BC	:	Bearing Capacity

Abstract

The study focuses on the soil bearing capacity and Liquefaction Potrntial of several locations in Kathmandu valley. The allowable bearing capacities are calculated by using different parameters such as angle of internal friction, relative density, cohesion, which are determine through SPT-N values. Similarly for calculating liquefaction potential index unit weights, fineness content, etc. were used. The study represents the examination of bearing capacity and LPI by using SPT-N values for areas of Kathmandu valley. The soil BC conducted at depths 1.5 m, 3 m and 4.5m for square footing that is framed into geotechnical maps with the help of QGIS 3.x and for liquefaction the LPI was used for plotting. The BC was plotted based on shear and deflection strengths. The significance shows the easy identification of soil BC of Kathmandu valley areas and helps to estimate appropriate designs for foundations and to determine the risk of liquefaction in certain areas.

Keywords: Bearing Capacity, PLAXIS 2D, Zonation, Borehole log, Liquefaction, LPI, GIS, Kathmandu

1.Introduction

1.1. Bearing Capacity

Due to rapid rate of urbanization in different parts of Kathmandu, a lot of structures from residential to commercial and structures that will have tourism value are being built which are also multi-storied. These structures however suitably conceptualized and designed from architectural, structural and usability viewpoints need to rest on Earth; transfer the entire load they are imposed to the ground. This act of transferring the load must be done so that the soil mass below the structure does not fail in shear and also does not settle significantly or above some serviceable limit. The part of the structure, usually called sub-structure, as it is below the ground surface, is called foundation of the structure. Thus, foundation should be suitably designed bearing in mind the load it has to transfer to the ground and the type of soil it has to transfer the load to. Here comes the need to determine bearing capacity of the soil upon which the foundation rests.

Bearing capacity of a soil is the load of the superstructure that the designed foundation can dissipate on the ground without causing shear failure and excessive settlement of the soil. Many methods as developed by various scientists over the years can be used to determine the bearing capacity of the soil. These methods should be so chosen that the characterstics of the soil are rightly addressed.

Superstructures transfer force and moments through substructure to the underlying soil. So load should be within the safe limit of both foundation as well as soil. The safe limit of the foundation varies with the type of the foundation and material used. So it varies with the type of structure. But bearing capacity of the soil can be found out by using borehole log of that area. In some other countries, bearing capacity zoning of highly urbanized cities have been done. But, in case of Nepal maps have been prepared only for some places with limited precision. This report attempts to prepare one such map of the valley with the available SPT data from various sites.

1.2. Liquefaction

The phenomenon by which loss of strength occurs in soil during dynamic condition such as one produced during a seismic event is called soil liquefaction. It is generally associated with medium to fine grained saturated soil. During liquefaction, soil looses shear strength imparting it a liquid like behavior.

Casagrande[7] for the first time used the term liquefaction to explain the behavior of soil after it looses it's strength. Allen Hazen,[8] used it later to explain the failure of Calaveras Dam. It was later scientifically studied and associated with the beavior of soil in fine sands during seismic conditions by Seed, Idris,[10] and many other scientists to follow.

Based on the effective stress principle, liquefaction occurs when the pore water pressure equals the total overburden stress thus decreasing the shear strength of the cohesionless soil to zero. Mathematically, $\sigma' = \sigma_{vo} - u$ where, σ'=Effective stress

σ_{vo} =Total overburden stress u =pore water pressure

Here, overburden stress remains constant but pore water pressure changes and may equal overburden pressure causing soil to have no bearing stress and acting as liquid i.e. liquefaction. Since critical void ratio is not constant but changes with confining pressure and volume change in dynamic loading conditions are different than one direction's static load conditions, critical void ratio concept may not be sufficient for quantitative evaluation of soil liquefaction.

Liquefaction is the phenomenon involving large settlements, sand boils, lateral spread, heavy-cracks or combination of all these occurring above or in the deposit of partially or fully saturated loose sand with just enough fines. For liquefaction to occur, it is necessary that the undrained conditions be established. The term "liquefying" was for the first time used by Allen Hazen[8]. Liquefaction only got serious attention in academics after 1964 Niigata and Alaska Earthquake. So, it's a comparatively new topic and it is evolving in terms of scientific study. The susceptibility study of liquefaction in cities is a absolute necessity due to the larger risk it offers.

1.3. Scope

Due to variation of bearing capacity of soil, soil test is essential for construction of civil engineering works. But, that is not possible for very small project or checking for large no of places. So, our map attempts to give tentative information about the bearing capacity of any place. This will help those projects to save funds and still create safe design. Due to rapid urbanization high rise buildings are of rapid demand in the Kathmandu valley as the space is very less. So for the preliminary study, our map can be used to find out the tentative area where the building can be constructed. This will help in saving time as well as money. This can be used as study materials by the upcoming researchers.

The study of liquefaction susceptibility is ever evolving and the approach of the study, the factors that have direct influence in deciding whether liquefaction is a potential hazard within a locality or not are gradually being identified. This rate of rapid growth in the literature relating to liquefaction is bringing the susceptibility study very close to practicable to identify places with appropriate level of hazard. In this light, as Kathmandu valley, is located in high seismic hazard zone, and the risk the hazards possess being absolutely high, it was relevant to conduct liquefaction susceptibility study in the valley.

1.4. Objectives

Objectives of this study are:

- Finding bearing capacity using theoretical approach and Numerical Modeling in Plaxis-2D.
- Create zoning of bearing capacity by plotting bearing capacity.
- Getting to know the actual susceptibilty that liquefaction possess in various places of the valley.

- Mapping the susceptibilty with respect to various locations for visualization.

1.5. Limitations

- Study is limited for fixed footing, which in our case is 2*2 isolated footing.
- For PLAXIS, axisymmetry is taken for model taking footing as circular.
- Zoning map may not give accurate data because; it is merely interpolation of acquired data. It does not take into account every change in every point.
- The same SPT data was used to determine the results using various methods. Since each method has it's own set of parameters so results are diffrent in each case. Here the median was taken into account.
- There were limited boreholes involved in the study, so interpolations between locations may not closely depict the scenario.
- The study involves deterministic approaches which may not clearly be representative.

2.Literature Review

2.1. Bearing Capacity

Foundation is a part of a structure which is meant to transfer load from the superstructure to the ground taking care of shear failure and settlement. In this project we are going to calculate the bearing capacity of soil for the shallow foundation, so only design of shallow foundation is further discussed. Foundations are designed to have an adequate load capacity depending on the type of subsoil/rock supporting the foundation by a geotechnical engineer, and the footing itself may be designed structurally by a structural engineer. The primary design concerns are settlement and bearing capacity under shear failure. When considering settlement, total settlement and differential settlement is normally considered. Differential settlement is when one part of a foundation settles more than another part. This can cause problems to the structure which the foundation is supporting. Expansive clay soils can also cause problems.

Looking down the pages of the history books, the first ever theory on determination of bearing capacity was given by Rankine (1885). He considered the soil mass to be in plastic equilibrium and derived principle stresses values for different soil particles to complete his theory. This work was superseded by Prandtl (1920) who considered punching shear failure of soil masses to arrive to his formula for determining ultimate bearing capacity. After Prandtl, Hogentogler and Terzaghi derived another formula for ultimate bearing capacity approximating the actual curved failure surface which had been approximated as logarithmic spiral in theory given by Prandtl.[3]

Later in 1943, Terzaghi gave a general theory for the bearing capacity under a strip footing making a lot of assumptions like the footing was long enough, shear strength was governed by MohrColumb equation, and he also ignored the shear strength of the soil mass that was above the base of the footing.[3]

Up until now this theory has been revised a lot of times by many famous scientists, so that it can be worked out in various different cases. Meyerhof (1951), Vesic (1973), Skempton (1951), Hansen (1962), Teng (1962) etc. have arrived at formulae specific to cases.[3]

The cases considered in this report assume that the foundation is subjected to centric vertical loading. For the determination of the ultimate bearing capacity of a horizontal footing with a vertical load, the following factors are included: [1]

- The unit weight, shear strength, and deformation characteristics of soil.
- The size, shape, depth, and roughness of the footing and
- The water table conditions and initial stresses in the foundation soil.

In designing shallow foundations, two possible failure mechanisms must be considered. [1]

- A shear failure in the soil

- Excessive settlement leading to differential settlement in excess of that tolerable for the supported structures.

Bearing capacity is the capacity of soil to support the loads applied to the ground. The bearing capacity of soil is the maximum average contact pressure between the foundation and the soil which should not produce shear failure in the soil. Ultimate bearing capacity is the theoretical maximum pressure which can be supported without failure; allowable bearing capacity is the ultimate bearing capacity divided by a factor of safety. Sometimes, on soft soil sites, large settlements may occur under loaded foundations without actual shear failure occurring; in such cases, the allowable bearing capacity is based on the maximum allowable settlement. Some terms used in bearing capacity are:

- **Ultimate bearing capacity(q_u):** The ultimate bearing capacity is the gross pressure at the base of foundation at which soil fails in shear.

- **Net ultimate bearing capacity(q_{nu}):** It is the ultimate pressure per unit area of the foundation that can be supported by the soil in excess of the pressure caused bt the surrounding soil at the foundation level. It is given as

$$q_{nu} = q_u - q \tag{2.1}$$

  where, q_u = ultimate bearing capacity (gross), q = surcharge

- **Net Safe Bearing Capacity(q_{ns}):** It is net pressure that can be applied to soil considering only shear failure. It can be obtained by

$$q_{ns} = \frac{q_u}{FOS} \tag{2.2}$$

  where, FOS = factor of safety, which is usually taken as 3.0

- **Gross Safe Bearing Capacity(q_s):** It is maximum gross pressure which the soil can carry safetly without shear failure. It is equal to net safe bearing capacity plus the original overburden pressure. ie.

$$q_s = q_{ns} + q \tag{2.3}$$

- **Net Safe Settlement Pressure($q_{n\rho}$):** It is net pressure which soil can carry without excessive settlement. For individual footing it is taken between 25mm and 40mm.

- **Net allowable Bearing Pressure(q_{na}):** It is net bearing bearing pressure which can be used for the design of foundation. As there should be no shearing failure and settlement should also be within the limits, this is smaller of the q_{ns} and $q_{n\rho}$. It is given as

$$q_{na} = \begin{cases} q_{ns}, & \text{if } q_{n\rho} > q_{ns} \\ q_{n\rho}, & \text{if } q_{ns} > q_{n\rho} \end{cases} \tag{2.4}$$

2.1.1. Requirement for design and construction of foundation

The design and the construction of a wellperforming foundation must possess some basic requirements:

- The design and the construction of the foundation are done such that it can sustain as well as transmit the dead and the imposed loads to the soil. This transfer has to be carried out without resulting in any form of settlement that can result in any form of stability issues for the structure.

- Differential settlements can be avoided by having a rigid base for the foundation. These issues are more pronounced in areas where the superimposed loads are not uniform in nature.

- Based on the soil and area it is recommended to have a deeper foundation so that it can guard any form of damage or distress. These are mainly caused due to the problem of shrinkage and swelling because of temperature changes.

- The location of the foundation chosen must be an area that is not affected or influenced by future works or factors.

2.1.2. Types of foundation

The two types of foundation are:-

- Shallow Foundation

  Shallow foundations, often called footings, are usually embedded about a metre or so into soil. One common type is the spread footing which consists of strips or pads of concrete (or other materials) which extend below the frost line and transfer the weight from walls and columns to the soil or bedrock.

- Deep Foundation

  A deep foundation is used to transfer the load of a structure down through the upper weak layer of topsoil to the stronger layer of subsoil below.

2.1.3. Choice for type of foundation

The choice of the appropriate type of foundation is governed by some important factors such as

- The nature of the structure.

- The load exerted by the structure.

- The subsoil characteristics.

- The allotted cost of foundations.

2.1.4. Three modes of shear failure

General Shear Failure

A continuous failure surface is developed between the edges of the footing which extends up to the ground. As the applied pressure through the footing increases to the range of ultimate bearing capacity, plastic conditions develop around the edge of the footing that spread downward and then outward to the ground surface. Equilibrium is developed along that failure surface. Heave is seen on both sides of the footing. This mode of failure prevails in very dense soil.

Local shear failure

This mode of failure prevails in highly compressible soil and the failure mode is characterized by occurrence of relatively large settlement. Partial development of the state of plastic equilibrium occurs and the failure surface does not extend to the ground surface. Slight heave formation occurs on the surface.

Punching Shear Failure

It occurs when there is relatively high compression of soil under footing accompanied by shearing in the vertical direction around the edges of the footing. Failure is not accompanied by any heaving or any tilting. This mode of failure prevails in a soil of low compressibility and where the foundation is located at a significant depth.

2.1.5. Factors affecting FOS

Important Features Affecting Factor of Safety

- Type of structure permanent or temporary.
- Sensitivity of structure.
- Extent of soil exploration.
- Nature of loading considered and assumption made in the design.
- Extent of quality control during construction.

It is recommended that the factor of safety should be between 2 and 4. These values are given in Table 2.1.

Table 2.1.: Recommended factor of safety

Typical Structure	Characteristics of the category	Soil Exploration	
		Through	Limited
Railway bridge, Warehouses, blast furnaces, silos, hydraulic retaining walls	Maximum design load likely to occur often, consequence of failure disastrous	3.0	4.0
Highway bridge, light industrial and public buildings	Maximum design load may occur occasionally, consequence of failure serious	2.5	3.5
Apartments and office buildings	Maximum design load unlikely to occur	2.0	3.0

2.1.6. Factors affecting Bearing Capacity of Soil

Factors affecting the Bearing Capacity of the soil are:

- Type of soil.
- Unit weight of soil.
- Surcharge load.
- Depth of foundation.
- Mode of failure.
- Shape and size of footing.
- Depth of water table.
- Eccentricity in footing load.
- Inclination of ground.
- Inclination of base of foundation.

2.1.7. Site Investigation Requirements

Site exploration shall be carried out by digging test pits, two as a minimum, and more if the subsurface soil condition shows a significant variation in soil type. Generally, the minimum depth of exploration for a building covered by this MRT shall be 2 m. In hilly areas, exploration up to the depth of sound bedrock, if it lies shallower than 2 m, should suffice. No exploration shall be required if the site is located on rock or on fluvial terraces (Tar) with boulder beds. The soil encountered in the test pits should be classified as per Table 2.2.

2.1.8. Standard Penetration Test

The SPT is an insitu dynamic penetration test designed to provide information of the geotechnical engineering properties of soils. The test is conducted in a bore hole by means of a standard split spoon sampler. Once the drilling is done to the desired depth, the drilling tool is removed and the sampler is placed inside the bore hole. By means of a drop hammer of 63.5kg mass falling through a height of 750mm

Table 2.2.: Foundation Soil Classification and Safe bearing Capacity

Type of foundation material	**Foundation Classification**	**Presumed Safe Bearing Capacity**(kN/m^2)
Rocks in different state of weathering, boulder bed, gravel, sandy gravel and sand gravel mixture, dense or loose coarse to Medium sand offering high resistance to penetration with excavated by tools, stiff to medium clay which is readily indented with a thumb nail.	Hard	> 200
Fine sand and silt (dry lumps easily pulverized by the finger), moist clay and sand clay mixture which can be indented with strong thumb pressure	Medium	> 150 and < 200
Fine sand, loose and dry; soft clay indented with moderate thumb pressure	Soft	> 100 and < 150

at the rate of 30 blows per minute, the sampler is driven into the soil. This is as per IS 2131:1963.The number of blows of hammer required to drive a depth of 150mm is counted. Further it is driven by 150 mm and the blows are counted. Similarly, the sampler is once again further driven by 150mm and the number of blows recorded. The number of blows recorded for the first 150mm not taken into consideration. The number of blows recorded for last two 150mm intervals are added to give the standard penetration number (N) in other words no of blows required for 150mm penetration beyond seating drive of 150mm. If the number of blows for 150mm drive exceeds 50, it is taken as refusal and the test is discontinued. The standard penetration number is corrected for dilatancy correction and overburden correction. There are many parameters of soils which can be correlated with SPT Nvalue, such as density, undrained shear strength, friction angle, modulus, etc. SPT N-value is accepted as an important indicator and is most widely used to describe soil characteristics.[5]

Problems with SPT

The Standard Penetration Test recovers a highly disturbed sample, which is generally not suitable for tests which measure properties of the insitu soil structure, such as density, strength, and consolidation characteristics. However, this results in blow counts which are not easily converted to SPT Nvalues. Many conversions have been proposed, some of which depend on the type of soil sampled, making reliance on blow counts with nonstandard samplers problematic.

Standard Penetration Test blow counts do not represent a simple physical property of the soil, and thus must be correlated to soil properties of interest, such as strength or density.

SPT Correction for field procedure

Dilatancy correction is done for fine sand /silt and below water table and N $>$ 15.

$$N' = 15 + \frac{1}{2}(N - 15) \tag{2.5}$$

The SPT values have been corrected in accordance with the proposal of Skempton, (1986) and Liao and Whitman (1987) as outlined below with consideration of field procedure, hammer efficiency, borehole diameter, and sample and rod length. Correction of SPT Nvalue using the relation after Skempton (1986) [6]

$$N_{60cs} = E_m * C_B * C_s * C_R * \frac{N'}{0.6} \tag{2.6}$$

where,
E_m = 0.55 for hand drop hammer
C_B = 1 for 65-115mm diameter
C_S = 1.0 for standard sampler

$$,C_R = \begin{cases} 0.70, & \text{for length 0-2.99m} \\ 0.75, & \text{for length 3-3.99m} \\ 0.85, & \text{for length 4-5.99m} \\ 0.95, & \text{for length 6-9.99m} \\ 1.00, & \text{for length} > \text{10m} \end{cases}$$

The overburden correction is done as

$$C_\sigma = 9.78\sqrt{\frac{1}{\sigma'_v}} \leq 1.7 \tag{2.7}$$

$$N_{60} = N_{60cs} * C_\sigma \tag{2.8}$$

2.1.9. Some Empirical Relationships

Peck, Hansen & Thornburn (1974)[9]

$$\phi_{deg} = 27.1 + 0.3 * N_{60} - 0.00054 * N_{60}^2 \tag{2.9}$$

$$\gamma_{sat}(kN/m^3) = \begin{cases} 16.8 + 0.15 * N_{60}, & \text{for cohesive soil} \\ 16 + 0.1 * N_{60}, & \text{for cohesion less soil} \end{cases} \tag{2.10}$$

$$\frac{C_u}{P_a} = 0.29 * N_{60}^{0.72} \tag{2.11}$$

where, P_a = 100 kN/m^2

2.1.10. Relation to packing ratio

Table 2.3 show relation of SPTN to packing ratio.

Table 2.3.: Correlation between SPTN value and soil packing(Meyerhof 1956)

	SPT N3(1ft)	Soil packing
Cohesionless	< 4	Very loose
	4-10	Loose
	10-30	Compact
	30-50	Dense
	> 50	Very Dense
Cohesive	< 2	Very soft
	2-4	Soft
	4-8	Firm
	8-15	Stiff
	15-30	Very Stiff
	> 30	Hard

2.1.11. Terzaghi's Bearing Capacity Theory

Based on Terzaghi's bearing capacity theory, column load P is resisted by shear stresses at edges of three zones under the footing and the overburden pressure, q ($= \gamma D$) above the footing. The first term in the equation is related to cohesion of the soil. The second term is related to the depth of the footing and overburden pressure. The third term is related to the width of the footing and the length of shear stress area. The bearing capacity factors, Nc, Nq, Ng, are function of internal friction angle, ϕ. The general bearing capacity derived by Terzaghi for square footing are

$$Q_u = 1.3 * C * N_c + q_0 * N_q * R_{W1} + 0.4 * \gamma * B * N_\gamma * R_{W2} \tag{2.12}$$

$$N_c = \cot\phi(N_q - 1) \tag{2.13}$$

$$N_q = \frac{e^{2\pi(0.75-\phi'/360)*\tan(\phi')}}{2\cos^2(45+\frac{\phi}{2})} \tag{2.14}$$

$$N_\gamma = \frac{\tan\phi(\frac{K_p}{\cos^2\phi} - 1)}{2} \tag{2.15}$$

$$K_p = \tan^2(45 + \frac{\phi}{2}) \tag{2.16}$$

$$R_{W1} = 0.5(1 + \frac{D_{W1}}{D_f}), \text{if } (\frac{D_{W1}}{D_f}) \leq 1 \tag{2.17}$$

$$R_{W2} = 0.5(1 + \frac{D_{W2}}{B}), \text{if } (\frac{D_{W2}}{B}) \leq 1 \tag{2.18}$$

Assumptions in Terzaghi's Bearing Capacity Theory.

1. Depth of foundation is less than or equal to its width.
2. Base of the footing is rough.
3. Soil above bottom of foundation has no shear strength; it is only a surcharge load against the overturning load.

4. Surcharge upto the base of footing is considered.

5. Load applied is vertical and noneccentric.

6. The soil is homogenous and isotropic.

7. L/B ratio is infinite.

2.1.12. Meyerhof's Bearing Capacity Theory

In 1951, Meyerhof published a bearing capacity theory which could be applied to rough shallow and deep foundations. Meyerhof (1951, 1963) proposed a bearing-capacity equation similar to that of Terzaghi but included a shape factor S_q with the depth term N_q. He also included depth factors and inclination factors.[32]

The failure surface at ultimate load under a continuous foundation as assumed by Meyerhof (1951) is shown in Figure 2.1. In this figure, abc is the elastic triangular wedge shown in Figure 2.1, bcd is the radial shear zone with cd being an arc of a log spiral, and bdef is a mixed shear zone in which the shear varies between the limits of radial and plane shear depending on the depth and roughness of the foundation. The plane be is referred to as an equivalent free surface. The normal and shear stresses on the plane be are P_o and s_o, respectively. The superposition method is used to determine the contribution of cohesion (c), on the ultimate bearing capacity Q_u of the continuous foundation and can be expressed as

$$Q_u = C * N_c * S_c * d_c + q_0 * N_q * S_q * d_q + 0.5 * \gamma * B * N_\gamma * S_\gamma * d_\gamma \quad (2.19)$$

$$N_q = \exp^{\pi * \tan(\phi)} * \tan^2(45 + \frac{\phi}{2}) \quad (2.20)$$

$$N_c = \cot(\phi) * (N_q - 1) \quad (2.21)$$

$$N_\gamma = (N_q - 1) * \tan(1.4 * \phi) \quad (2.22)$$

$$S_c = 1 + 0.2 * K_p \quad (2.23)$$

$$S_q = 1 + 0.1 * K_p \quad (2.24)$$

$$S_\gamma = 1 + 0.1 * K_p \quad (2.25)$$

$$d_c = 1 + 0.2 * \sqrt{K_p} * (\frac{D}{B}) \quad (2.26)$$

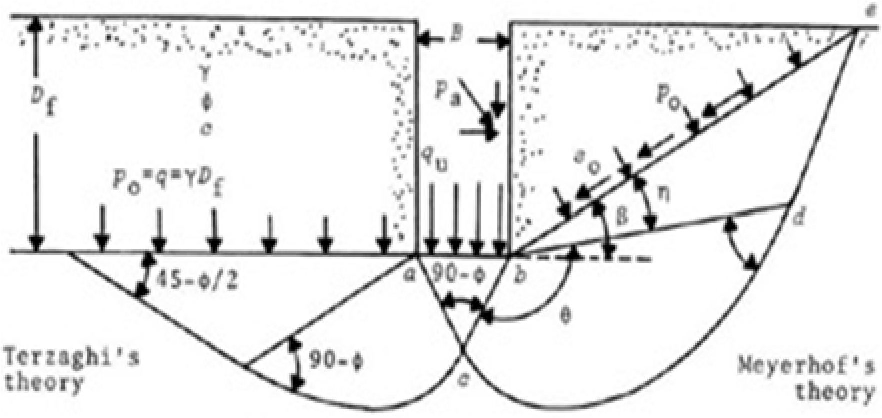
$$d_q = d_\gamma = 1 + 0.1 * \sqrt{K_p} * (\frac{D}{B}) \quad (2.27)$$

$$K_p = \tan^2(45 + \frac{\phi}{2}) \quad (2.28)$$

2.1.13. Hansen's Bearing Capacity Theory

The Hansen bearing capacity equation is an extension of the Terzaghi method which includes foundations on slopes and other conditions not considered in the Terzaghi method. And He also adjusted the values to give answer more inclined with the

Figure 2.1.: Meyerhof's Analysis[32]



experiment. The Hansen equation implicitly allows any $\frac{D}{B}$ and thus can be used for both shallow and deep bases.

$$Q_u = C * N_c * S_c * d_c * i_c + q_0 * N_q * S_q * d_q * i_q + 0.5 * \gamma * B * N_\gamma * S_\gamma * d_\gamma * i_\gamma \tag{2.29}$$

$$N_q = \exp^{\pi * \tan(\phi)} * \tan^2(45 + \frac{\phi}{2}) \tag{2.30}$$

$$N_c = \cot(\phi) * (N_q - 1) \tag{2.31}$$

$$N_\gamma = 1.8 * (N_q - 1) * \tan(\phi) \tag{2.32}$$

For square footing, $S_c = S_q = S_\gamma = 1.3$

$$d_c = d_q = 1 + 0.35 * (\frac{D}{B}) \tag{2.33}$$

$$d_\gamma = 1 \tag{2.34}$$

$$i_c = 1 - \frac{H}{2 * c * B * L} \tag{2.35}$$

$$i_q = 1 - \frac{1.5 * H}{V} \tag{2.36}$$

$$i_\gamma = i_q^2 \tag{2.37}$$

2.1.14. Vesic's Bearing Capacity Theory

Vesic (1973) confirmed that the basic nature of failure surfaces in soil as suggested by Terzaghi as incorrect. He made same assumtions as that of Hansen. However, the angle which the inclined surfaces AC and BC make with the horizontal was found to be closer to 45 + $\frac{\phi}{2}$ instead of 45 . The values of the bearing capacity factors , for a given angle of shearing resistance change if above modification is incorporated in the analysis as under: [3]

$$Q_u = C * N_c * S_c * d_c * i_c + q_0 * N_q * S_q * d_q * i_q + 0.5 * \gamma * B * N_\gamma * S_\gamma * d_\gamma * i_\gamma \tag{2.38}$$

$$N_q = \exp^{\pi * \tan(\phi)} * \tan^2(45 + \frac{\phi}{2}) \tag{2.39}$$

$$N_c = \cot(\phi) * (N_q - 1) \tag{2.40}$$

$$N_\gamma = 2 * (N_q + 1) * \tan(\phi) \tag{2.41}$$

$$S_c = 1 + \frac{N_q}{N_c} \tag{2.42}$$

$$S_q = 1 + \tan(\phi) \tag{2.43}$$

$$S_\gamma = 0.6, \text{for square footing} \tag{2.44}$$

$$d_c = 1 + 0.4 * \frac{D}{B} \tag{2.45}$$

$$d_q = 1 + 2 * \tan(\phi) * (1 - \sin(\phi))^2 * \frac{D}{B} \tag{2.46}$$

$$d_\gamma = 1, for \frac{D}{B} < 1, \text{use Hansen value} \tag{2.47}$$

$$i_c = i_q = (1 - \frac{\alpha}{90})^2 \tag{2.48}$$

$$i_\gamma = (1 - \frac{\alpha}{\phi})^2 \tag{2.49}$$

2.1.15. Teng's method

Teng expressed the charts given by Terzaghi and Peck (1948) in the form of following formulae. He also added the allowance for increase in preface with depth by introducing a depth factor.

$$q_a = 35(N - 3)(\frac{B + 0.3}{B})^2 W_\gamma R_d \tag{2.50}$$

where, q_a = allowable bearing capacity for 25 mm settlement.,
W_γ = water table correction factor.
R_d = depth factor = $1 + \frac{D_f}{B}$
Also, from shear criteria,

$$q_n u = 0.11 N^2 B W_\gamma + 0.33(100 + N^2) D_f * W_\gamma \tag{2.51}$$

2.1.16. Peck method

Terzaghi and Peck (1967) gave charts for the safe bearing pressures introducing a total settlement of 25 mm and a differential settlement of 19 mm for different footings. Peck (1974) revised the Terzaghi and Peck curves to consider in later research, and gave following equations for the safe settlement pressure.[3]

$$q_{n\rho} = 0.41 C_w N s \tag{2.52}$$

Where, $q_{n\rho}$ is the safe settlement pressure in kN/m^2
N is corrected SPT value
s is settlement in mm
C_w is water table correction factor.

We calculate using Peck method bu taking deflection of 25mm so for 25 mm deflection the above equations becomes,

$$q_{n\rho} = 10.25 C_w N s \tag{2.53}$$

Where water table correction is found using equation,

$$C_w = 0.5 + 0.5 D_w/(D_f + B) \tag{2.54}$$

where, D_w is Depth of water below ground surface.
D_f is depth of footing.
B is width of footing.

2.1.17. Bowles theory

The bearing capacity of a soil is given by Terzaghi and Peck was found to be very conservative. Meyerhof (1956,1974) published equation for computing the allowable bearing for a 25 mm settlement, which also underestimated the value. Bowels, for this reason, adjusted the Meyerhof equation by a multiplication factor of 1.5.

$$q_a = \begin{cases} \frac{N}{F_1} R_d * W_\gamma, & B \leq F_4 \\ \frac{N}{F_2} (\frac{B+F_3}{B})^2 R_d, & B > F_4 \end{cases} \tag{2.55}$$

$$R_d = 1 + 0.33 \frac{D}{B} \leq 1.33 \tag{2.56}$$

(Meyerhof 1965) where,
q_a = allowable bearing capacity for settlement of 25mm, unit is kPa.,
N = For E_r 55
F_1 = 0.05, F_2 = 0.08, F_3 = 0.3 ,and F_4 = 1.2, for SI units.

2.1.18. Finite Element Method

The finite element method (FEM) is the most widely used method for solving problems of engineering and mathematical models. Typical problem areas of interest include the traditional fields of structural analysis, heat transfer, fluid flow, mass transport, and electromagnetic potential. The FEM is a particular numerical method for solving partial differential equations in two or three space variables (i.e., some boundary value problems). To solve a problem, the FEM subdivides a large system into smaller, simpler parts that are called finite elements. This is achieved by a particular space discretisation in the space dimensions, which is implemented by the construction of a mesh of the object: the numerical domain for the solution, which has a finite number of points.

PLAXIS

PLAXIS is a finite element program for geotechnical applications in which soil models are used to simulate the soil behavior. The PLAXIS code and its soil models have been developed with great care. Although a lot of testing and validation have been performed, it cannot be guaranteed that the PLAXIS code is free of errors. Moreover, the simulation of geotechnical problems by means of the finite element method implicitly involves some inevitable numerical and modeling errors. The accuracy at which reality is approximated depends highly on the expertise of the user regarding the modeling of the problem, the understanding of the soil models and their limitations, the selection of model parameters, and the ability to judge the reliability of the computational results. Hence, PLAXIS may only be used by professionals that possess the aforementioned expertise. The user must be aware of his/her responsibility when he/she uses the computational results for geotechnical design purposes.

2.1.19. Geographic information system

Geographical Information System (GIS) is a computer based information system used to digital represent and analyze the geographical features, present on the Earth's surface and events that taking place on it. The meaning of GIS is to represent digitally is to convert analogue (smooth line) into digital form. "Every object present on the Earth can be georeferenced", is the fundamental key of associating any database to GIS. Here, the term 'database' is a collection of information about thing and their relationship to each other and 'geo referencing' refers to the location of a layer or coverage in space defined by coordinate reference system.

Work on GIS began in late 1950s, but first GIS software came only in late 1970s from lab of the ESRI. Canada was the pioneer in the development of GIS as a result of innovation dating back to early 1960s. Much of the credit for the early development of GIS goes to Roger Tomilson. Evolution of GIS has transformed and revolution and revolutionized and the ways in which planners, engineers, managers etc. conduct the database management and analysis.

GIS is no longer viewed as complicated, expensive tool for geographers and cartographers to plot out maps. It has tremendous potential to affect a wide variety of fields, from community planning and economic development to political district mapping and Engineering solutions. It is used to find location and conditions of that location, trends and patterns of location about the recent changes in location. Also modelling and mapping can be done in GIS.

Map is a small scale representation of Earth's surface. Representation of earth on a map encounters some distortion in distance, area, shape and direction. It is necessary to apply some kind of scale reduction to represent earth's features into a map. Well designed map contains title, legend, credits, map scales, mapped area, map symbols, place name and labelling, north arrow, boarder, Inset and graticule.

Every Spatial features needs to be referenced GIS use. Spatial reference systems provide a framework to define positions on the Earth's surface. We are used to working with coordinate systems, but due to Earth's irregular system, this method becomes intricate. Here we represent spherical or ellipsoidal surface of earth in flat plane. For that we use projection of earth on a cylindrical surface. This can be done in many methods, we use MUTM (Modified Universal Traverse Mercator) which divides Earth into 120 parts of 3 degree each for using projections, which is slightly better than UTM projection for calculations in Nepal. We use MUTM coordinate system with 84 degree datum.

QGIS

QGIS is a free and opensource crossplatform desktop geographic information system (GIS) application that supports viewing, editing, and analysis of geospatial data. It allowing users to analyze and edit spatial information, in addition to composing and exporting graphical maps. It is a good alternative of ArcGIS which is free and has a large community. It is written in C++ available under the conditions of the GPL license. It is based on the C++ crossplattform library Qt from Trolltech. Therefore, it runs on most existing operating systems, including Linux, Unix, Mac OS X and Windows.

The main focus of QGIS is interactive two dimensional viewing of spatial data. However, there is also functionality for editing vector data and a GRASS plugin to use the analytical functionality of the GRASS program from within the QGIS GUI. QGIS supports a large number of vector and raster formats, including PostGIS, GRASS, Shapefile, GML, WFS, GPX, WMS, GeoTiff, PNG, JPG and many others. QGIS supports reprojecting onthefly for vector data.

2.2. Liquefaction

2.2.1. Introduction

Liquefaction is one of the major causes of heavy destruction during a seismic event. It occurs in the deposit of loose and saturated sand with certain range of percentage of fines [10]. The occurrence of liquefaction is distributed around the epicentre and is generally observed near river, lakes owing to the favourable soil properties and the ground water level there. Loose sand tends to contract during the earthquakes proper drainage not available either due to the deposit being a large one or due to the lower values of coefficient of permeability of the deposit, which causes the pore water pressure to rise and perhaps beyond the value of effective stress at the considered level. It results in the temporary loss of shear strength imparting liquid like behavior to the deposit. This introduces large deformation in the structures resting on the ground above the deposit. This introduces large deformations in the structures resting on the ground above the deposit. Lateral spread, sand boiling and surface cracks are the prominent effects observed during a liquefaction event.

Most dramatic instances of the damages due to liquefaction to the civilengineering structures were observed during the 1964 Niigata and Alaska Earthquake. The results of those liquefaction were substantial incidents of bearing failures beneath the buildings, floating of the underground tanks and collapse and damages to several bridges nearer to the epicentre. These events for the first time drew attention of the engineering community towards the scientific study of the phenomenon. Since then, it has frequently been observed, recorded and studied during various major earthquakes occurring around the globe.

The documentation and study of such events have been playing a vital role in understanging of the phenomenon of liquefaction at a certain place. Several techniques have been developed along the years, which can be broadly be grouped under :

1. methods that are based on the soil properties which are determined by laboratory testing
2. methods that are based on the In situ test results
3. methods that are based on numerical modelling
4. combination of laboratory testing and back analysis of any past records of occurrence of liquefaction.

In this report, liquefaction hazard mapping has been done by the 2^{nd} method from site observed SPT values.

The causes of liquefaction during a seismic event can be attributed to the loss of local shear strength due to the undrained conditions being established under the cyclic loading introduced by the shaking. However, the parameters which assist in establishment of such conditions can be in broad discussed as follows:

- Seismic causes Intensity of the earthquake basically depends upon the magnitude of the earthquake, the distance of the site from the epicentre of the earthquake, the stiffness of the medium the seismic waves travel through and the attenuation of the energy. All these factors dictate the local PGA, which plays essential role for liquefaction to occur.
- Site Conditions Liquefaction generally occurs at the places nearer to the water bodies as the land nearby is ever saturated. Moreover, the young deposition of sand with no past history of exposure to the shaking due to the quake with uniform gradation in very loosely packed state makes the site much more vulnerable.

The dynamic strength of soil is affected strongly by the characteristics of soil grain such as grain size, grain shape, grain distribution and mineral composition. Seed presented the relationship between the liquefaction resistance and the mean grain size (D_{50}).[11] The liquefaction resistance increases with increasing with the D_{50} of soil specimen. Ishibashi showed that for a given mean grain size (D_{50}), soil specimen with wellgraded grain distribution have lightly greater liquefaction resistance than that with uniform grain size distribution.[13]

Concerning the fine content in a soil, several studies show that the liquefaction resistance of the soil will first go on decreasing with increasing fine content, reach to a minimum value and then go on increasing afterwards. Above 70% silt content hazard of the liquefaction was found substantially low.[13] Tokimatsu and Yoshimi further concluded that the sand with more than 10% fines have much greater liquefaction resistance than clean sands with same SPT Nvalues.[16]

Factors affecting the cyclic strength with the level of effect is shown in Table **??**. [12]

Table 2.4.: Factors affecting the cyclic strength with level of effect

Factors Affecting Liquefaction	Pure Sand	Sand with silt content
Average effective Confining Pressure	R	R
Void Ratio, e	V	V
Saturated degree, Sf	V	V
Over-consolidation Ratio, OCR	L	V
Pre-strain history	V	V
Sample Prepared Method	V	V
Grain Size, Distribution and Mineral Contents	V	V
Frequency of Loading	R	L
Time Effect	R	R
Volume change during shear strain $\gamma < 0.5\%$	U	U

Note:
V: Major effect factor L : Minor effect factor
R: Light effect factor U : Significance unknown

Regarding the silty soils in specific, so called Chinese Criteria [19] has been presented in Seed [11] , which is as follows:

- Clay Content (defined as % finer than 0.005 mm) $<$15%
- Liquid Limit $<$35
- Water Content $>$0.9 * Liquid Limit

With increasing relative density, it is much unfavourable for the soil element to develop excess pore water pressure. The liquefaction study carried out by Seed post Nigata earthquake led to the result that the soil liquefaction was much likely to occur when the relative density was about 50%. Mulilis presented that the liquefaction resistance of soil has liquefaction resistance of soil has linear relationship with the relative density as the relative density of soil is less than 70%, and the relationship is also a function of confining pressure.[14]

Liquefaction resistance of soil increases with increasing of the confining stress as demonstrated by Seed, based on the results of the cyclic triaxial test, however the required cyclic shear stress ratio to develop liquefaction decreases with increasing effective confining pressure.[15]

Geology of Kathmandu Valley and liquefaction susceptibility

Kathmandu valley is geologically characterized by occurrence of fluviolacustrine sediments of Pliocene to Quaternary age that comprise Kathmandu complex with Phulchoki and Bhimphedi group as basement rocks. Thickness of sediment deposit is varied according to the location. For instance, the central valley consists unconsolidated sediments of about 550–600 m depth and the depth is limited to 50–70 m at the edges. Several studies(JICA, UNDP) to be discussed conclude that the river basins in particular are much vulnerable. Some recent ones(Gautam et al) show that the Kalimati formation is the most hazardous formation in Kathmandu Valley.

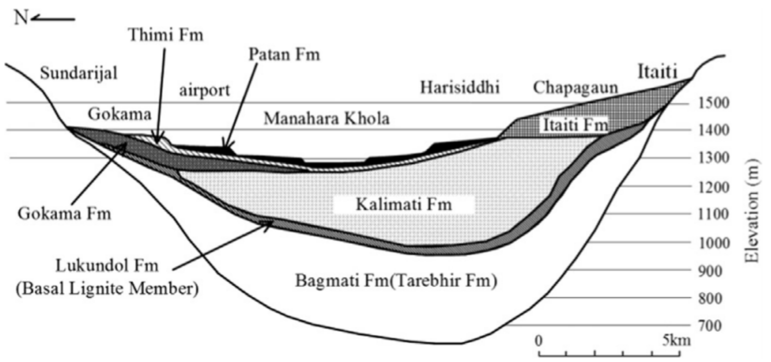


Figure 2.2.: A schematic crosssection showing the stratigraphic framework and depositional environments of the basinfill sediments in the Kathmandu Valley (from Sakai [23]).

Liquefaction Susceptibility Maps of Kathmandu

UNDP/UNCHS Liquefaction Susceptibility Maps of 1994

The very first attempt to produce liquefaction susceptibility map of Kathmandu valley was done by UNDP/UNCHS in 1994. The analysis was made on the basis of geological and hydrological considerations on the basis of qualitative method developed by Juang[24]. All Flood plains and some part of central part of valley was presented as the most liquefaction prone area of the whole valley. As the qualititative method of evaluation of liquefaction potential has it's own limitations, the study could not produce a comprehensive map.

Map Presented By JICA

JICA prepared a map in 2002 based on qualitative method of evaluation of Liquefaction Susceptibility, using borehole log data from limited places. The work as carried out under the project "The Project for Assessment of Earthquake Disaster Risk for the Kathmandu Valley in Nepal". The method proposed by Iwasaki [25] was used. The map then got revised in 2018 when JICA published a report on seismic risk assessment in Kathmandu Valley. The results of the map were somewhat closed to the results proposed by UNDP back in 1994, considering the aspect of the result that both of the maps showed considerable liquefaction potential in the areas

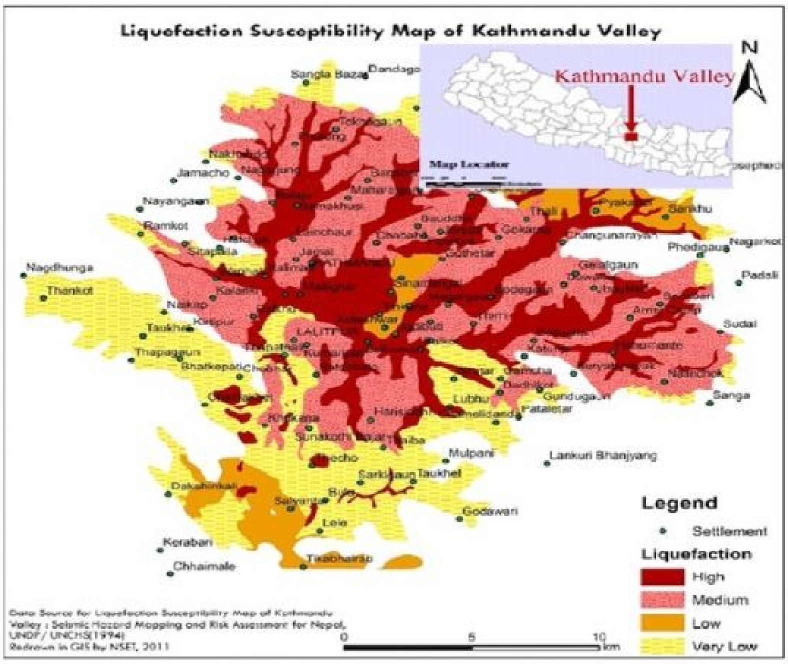


Figure 2.3.: UNDP/UNCHS Liquefaction Susceptibility Maps of 1994

in the flood plains of Bagmati river. The map also showed various places where liquefaction was observed in the recent 2015 Gorkha earthquake and 1934 Bihar Nepal Earthquake.

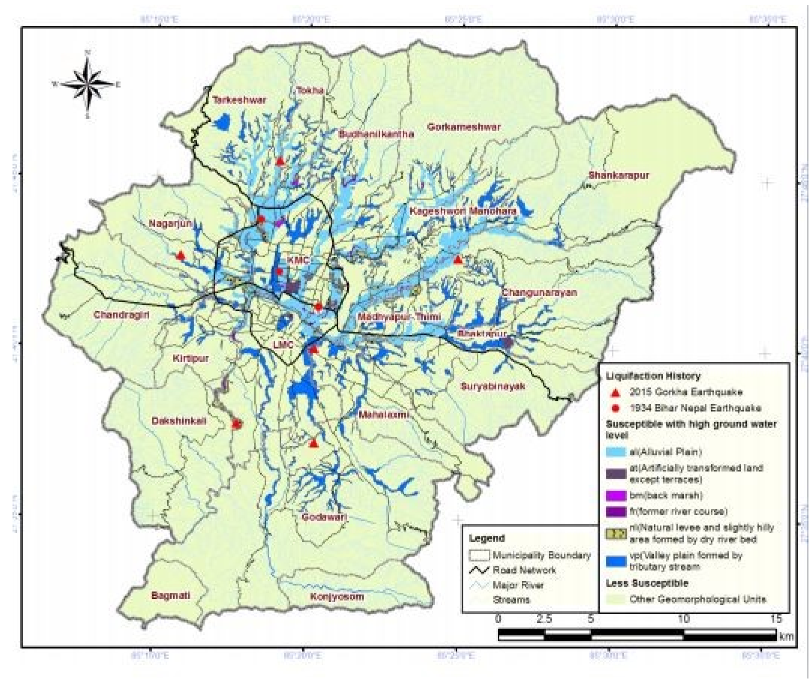


Figure 2.4.: Liquefaction Susceptibility Map Presented By JICA

Liquefaction Susceptibility Map produced by JICA(2018), updated one from that published in 2004.

Other maps developed throughout the years

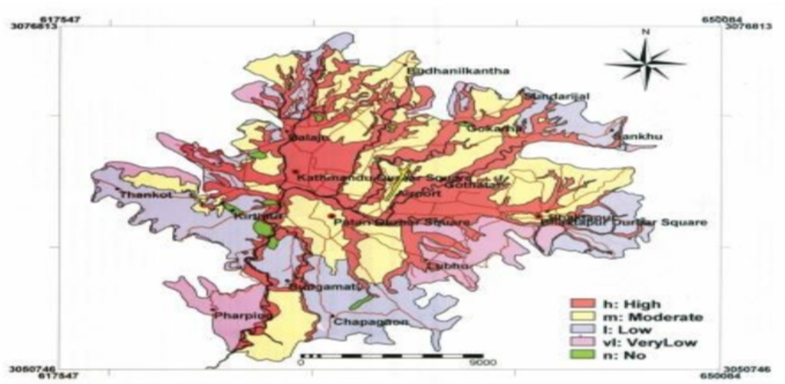


Figure 2.5.: Liquefaction Susceptibility Map (Piya)

Piya (2004) have developed one using both of the qualitative and quantitative methods proposed by Juang[24], Iwasaki[25] and Seed and Idriss[11]. The map divides the valley into 5 categories: no, very low, low, moderate and high on the basis of susceptibility to liquefaction. The core areas of the valley and the areas along the flood plains as indicated previously by other maps were again found to be vulnerable to liquefaction from the study.

Subedi[27] produced another of the liquefaction susceptibility maps based on the qualitative method put forward by Youd[26], using the borehole log from varoius places, although the data set was still limiting, of Kathmandu. The liquefaction susceptibility map was prepared for a/g = 0.3. The map though did only figure out the central zone to be more vulnerable to liquefaction.

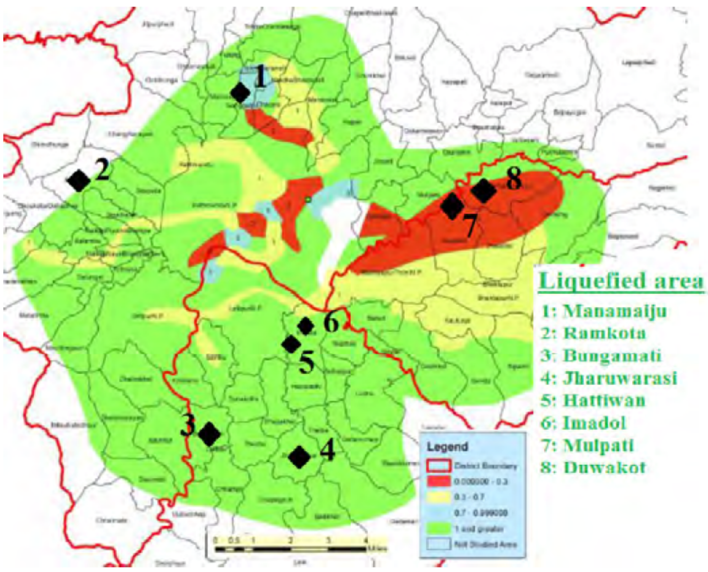


Figure 2.6.: Subedi . (2013), Liquefaction Susceptibility Map

Gautam (2015)[17] computed FS for various localities of Kathmandu Valley and also the LPI corresponding to those boreholes using SPT data.

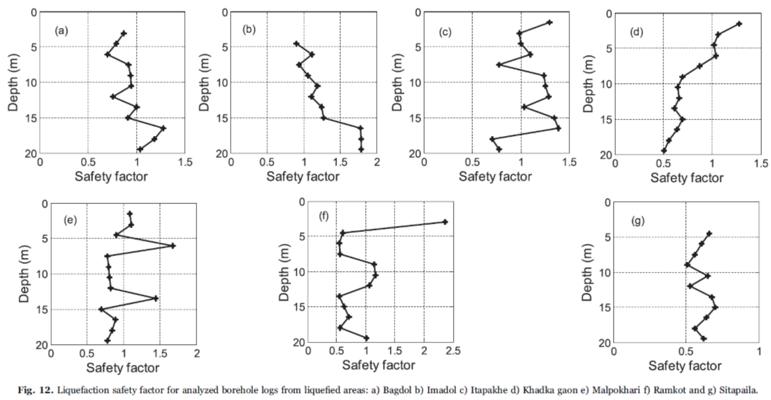


Figure 2.7.: Liquefaction safety factor for for different borehole logs, D.Gautam .(2015)

Bastola and Acharya(2016)[29] prepared another using quantitative methods of liquefaction susceptibility map preparation. Liquefaction Potential Index(LPI) was calculated for various borehole data and the area most prone to liquefaction was highlighted in the map.

2.2.2. Methods for liquefaction calculation

There are qualitative and quantitative methods and deterministic and probabilistic approaches to assess the liquefaction potential. In this research, the stressbased approach suggested by Idriss and Boulanger[30] has been adopted to perform an analysis of the factor of safety (FS) with respect to liquefaction on each layer and Iwasaki . [25] method has been used to estimate the liquefaction potential index(LPI) of the sites. The stressbased approach for evaluating the potential 1or liquefaction triggering, initiated by Seed and Idriss [31], has been used widely for the last 45 years. The basic framework, as adopted by numerous researchers, compares the earthquakeinduced cyclic stress ratios (CSR) with the cyclic resistance ratios (CRR) of the soil. This method uses the Standard Penetration Test (SPT) blow count data and geotechnical properties of the soil layers to predict the earthquake potential.

2.2.3. Stress based approach

Stress based approach suggested by Idriss and Boulanger [30] to find Factor of Safety. In this method, the stress (loading) that results in liquefaction is defined as the cyclic stress ratio (CSR), and the property of the soils to resist liquefaction is termed as the cyclic resistance ratio (CRR). The FS with respect to liquefaction can be calculated using:

$$FS = \frac{CRR}{CSR} \tag{2.57}$$

Here, $CRR = CRR_{7.5} * M.S.F * K_\alpha$

Where, $CRR_{7.5}$ is the cyclic resistance ratio calibrated for the earthquake of magnitude 7.5; MSF is the magnitude scaling factor that accounts for the effects of shaking duration and K_α is a factor for the presence of sustained static shear stresses, which may exist beneath foundations or within slopes.

MSF and K_σ were calculated using [30]:

$$MSF = 6.9e^{-\frac{M_w}{4}} - 0.058 \leq 1.8 \tag{2.58}$$

Where,

Mw is magnitude of earthquake.

$$K_\sigma = 1 - C_\sigma ln(\frac{\sigma'_v}{P}) \leq 1.1 \tag{2.59}$$

Where, σ'_v is Vertical effective stress P is atmostpheric pressure at location C_σ is given as,

$$C_\sigma = \frac{1}{18.9 - 2.55\sqrt{(N_1)_{60cs}}} \leq 0.3 \tag{2.60}$$

$(N_1)_{60cs}$ is the corrected SPT value.

The $CRR_{7.5}$ is calculated using [30]

$$CRR_{7.5} = exp(\frac{(N_1)_{60cs}}{14.1} + (\frac{(N_1)_{60cs}}{126})^2 + (\frac{(N_1)_{60cs}}{23.6})^3 + (\frac{(N_1)_{60cs}}{25.4})^4) - 2.8 \tag{2.61}$$

This provides cyclic resistance ratio for liquefaction of soil during earthquake. Here $(N_1)_{60cs}$ is corrected for fineness content in soil.

$$(N_1)_{60cs} = (N_1)_{60} + \Delta(N_1)_{60} \tag{2.62}$$

$$\Delta(N_1)_{60} = exp(1.63 + \frac{9.7}{FC + 0.01} + (\frac{15.7}{FC + 0.01})^2) \tag{2.63}$$

(2.64)

Here, FC is fines content in soils.

Cyclic stress ratio can be found using equation,

$$CSR = 0.65\frac{\sigma_v}{\sigma'_v}\frac{a_{max}}{g}r_d \tag{2.65}$$

Where, a_{max} is peak horizontal acceleration at surface. g is acceleration due to gravity. σ'_v is effective overburden stress. σ_v is total overburden stress. Shear reduction factor rd is given by;

$$r_d = exp[-1.012 - 1.126(\frac{z}{11.73} + 5.133) + M_w(0.106 + 0.118\sin(\frac{z}{11.28} + 5.142))] \tag{2.66}$$

Here, z is the soil depth in m.

2.2.4. Liquefaction potential index

We consider 20 m depth for analysis of liquefaction potential of soil. Higher weightage is given to uppermost layers of soil as top layers are more responsible for liquefaction. We use Iwasaki . method to obtain liquefaction potential index by integrating safety factors on upper 20 m soil column as follows.

$$LPI = \int_0^{20} F(z).W(z).dz \tag{2.67}$$

Where, LPI is liquefaction potential index

F(z) is function of safety factor (FS) given by,

$$F(z) = \begin{cases} 0, & \text{for} FS > 1.2 \\ 2 * 10^6 e^{-18.427FS}, & \text{for} 1.2 \geq FS > 0.95 \\ 1 - FS, & \text{for FS} \leq 0.95 \end{cases}$$

W(z) is depth dependent factor which can be expressed as

$$W(z) = 10 - 0.5z \tag{2.68}$$

But instead of above given integral we estimate the integral using summation given as,

$$LPI = \sum_F (z).W(z).\delta z \tag{2.69}$$

3.Material And Methods

Methodology is the systematic, theoretical analysis of the methods applied to a field of study. It comprises the theoretical analysis of the body of methods and principles associated with a branch of knowledge.

3.1. Working Steps

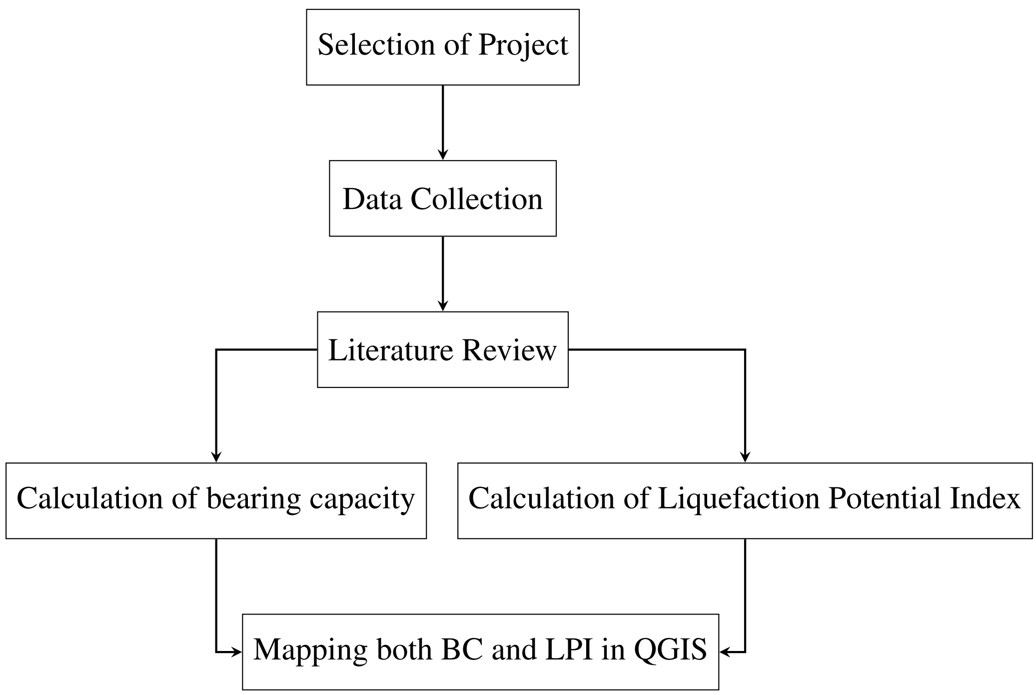


Figure 3.1.: Project Flowchart

3.1.1. Selection of Project

As a matter of interest, we choose geotechnical field for our final year project. We discussed with our supervisor and attempted to try the Bearing Capacity Zonation and Liquefaction Potential Index Mapping. This project enables any future uses to find tentative bearing capacity and LPI of Kathmandu valley.

3.1.2. Data Collection

Data required for our project was SPT value and summary sheet for different locations as SPT was commonly used for bearing capacity calculation as well as LPI analysis of any place. Our data was provided by our supervisor as well as from Multilab. We collected about 104 boreholes from about 31 locations.

3.1.3. Literature Review

Detailed information about the project was needed, for that we studied various books as well as journals related to shallow foundation bearing capacity. As well as bearing capacity calculations from shear as well as deflection methods. For liquefaction we read various papers by Seed, Idris and research on Nepal earthquake 2015, etc.

3.1.4. Foundation Selection

In this project work, square footing has been used. Buildings in Kathmandu valley have a depth of nearly 2m. Thus bearing capacity has been calculated for depths 1.5m, 3m and 4.5m for a footing dimension 2m * 2m as in Figure 3.2. Ground water table has been used as given in the bore logs. Also, the permissible settlement of 25mm is taken for settlement criteria approach.

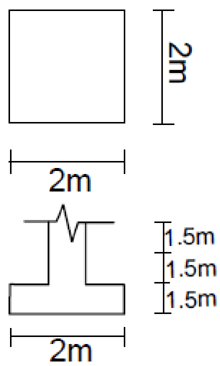


Figure 3.2.: Footing Dimension

3.1.5. Calculation of bearing capacity from theoretical approaches

The various parameters of soil like cohesion, internal angle of friction, young's modulus of elasticity, unit weight, poisons ratio, etc were interpreted from SPT N value through various literatures available. Methods like Terzaghi, Meyerhof, Hansen, Vesic and Teng are used for the calculation of bearing capacity under shear criteria. And, Bowels, Teng, Peck and Meyerhof methods were used for settlement criteria.

3.1.6. Use PLAXIS 2D for Numerical Modeling

In this project a numerical model is developed using PLAXIS. Finite element analysis is carried out using Mohr coulomb failure criteria to represent two-dimensional soil models. Foundation is modelled as square footing and load increment is applied till the soil model fails. Ultimate bearing capacity is identified as that minimum pressure on footing at which the foundation soil experiences shear failure. And for deflection criteria, reaction at 25mm deflection is noted which is ultimate bearing capacity. In plaxis effective stress is considered as an ultimate bearing capacity.

3.1.7. Calculation of liquefaction potential index

For calculating liquefaction index, stress based approach was used and factor of safety was calculated using ratio of cyclic resistance ratio to cyclic stress ratio and from that LPI was calculated using data for up to 20m or for up to given data.

3.1.8. Mapping of BC and LPI using QGIS

We used QGIS for mapping. Map of Nepal was taken and we put our location on map. After using map of only two districts i.e. Kathmandu and Lalitpur (as our data lies on those districts). The value of all points are interpolated and clipped by our district maps. Suitable colour and map elements are selected accordingly.

IDW interpolation method was used in this software. The least value of the location was plotted. Consequently, the study area was categorized into following zones:

For Bearing Capacity:

1. Weak soil region having BC $\leq$ 100 kPa
2. Soft soil region having BC $>$100 and $\leq$ 150 kPa
3. Moderate soil region having BC $>$150 and $\leq$ 200 kPa
4. Moderately hard soil region having BC $>$200 and $\leq$ 250 kPa
5. Hard soil region having BC $>$250 kPa

For LPI:

1. Very low from 0 – 2
2. Low from 2 – 5
3. High from 5 – 15
4. Very high from $>$15

3.2. Determination soil properties for calculation

3.2.1. Determination of E

The value of E can be estimated for different types of soil as given in [9].

For cohesive soil:

$$\frac{E}{P_a}(kN/m^3) = \begin{cases} 15 - 40 * N_{60}, & \text{for very soft soil} \\ 40 - 80 * N_{60}, & \text{for soft soil} \\ 80 - 200 * N_{60}, & \text{for compact and dense} \end{cases} \tag{3.1}$$

And for cohesionless soil:

$$\frac{E}{P_a}(kN/m^3) = \begin{cases} 5 * N_{60}, & \text{with fines} \\ 10 * N_{60}, & \text{without fines} \end{cases} \tag{3.2}$$

3.2.2. Determination of C

The values of C is determined by using Equation 2.11. For cohesionless soil this value is taken as 0.

3.2.3. Determination of ϕ

The value of ϕ is determined by using Equation 2.9. For cohesive soil this value is taken as 0.

3.2.4. Determination of ν

The value of ν is taken as:-

$$\nu = \begin{cases} 0.3, & \text{for cohesionless soil} \\ 0.45, & \text{for cohesive soil} \end{cases} \tag{3.3}$$

3.2.5. Determination of other parameters

Other parameters are calculated from Emperical Formulas in subsection 2.1.9.

3.3. Removing Outliers

The outliers were removed by calculating Q_1 and Q_3 and calculating IQD. Then only values that were between $Q_1 - 1.5$ ILD and $Q_3 + 1.5$ ILD were selected for further calculation like mean and standard deviation.

3.4. Selection Median

In summary Terzaghi was excluded from shear since it has no depth corrections. Meyerhof ,Hansen, and Vesic give similar results so their average was used as a value. Finally median for summary was selected from every such values in that locations.

3.5. Correlation and Regression

Pearson's Correlation was used for correlation. The regression was obtained by fitting 1st degree polynomial. The value of Pearson's Correlation lies between -1 to +1. where

- **Positive Correlation**: both variables change in the same direction.
- **Neutral Correlation**: No relationship in the change of the variables.
- **Negative Correlation**: variables change in opposite directions.

4.Result

104 Borehole Log Data of 31 locations inside Kathmandu and Lalitpur district areas were taken into consideration. The results were obtained after calculating Bearing Capacity at 1.5m, 3m, and 4.5m depth by shear criteria using Terzaghi, Meyerhof, Hansen, Vesic and Teng methods and Plaxis2D software and by deflection criteria using Bowels, Teng, Peck, Meyerhof methods and Plaxis2D software. The median value of those methods are taken and mapped for those depths. Liquefaction Potential Index of the area is also mapped. While mapping, to make the map uniform and consistent and for better results in interpolation, outlier values having too small or high values are disregarded.

4.1. Location Table

Table 4.1.: Location Table

S.N.	Location	Latitude	Longitude
1	Rastriya Banijya Bank: Thapathali, Kathmandu	27.65586	85.30645
2	Building Complex: Anamnagar, Kathmandu	27.69728	85.32746
3	Building Complex: Bakhundol Lalitpur	27.68302	85.31033
4	Hindu vidhypeth: Balkumari, Lalitpur	27.67114	85.33793
5	DI Skin Health and Referral Center (P). Ltd.: Bansbari, Kathmandu	27.73704	85.33354
6	Building: Bhaisipati, Lalitpur	27.64805	85.29596
7	Brihaspati Vidyasadan School: Gahanapokhari, Kathmandu	27.71425	85.32957
8	Green Hill City (P). Ltd. : Mulpani, Kathamndu	27.71577	85.38647
9	Building Site: Itachhe tol, Bhaktapur	27.67284	85.42261
10	Buddha Air (P). Ltd. : Jawalakhel, Lalitpur	27.67357	85.31187
11	Tamrakar Samaj: Jawalakhel	27.67475	85.31220
12	Tangal, Kathmandu	27.72009	85.32626
13	Harihar Bhavan, Lalitpur	27.68047	85.31111
14	Janamaitri Campus: Kuleswore, Kathmandu	27.69173	85.29005
15	Amrit Science Campus: Lainchour, Kathmandu	27.71776	85.31061
16	Mahendra Ratna Campus: Tahachal, Kathmandu	27.70346	85.29821
17	Bhatbhateni Supermarket & Departmental Store: Satdobato, Lalitpur	27.65712	85.32002
18	Nepal Mountaineering Association : Naxal, Nagpokhari Kathmandu	27.71303	85.32167
19	Patanjali Yogpeeth Nepal : Mandikatar, Kathmandu	27.74115	85.34555
20	Mandikhatar, Kathmandu	27.73878	85.34535
21	CIWEC Clinic: Lainchaur, Kathmandu	27.72040	85.31555
22	Vastukala Pharamarsha Nepal : Kupondole, Lalitpur	27.68376	85.31634
23	Building: Kupondole, Lalitpur	27.68628	85.31470
24	NAST Technology : Khumaltar, Lalitpur	27.65610	85.32768
25	Building: Khumaltar, Lalitpur	27.64870	85.32034
26	Building: Kalopul, Pumori, Kathmandu	27.71183	85.33536
27	Building Site : Gwarkho, Lalitpur	27.66601	85.32847
28	Building: Kumaripati, Lalitpur	27.67025	85.31863
29	Building: Kupandole, Lalitpur	27.68703	85.30930
30	Nepal Rastra Bank: Thapathali	27.69023	85.31993
31	Exam Mega Hall Construction Project : Kirtipur, Kathmandu	27.68426	85.29536

4.2. Locations map

Figure 4.1.: Borehole locations

4.3. Shear Strength Table(kPa)

Table 4.2.: Shear Strength Table

S.N.	Location	1.5m	3.0m	4.5m
1	Thapathali, Kathmandu	556.783	881.966	1219.911
2	Anamnagar, Kathmandu	226.203	253.102	210.010
3	Bakhundol Lalitpur	78.274	109.557	126.082
4	Balkumari, Lalitpur	347.149	705.395	497.897
5	Bansbari, Kathmandu	226.203	411.124	573.964
6	Bhaisipati, Lalitpur	318.034	654.486	375.495
7	Gahanapokhari, Kathmandu	160.596	211.665	408.875
8	Mulpani, Kathamndu	85.764	155.830	738.492
9	Itachhe tol, Bhaktapur	103.915	141.288	161.811
10	Jawalakhel, Lalitpur	295.379	525.479	351.012
11	Jawalakhel	154.538	188.042	218.952
12	Tangal, Kathmandu	818.280	1500.181	1701.000
13	Harihar Bhavan, Lalitpur	678.380	862.325	1080.162
14	Kuleswore, Kathmandu	258.687	440.825	510.316
15	Lainchour, Kathmandu	427.627	1031.251	1534.093
16	Tahachal, Kathmandu	213.742	278.658	324.310
17	Satdobato, Lalitpur	664.956	750.835	216.900
18	Naxal, Nagpokhari Kathmandu	661.987	1034.337	1088.942
19	Mandikatar, Kathmandu	216.255	558.979	750.723
20	Mandikhatar, Kathmandu	166.394	374.942	819.365
21	Lainchaur, Kathmandu	961.112	1349.100	1269.905
22	Kupondole, Lalitpur	197.198	707.709	1129.132
23	Kupondole, Lalitpur	177.101	213.827	248.214
24	Khumaltar, Lalitpur	130.857	158.837	179.932
25	Khumaltar, Lalitpur	113.986	140.911	169.485
26	Kalopul, Pumori, Kathmandu	702.484	1078.437	1160.662
27	Gwarkho, Lalitpur	101.891	139.931	175.822
28	Kumaripati, Lalitpur	976.011	1705.445	1978.329
29	Kupandole, Lalitpur	107.883	127.698	152.281
30	Thapathali	381.822	577.350	761.849
31	Kirtipur, Kathmandu	363.008	713.392	1008.880
Mean($\overline{x}$)		350.726	580.094	682.026
Standard deviation(σ)		262.236	428.627	505.678
Minimum(x_{min})		78.274	109.557	126.082
Maximum(x_{max})		976.011	1705.445	1978.329

4.4. 1.5m Bearing Capacity(shear)

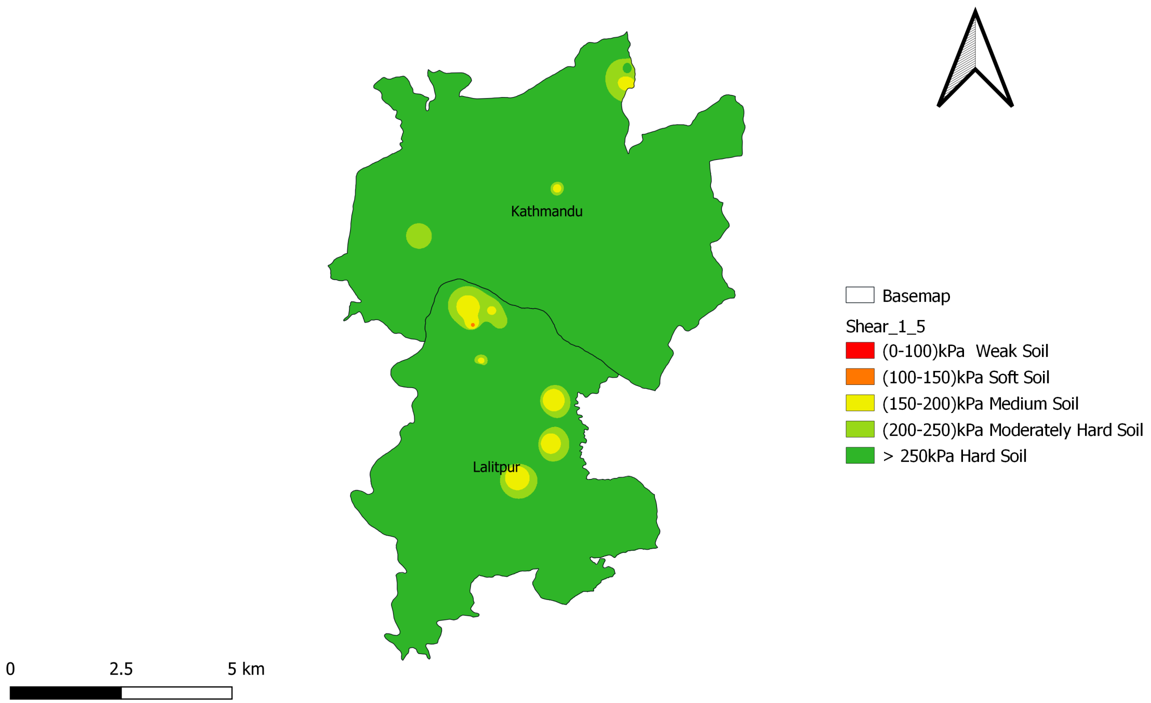


Figure 4.2.: BC at 1.5m depth

4.5. 3.0m Bearing Capacity(shear)

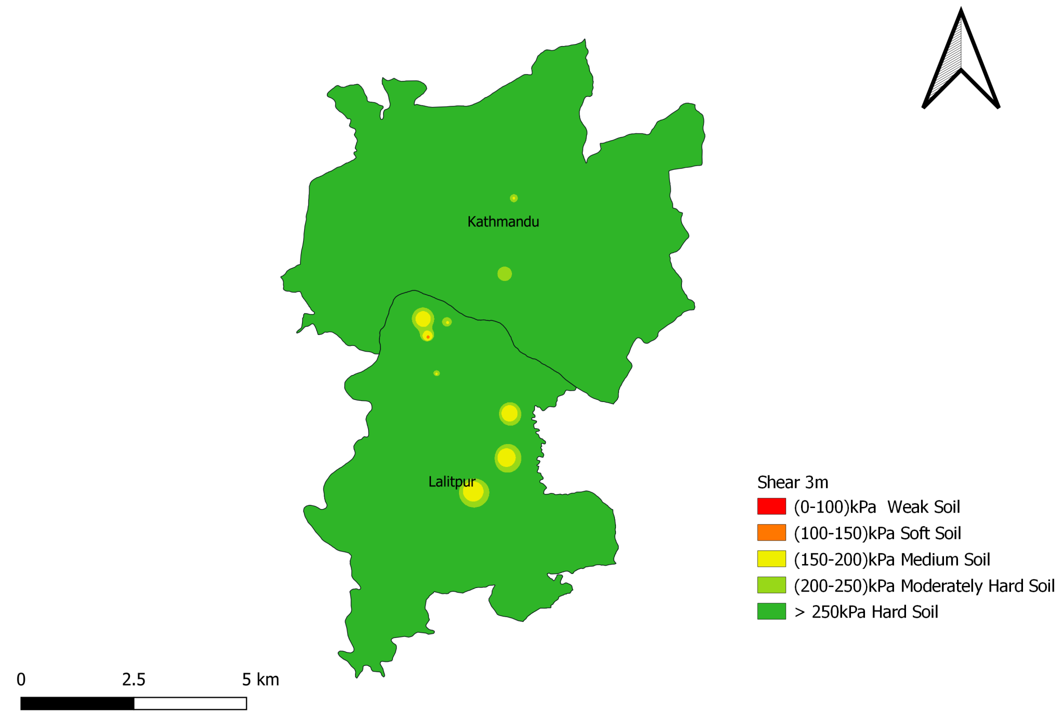


Figure 4.3.: BC at 3.0m depth

4.6. 4.5m Bearing Capacity(shear)

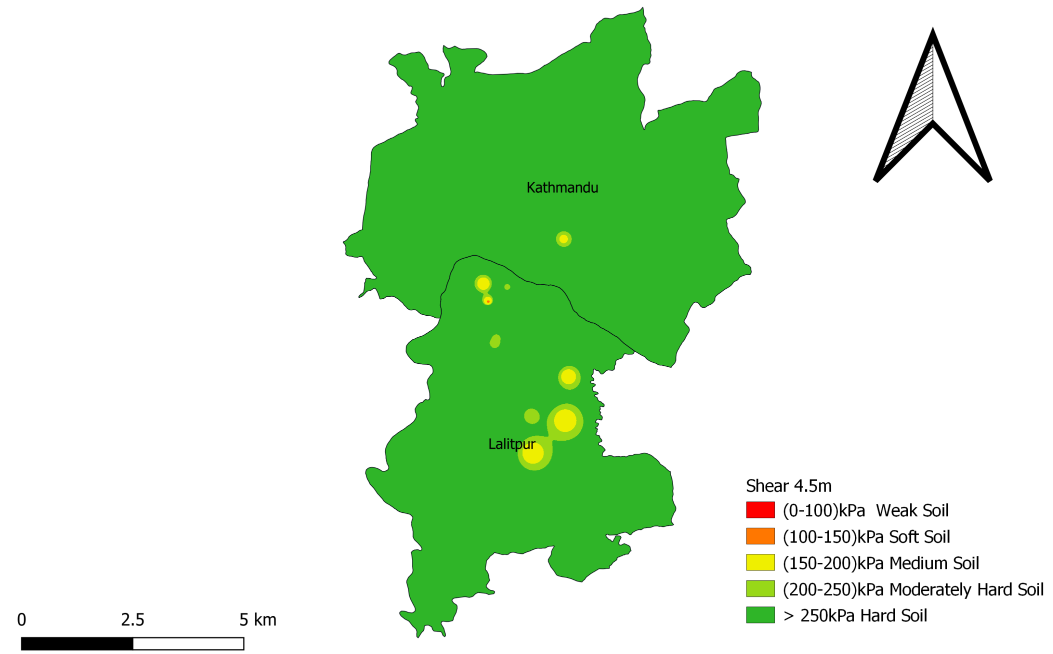


Figure 4.4.: BC at 4.5m depth

4.7. Settlement Strength Table(kPa, for 25mm)

Table 4.3.: Settlement Strength Table

S.N.	Location	1.5m	3.0m	4.5m
1	Thapathali, Kathmandu	32.327	38.642	50.943
2	Anamnagar, Kathmandu	178.573	98.242	71.612
3	Bakhundol Lalitpur	44.627	44.584	45.737
4	Balkumari, Lalitpur	277.689	199.590	138.268
5	Bansbari, Kathmandu	143.756	135.484	150.310
6	Bhaisipati, Lalitpur	310.341	303.309	200.444
7	Gahanapokhari, Kathmandu	145.774	155.979	145.323
8	Mulpani, Kathamndu	65.598	120.769	182.885
9	Itachhe tol, Bhaktapur	71.789	74.786	83.443
10	Jawalakhel, Lalitpur	371.723	312.830	175.017
11	Jawalakhel	226.421	359.938	174.803
12	Tangal, Kathmandu	174.929	133.731	129.194
13	Harihar Bhavan, Lalitpur	43.732	41.417	39.361
14	Kuleswore, Kathmandu	91.046	66.566	50.069
15	Lainchour, Kathmandu	182.240	245.151	236.805
16	Tahachal, Kathmandu	43.164	60.422	72.989
17	Satdobato, Lalitpur	510.209	252.241	144.841
18	Naxal, Nagpokhari Kathmandu	73.785	85.657	108.810
19	Mandikatar, Kathmandu	248.511	248.768	168.528
20	Mandikhatar, Kathmandu	127.783	266.774	281.543
21	Lainchaur, Kathmandu	174.929	181.025	188.245
22	Kupondole, Lalitpur	248.511	319.444	341.663
23	Kupondole, Lalitpur	143.756	104.626	97.679
24	Khumaltar, Lalitpur	133.930	60.043	48.454
25	Khumaltar, Lalitpur	109.923	101.519	83.482
26	Kalopul, Pumori, Kathmandu	119.431	112.012	101.643
27	Gwarkho, Lalitpur	76.146	76.876	62.440
28	Kumaripati, Lalitpur	606.172	523.712	466.218
29	Kupandole, Lalitpur	53.935	50.015	49.253
30	Thapathali	105.779	85.681	77.141
31	Kirtipur, Kathmandu	103.824	89.948	65.702
Mean($\overline{x}$)		142.206	147.536	118.102
Standard deviation(σ)		85.117	94.886	62.637
Minimum(x_{min})		32.327	38.642	39.361
Maximum(x_{max})		371.723	359.938	281.543

4.8. 1.5m Bearing Capacity(settlement)

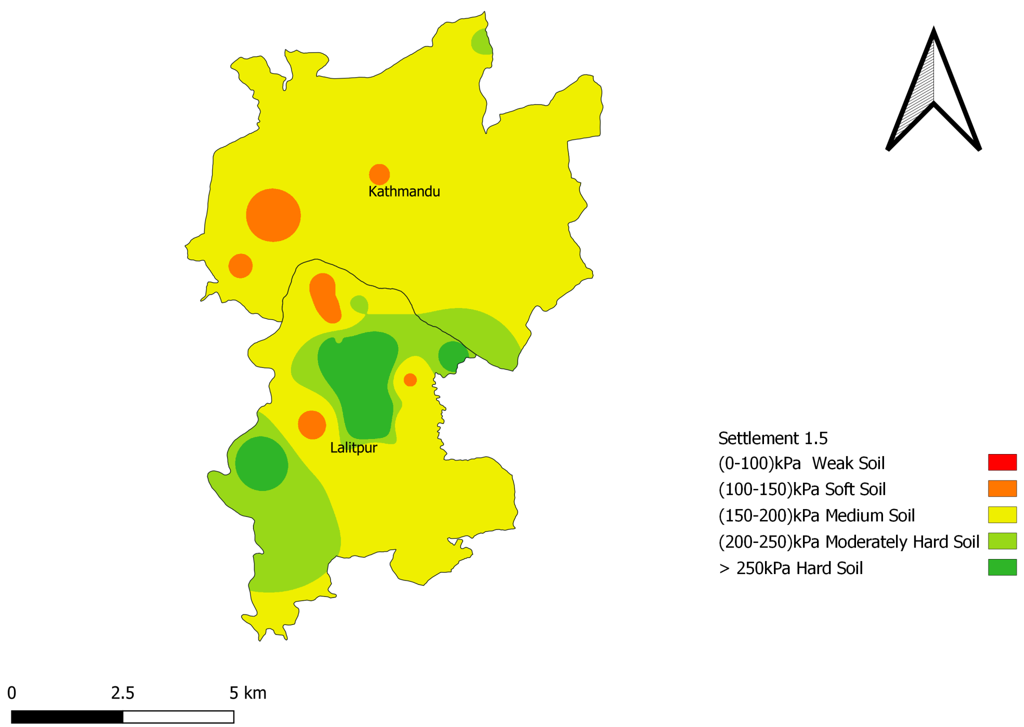


Figure 4.5.: BC at 1.5m depth

4.9. 3.0m Bearing Capacity(settlement)

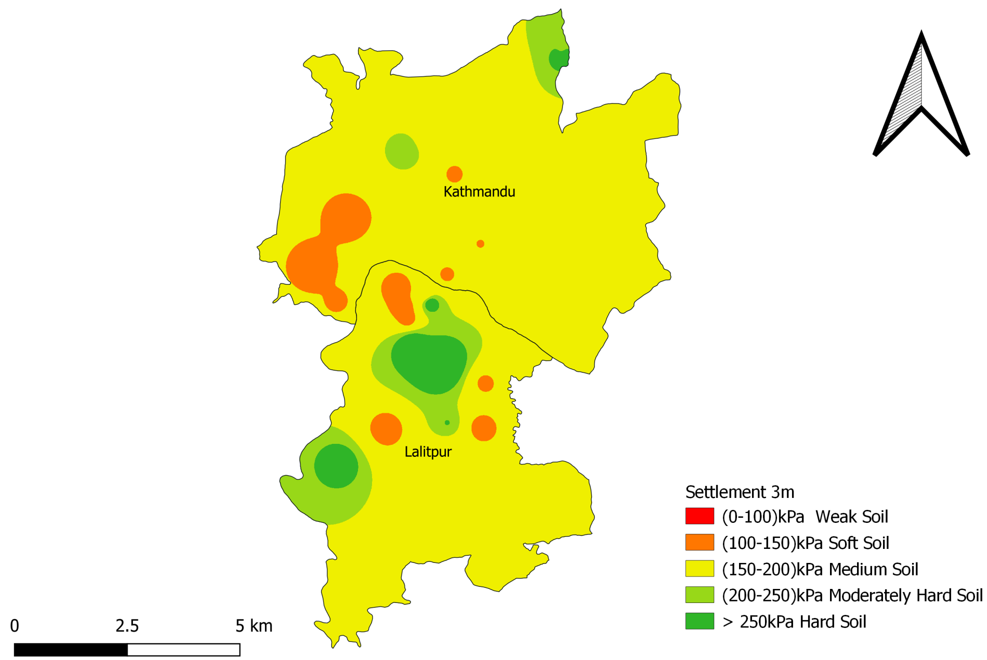


Figure 4.6.: BC at 3.0m depth

4.10. 4.5m Bearing Capacity(settlement)

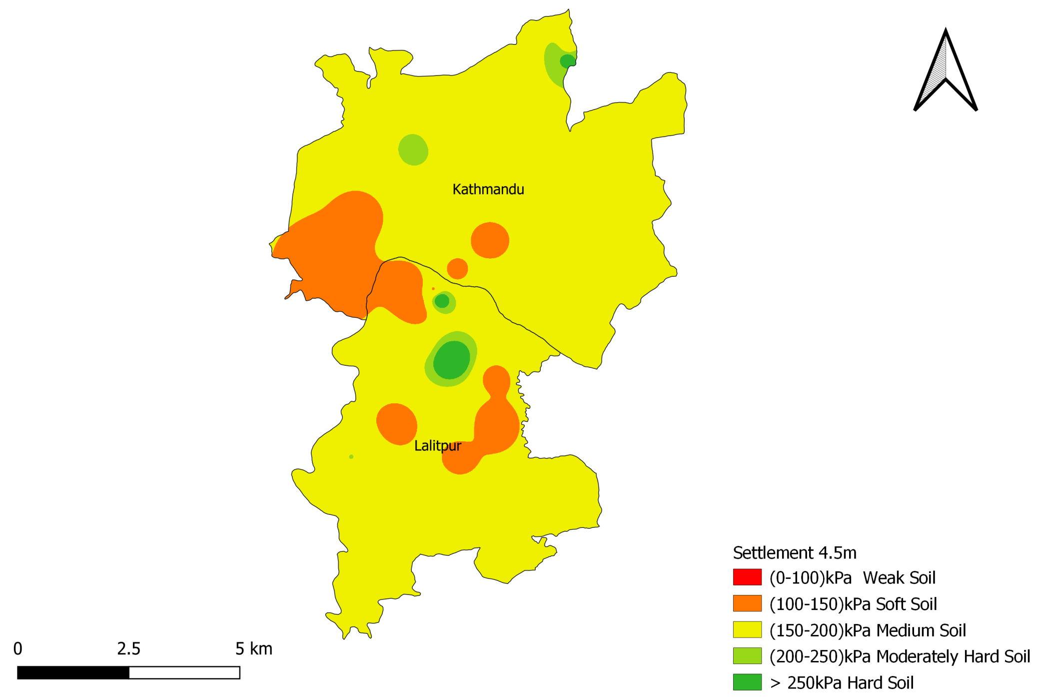


Figure 4.7.: BC at 3.0m depth

4.11. Relation of depth vs Bearing Capacity

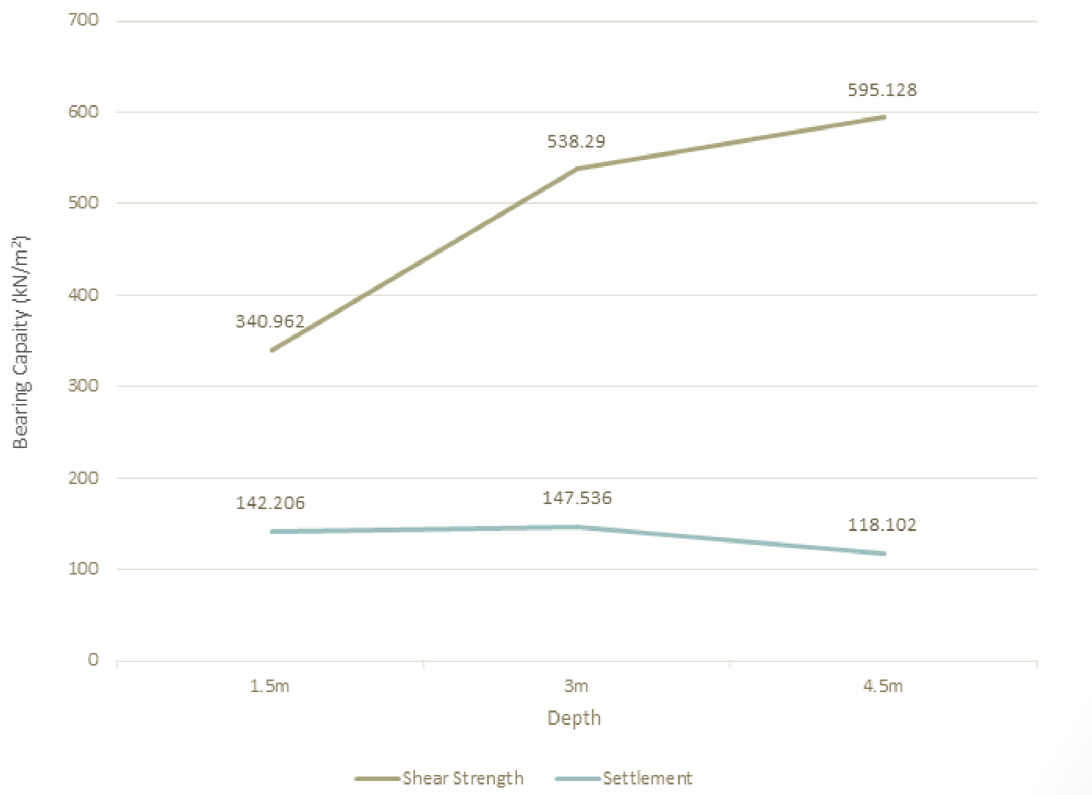


Figure 4.8.: Relation of depth vs Bearing Capacity

4.12. Net Allowable Strength Table(kPa, for 25mm)

Table 4.4.: Net Allowable Strength Table

S.N.	Location	1.5m	3.0m	4.5m
1	Thapathali, Kathmandu	32.327	38.642	50.943
2	Anamnagar, Kathmandu	178.573	98.242	71.612
3	Bakhundol Lalitpur	44.627	44.584	45.737
4	Balkumari, Lalitpur	277.689	199.590	138.268
5	Bansbari, Kathmandu	143.756	135.484	150.310
6	Bhaisipati, Lalitpur	310.341	303.309	200.444
7	Gahanapokhari, Kathmandu	145.774	155.979	145.323
8	Mulpani, Kathamndu	65.598	120.769	182.885
9	Itachhe tol, Bhaktapur	71.789	74.786	83.443
10	Jawalakhel, Lalitpur	295.379	312.830	175.017
11	Jawalakhel	154.538	188.042	174.803
12	Tangal, Kathmandu	174.929	133.731	129.194
13	Harihar Bhavan, Lalitpur	43.732	41.417	39.361
14	Kuleswore, Kathmandu	91.046	66.566	50.069
15	Lainchour, Kathmandu	182.240	245.151	236.805
16	Tahachal, Kathmandu	43.164	60.422	72.989
17	Satdobato, Lalitpur	510.209	252.241	144.841
18	Naxal, Nagpokhari Kathmandu	73.785	85.657	108.810
19	Mandikatar, Kathmandu	216.255	248.768	168.528
20	Mandikhatar, Kathmandu	127.783	266.774	281.543
21	Lainchaur, Kathmandu	174.929	181.025	188.245
22	Kupondole, Lalitpur	197.198	319.444	341.663
23	Kupondole, Lalitpur	143.756	104.626	97.679
24	Khumaltar, Lalitpur	130.857	60.043	48.454
25	Khumaltar, Lalitpur	109.923	101.519	83.482
26	Kalopul, Pumori, Kathmandu	119.431	112.012	101.643
27	Gwarkho, Lalitpur	76.146	76.876	62.440
28	Kumaripati, Lalitpur	606.172	523.712	466.218
29	Kupandole, Lalitpur	53.935	50.015	49.253
30	Thapathali	105.779	85.681	77.141
31	Kirtipur, Kathmandu	103.824	89.948	65.702
Mean($\overline{x}$)		134.107	141.806	118.102
Standard deviation(σ)		73.815	86.726	62.637
Minimum(x_{min})		32.327	38.642	39.361
Maximum(x_{max})		310.341	319.444	281.543

4.13. 1.5m Bearing Capacity(Net Allowable)

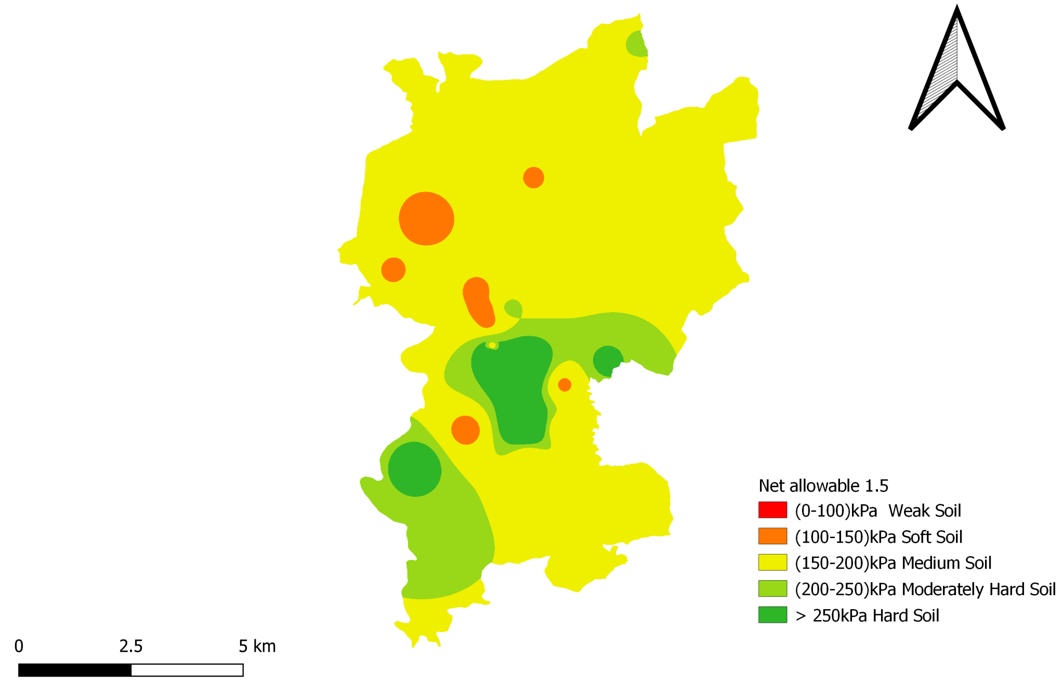


Figure 4.9.: BC at 1.5m depth

4.14. 3.0m Bearing Capacity(Net Allowable)

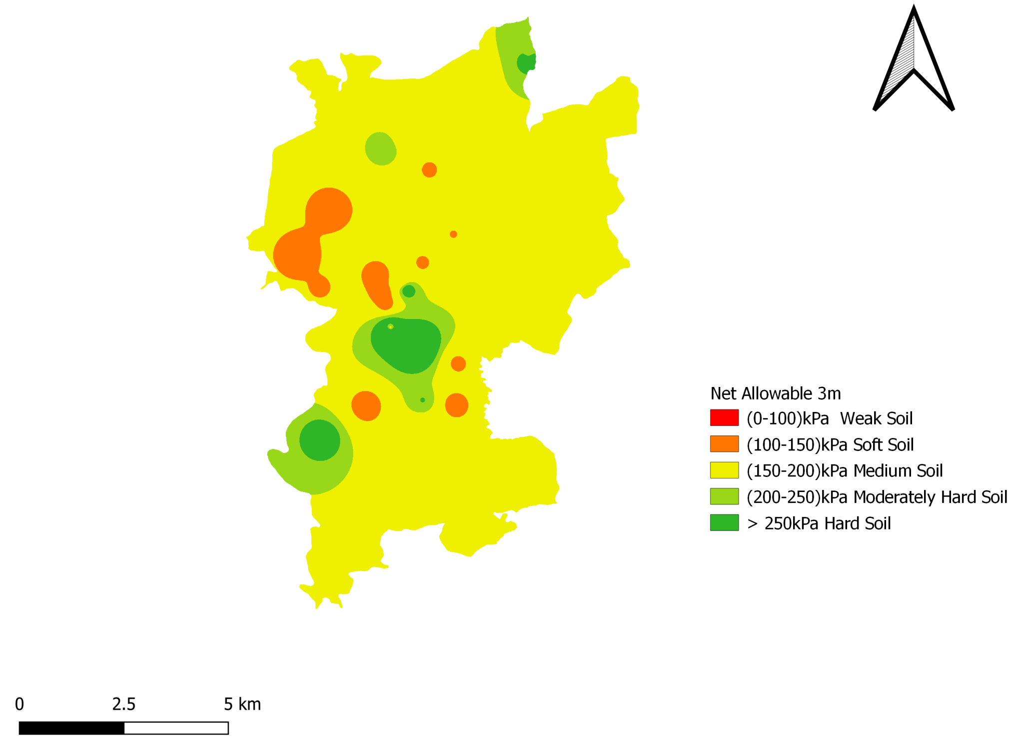


Figure 4.10.: BC at 3.0m depth

4.15. 4.5m Bearing Capacity(Net Allowable)

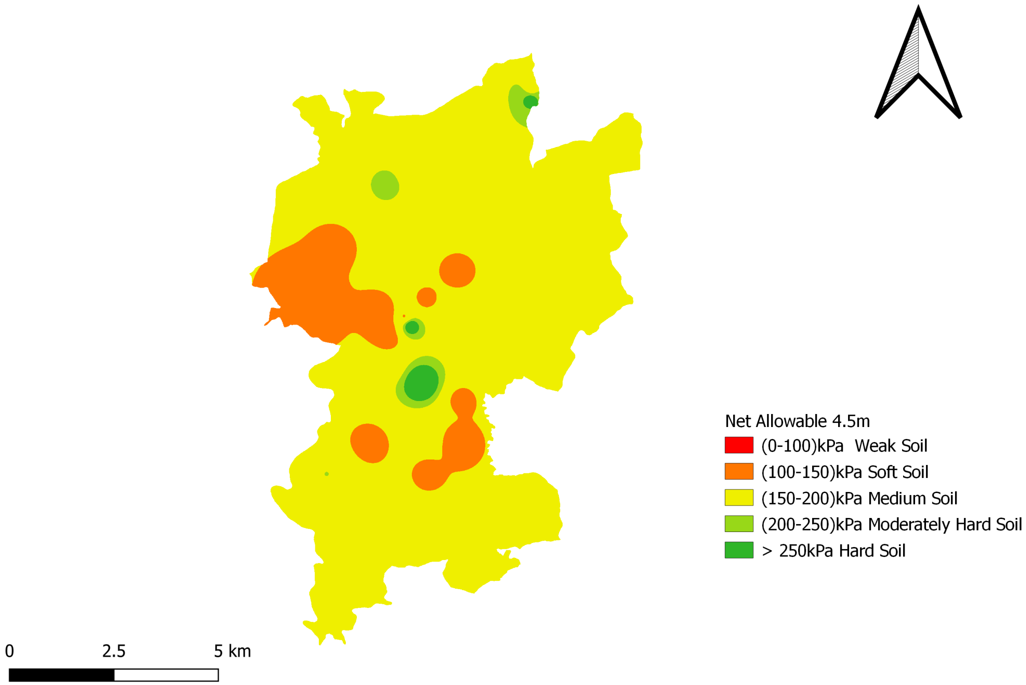


Figure 4.11.: BC at 4.5m depth

4.16. Liquefaction(LPI) Table

Table 4.5.: Liquefaction(LPI) Table

S.N.	Location	LPI
1	Thapathali, Kathmandu	26.184
2	Anamnagar, Kathmandu	18.597
3	Bakhundol Lalitpur	6.858
4	Balkumari, Lalitpur	16.423
5	Bansbari, Kathmandu	1.518
6	Bhaisipati, Lalitpur	0.045
7	Gahanapokhari, Kathmandu	0.670
8	Mulpani, Kathamndu	1.325
9	Itachhe tol, Bhaktapur	0.479
10	Jawalakhel, Lalitpur	0.743
11	Jawalakhel	12.442
12	Tangal, Kathmandu	4.132
13	Harihar Bhavan, Lalitpur	31.190
14	Kuleswore, Kathmandu	17.653
15	Lainchour, Kathmandu	1.319
16	Tahachal, Kathmandu	50.302
17	Satdobato, Lalitpur	0.383
18	Naxal, Nagpokhari Kathmandu	1.661
19	Mandikatar, Kathmandu	1.028
20	Mandikhatar, Kathmandu	2.204
21	Lainchaur, Kathmandu	4.616
22	Kupondole, Lalitpur	2.649
23	Kupondole, Lalitpur	10.705
24	Khumaltar, Lalitpur	16.796
25	Khumaltar, Lalitpur	11.200
26	Kalopul, Pumori, Kathmandu	6.137
27	Gwarkho, Lalitpur	19.032
28	Kumaripati, Lalitpur	0.000
29	Kupandole, Lalitpur	20.590
30	Thapathali	4.920
31	Kirtipur, Kathmandu	8.512
Mean($\overline{x}$)		8.334
Standard deviation(σ)		8.579
Minimum(x_{min})		0.000
Maximum(x_{max})		31.190

4.17. LPI

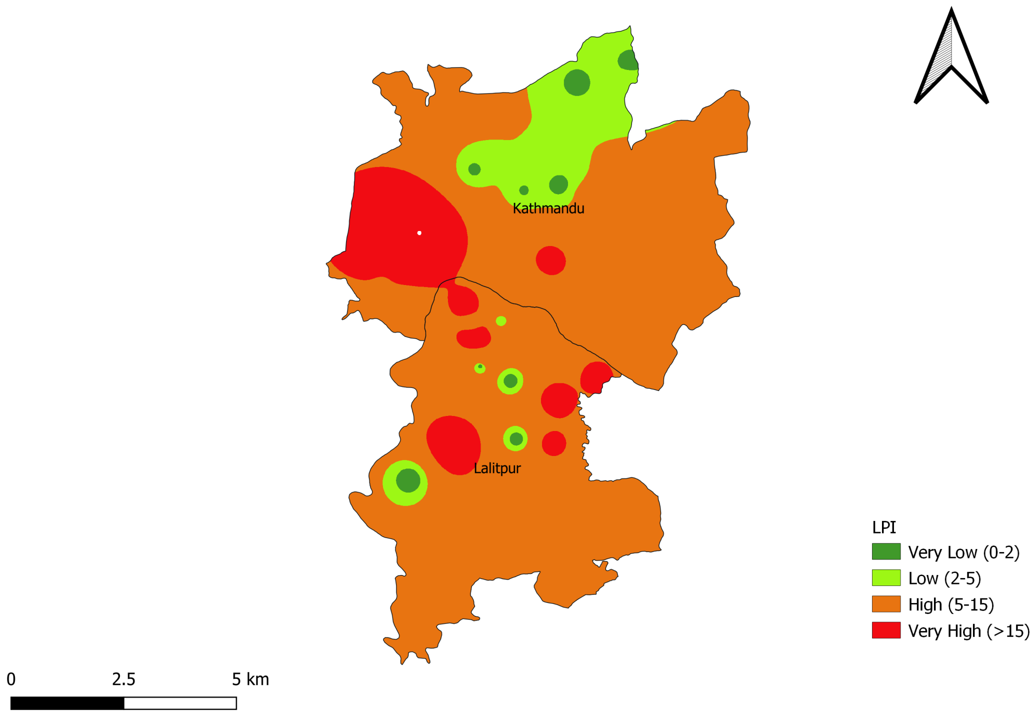


Figure 4.12.: LPI

4.18. Summary for Area

Total Area: 85546375.23 m^2

4.18.1. LPI

Liquefaction Potential	Area(m^2)	%
Very low	1156807.604	1.352257885
Low	9528705.043	11.13864266
High	64499949.72	75.39764198
Very High	10360912.86	12.11145748

4.18.2. Shear(1.5m)

Soil Type	Area(m^2)	%
Weak soil	6373.329037	0.007450145
Soft soil	301298.4954	0.352204865
Medium	878072.0773	1.026428151
Moderately hard	2300390.906	2.689057134
Hard	82055748.03	95.91960829

4.18.3. Shear(3.0m)

Soil Type	Area(m^2)	%
Weak soil	4164.246861	0.004867824
Soft soil	155524.4635	0.181801348
Medium	437474.4461	0.511388641
Moderately hard	819442.5286	0.957892753
Hard	84125277.15	98.33879802

4.18.4. Shear(4.5m)

Soil Type	Area(m^2)	%
Weak soil	2843.875905	0.003324368
Soft soil	104410.8725	0.122051779
Medium	551153.307	0.644274296
Moderately hard	1246811.059	1.457468017
Hard	83636663.72	97.76763012

4.18.5. Settlement(1.5m)

Soil Type	Area(m^2)	%
Weak soil	2835547.411	3.314631863
Soft soil	19632951.23	22.95006793
Medium	46110603.92	53.90129482
Moderately hard	11795026.1	13.78787361
Hard	5167754.179	6.040880358

4.18.6. Settlement(3.0m)

Soil Type	Area(m^2)	%
Weak soil	4475346.571	5.231485915
Soft soil	26164648.6	30.58533869
Medium	45074976.04	52.69069077
Moderately hard	6731174.957	7.868451398
Hard	3095736.665	3.618781808

4.18.7. Settlement(4.5m)

Soil Type	Area(m^2)	%
Weak soil	10479251.05	12.24978969
Soft soil	54117790.45	63.26134836
Medium	18542807.26	21.67573694
Moderately hard	1598689.918	1.868799133
Hard	803344.1596	0.939074458

4.18.8. Net Allowable(1.5m)

Soil Type	Area(m^2)	%
Weak soil	4475616.392	5.231801324
Soft soil	26166517.1	30.58752289
Medium	45080608.34	52.69727468
Moderately hard	6744721.273	7.884286452
Hard	3079822.333	3.600178646

4.18.9. Net Allowable(3.0m)

Soil Type	Area(m^2)	%
Weak soil	2835619.316	3.314715916
Soft soil	19634486.32	22.95186239
Medium	46130780.34	53.92488018
Moderately hard	11805693.59	13.80034345
Hard	5140705.862	6.00926205

4.18.10. Net Allowable(4.5m)

Soil Type	Area(m^2)	%
Weak soil	10480085.37	12.25076496
Soft soil	54121503.26	63.26568849
Medium	18543457.22	21.67649672
Moderately hard	1598962.234	1.869117458
Hard	803277.3478	0.938996358

4.19. Summary of Result from Various Methods

Table 4.6.: Methods summary Table

S.N.	**Method**	**Mean($\overline{x}$)**	**Standard deviation (σ)**	**Minimum (x_{min})**	**Minimum (x_{min})**
1	Terzaghi(1.5m)	273.165	195.294	68.073	853.968
2	Terzaghi(3.0m)	486.183	374.592	68.073	1586.820
3	Terzaghi(4.5m)	558.054	464.913	68.073	1978.576
4	Meyerhof(1.5m)	318.623	261.939	65.041	1026.956
5	Meyerhof(3.0m)	682.630	569.958	73.525	2190.626
6	Meyerhof(4.5m)	853.622	756.113	82.008	3197.508
7	Hansen(1.5m)	352.225	267.698	78.817	1143.045
8	Hansen(3.0m)	773.252	631.410	78.817	2498.216
9	Hansen(4.5m)	1039.835	944.778	78.817	3827.666
10	Vesic(1.5m)	366.964	285.722	78.817	1223.801
11	Vesic(3.0m)	791.445	650.804	78.817	2584.092
12	Vesic(4.5m)	1054.421	960.962	78.817	3888.722
13	Plaxis Shear(1.5m)	388.225	310.462	21.890	1191.875
14	Plaxis Shear(3.0m)	563.378	470.487	105.480	1984.930
15	Plaxis Shear(4.5m)	738.074	626.830	120.814	2244.375
16	Teng Shear(1.5m)	153.173	93.268	52.903	461.283
17	Teng Shear(3.0m)	346.263	245.070	94.750	1055.146
18	Teng Shear(4.5m)	450.276	268.759	129.275	1231.453
19	Bowels(1.5m)	217.306	128.281	43.732	612.250
20	Bowels(3.0m)	216.309	131.719	52.400	592.947
21	Bowels(4.5m)	178.876	95.570	54.671	452.777
22	Peck(1.5m)	151.702	91.971	31.946	412.740
23	Peck(3.0m)	141.799	83.494	32.672	359.938
24	Peck(4.5m)	122.204	66.145	33.091	277.131
25	Teng Settlement(1.5m)	165.761	126.774	-16.572	557.774
26	Teng Settlement(3.0m)	185.825	141.252	3.668	581.152
27	Teng Settlement(4.5m)	151.782	101.696	11.532	464.391
28	Plaxis Settlement(1.5m)	64.355	19.113	35.110	111.952
29	Plaxis Settlement(3.0m)	68.618	14.859	40.915	107.151
30	Plaxis Settlement(4.5m)	76.632	18.282	47.316	128.371
31	Meyerhof Settlement(1.5m)	144.871	85.521	29.155	408.167
32	Meyerhof Settlement(3.0m)	144.206	87.813	34.933	395.298
33	Meyerhof Settlement(4.5m)	119.250	63.713	36.448	301.851

4.20. Correlation and regression between methods

4.20.1. Terzaghi

Method(x)	Correlation	Regression
Meyerhof	0.9961	0.5746 x + 71.0810
Hansen	0.9834	0.5368 x + 61.5623
Vesic	0.9862	0.5262 x + 60.1358
Plaxis Shear	0.3230	0.2980 x + 315.0004
Teng Shear	0.6134	0.7774 x + 175.1218
Bowels	0.4626	1.2177 x + 191.7191
Peck	0.4195	1.7164 x + 215.3036
Teng Settlement	0.4887	1.2721 x + 226.9952
Plaxis Settlement	0.4708	10.0284 x -238.9545
Meyerhof Settlement	0.4626	1.8265 x + 191.7191

4.20.2. Meyerhof

Method(x)	Correlation	Regression
Terzaghi	0.9961	1.7266 x -117.0397
Hansen	0.9867	0.9337 x -16.1185
Vesic	0.9888	0.9145 x -18.1031
Plaxis Shear	0.3068	0.4907 x + 440.4858
Teng Shear	0.6224	1.3674 x + 175.2632
Bowels	0.4544	2.0735 x + 220.9309
Peck	0.4075	2.8903 x + 266.2143
Teng Settlement	0.4813	2.1716 x + 279.8926
Plaxis Settlement	0.4789	17.6807 x -556.0667
Meyerhof Settlement	0.4544	3.1103 x + 220.9309

4.20.3. Hansen

Method(x)	Correlation	Regression
Terzaghi	0.9834	1.8014 x -84.8532
Meyerhof	0.9867	1.0427 x + 37.7142
Vesic	0.9998	0.9772 x -0.2805
Plaxis Shear	0.3349	0.5659 x + 465.9312
Teng Shear	0.5797	1.3458 x + 252.3916
Bowels	0.3820	1.8421 x + 345.3049
Peck	0.3342	2.5044 x + 395.5045
Teng Settlement	0.4125	1.9667 x + 390.0802
Plaxis Settlement	0.4425	17.2650 x -457.5097
Meyerhof Settlement	0.3820	2.7632 x + 345.3049

4.20.4. Vesic

Method(x)	Correlation	Regression
Terzaghi	0.9862	1.8484 x -88.9498
Meyerhof	0.9888	1.0692 x + 37.3341
Hansen	0.9998	1.0230 x + 0.5485
Plaxis Shear	0.3339	0.5773 x + 478.1299
Teng Shear	0.5838	1.3867 x + 254.7966
Bowels	0.3914	1.9311 x + 342.5569
Peck	0.3445	2.6417 x + 392.6198
Teng Settlement	0.4212	2.0550 x + 390.8499
Plaxis Settlement	0.4451	17.7686 x -475.1583
Meyerhof Settlement	0.3914	2.8967 x + 342.5569

4.20.5. Plaxis Shear

Method(x)	Correlation	Regression
Terzaghi	0.3230	0.3502 x + 402.4522
Meyerhof	0.3068	0.1919 x + 434.0758
Hansen	0.3349	0.1982 x + 415.9656
Vesic	0.3339	0.1931 x + 416.3466
Teng Shear	-0.0620	-0.0852 x + 606.5472
Bowels	-0.0989	-0.2821 x + 640.5997
Peck	-0.0373	-0.1656 x + 598.5786
Teng Settlement	-0.0923	-0.2605 x + 625.4717
Plaxis Settlement	0.0833	1.9246 x + 433.4478
Meyerhof Settlement	-0.0989	-0.4232 x + 640.5997

4.20.6. Teng Shear

Method(x)	Correlation	Regression
Terzaghi	0.6134	0.4840 x + 164.3791
Meyerhof	0.6224	0.2833 x + 195.0166
Hansen	0.5797	0.2497 x + 202.1657
Vesic	0.5838	0.2457 x + 200.6771
Plaxis Shear	-0.0620	-0.0452 x + 425.2438
Bowels	0.8469	1.7591 x -25.1633
Peck	0.7514	2.4256 x + 17.4066
Teng Settlement	0.8800	1.8073 x + 31.9734
Plaxis Settlement	0.5923	9.9545 x -319.8311
Meyerhof Settlement	0.8469	2.6386 x -25.1633

4.20.7. Bowels

Method(x)	Correlation	Regression
Terzaghi	0.4626	0.1757 x + 156.0270
Meyerhof	0.4544	0.0996 x + 169.5154
Hansen	0.3820	0.0792 x + 178.7789
Vesic	0.3914	0.0793 x + 177.2090
Plaxis Shear	-0.0989	-0.0346 x + 261.1880
Teng Shear	0.8469	0.4077 x + 78.5048
Peck	0.9262	1.4395 x + 14.6612
Teng Settlement	0.9961	0.9849 x + 41.1175
Plaxis Settlement	0.5438	4.4000 x -76.5516
Meyerhof Settlement	1.0000	1.5000 x + 0.0000

4.20.8. Peck

Method(x)	Correlation	Regression
Terzaghi	0.4195	0.1025 x + 107.6899
Meyerhof	0.4075	0.0575 x + 116.0278
Hansen	0.3342	0.0446 x + 122.2639
Vesic	0.3445	0.0449 x + 121.1565
Plaxis Shear	-0.0373	-0.0084 x + 162.3026
Teng Shear	0.7514	0.2328 x + 64.5187
Bowels	0.9262	0.5959 x + 13.6502
Teng Settlement	0.9161	0.5828 x + 38.9951
Plaxis Settlement	0.5052	2.6305 x -32.5722
Meyerhof Settlement	0.9262	0.8939 x + 13.6502

4.20.9. Teng Settlement

Method(x)	Correlation	Regression
Terzaghi	0.4887	0.1878 x + 112.1201
Meyerhof	0.4813	0.1067 x + 126.3406
Hansen	0.4125	0.0865 x + 134.9648
Vesic	0.4212	0.0863 x + 133.4767
Plaxis Shear	-0.0923	-0.0327 x + 222.0370
Teng Shear	0.8800	0.4285 x + 32.1555
Bowels	0.9961	1.0075 x -39.8615
Peck	0.9161	1.4400 x -23.4806
Plaxis Settlement	0.5551	4.5429 x -124.9285
Meyerhof Settlement	0.9961	1.5112 x -39.8615

4.20.10. Plaxis Settlement

Method(x)	Correlation	Regression
Terzaghi	0.4708	0.0221 x + 61.5182
Meyerhof	0.4789	0.0130 x + 62.8954
Hansen	0.4425	0.0113 x + 63.2938
Vesic	0.4451	0.0111 x + 63.2368
Plaxis Shear	0.0833	0.0036 x + 70.1845
Teng Shear	0.5923	0.0352 x + 58.1759
Bowels	0.5438	0.0672 x + 56.0315
Peck	0.5052	0.0970 x + 56.9684
Teng Settlement	0.5551	0.0678 x + 58.4611
Meyerhof Settlement	0.5438	0.1008 x + 56.0315

4.20.11. Meyerhof Settlement

Method(x)	Correlation	Regression
Terzaghi	0.4626	0.1171 x + 104.0180
Meyerhof	0.4544	0.0664 x + 113.0102
Hansen	0.3820	0.0528 x + 119.1859
Vesic	0.3914	0.0529 x + 118.1394
Plaxis Shear	-0.0989	-0.0231 x + 174.1253
Teng Shear	0.8469	0.2718 x + 52.3366
Bowels	1.0000	0.6667 x + 0.0000
Peck	0.9262	0.9596 x + 9.7741
Teng Settlement	0.9961	0.6566 x + 27.4117
Plaxis Settlement	0.5438	2.9333 x -51.0344

5.Discussion

Calculation of bearing capacity of soil has significant importance especially in urban areas like Kathmandu Valley where maximum land area is being used on building construction and the inadequacy of remaining land means high rise buildings are being constructed more and more. We can interpret the maps shown above to figure out the soil's bearing capacity and liquefaction potential which determines the feasibility of construction in that area.

The value of bearing capacity and LPI can be interpreted as shown below

- Region having bearing capacity $\leq$ 100kPa : Weak soil
- Region having bearing capacity $>$100kPa and $\leq$150kPa : Soft soil
- Region having bearing capacity $>$150kPa and $\leq$200kPa : Medium soil
- Region having bearing capacity $>$200kPa and $\leq$250kPa : Moderately hard soil
- Region having bearing capacity $>$250kPa : Hard soil

For LPI value of soil:

- LPI 0-2: Very low potential
- LPI 2-5: Low potential
- LPI 5-15: High potential
- LPI $>$15: Very High potential

5.1. Summary of bearing capacity at diffrent depths

5.1.1. Bearing Capacity at 1.5m depth

At 1.5m depth, by shear failure criteria, the highest bearing capacity was found as 1135.052kPa at Kumaripati and the lowest bearing capacity was found at Bakhundol which was 80.665kPa. By settlement strength criteria, the highest value was at Satdobato as 510.209kPa and lowest value was 32.327kPa at Thapathali. For settlement criteria, the soil at Bakhundol, Mulpani, Itachhe Tol, Harihar Bhawan, Kuleshwor, Tahachal, Nagpokhari, Gwarko and Kupondole were found to be weak soils as their Bearing capacity value was less than 100kPa. The soil at Balkumari, Bhaisepati, Jawalakhel, Satdobato and Kumaripati were found to be hard soil with bearing capacity greater than 250kPa.

5.1.2. Bearing Capacity at 3m depth

At 3m depth, by shear strength criteria, the highest bearing capacity was found as 1115.63kPa at Kumaripati and the lowest bearing capacity was found at Bakhundol which was 80.665kPa. By settlement criteria, the highest value was at Jawalakhel as 359.938 and lowest value was K38.642Pa at Thapathali. By shear failure criteria, Thapathali, Anamnagar, Bakhundol, Itachhe Tol, harihar Bhawan, Kuleshwor, Tahachal,Nagpokhari, Khumaltar, Gwarko, Kupondole and Kirtipur were found to be weak soils as their Bearing capacity value was less than 100kPa. The soil at Bhaisipati, Jawalakhel, Satdobato, Mandikatar, Kupondole and Kumaripati were found to be hard soils with bearing capacity greater than 250kPa.

5.1.3. Bearing Capacity at 4.5m depth

At 4.5m depth, by shear failure criteria, the highest bearing capacity was found as 1701.000kPa at Tangal and the lowest bearing capacity was found at Bakhundol which was 84.495kPa. By settlement criteria, the highest value was at Mandikatar as 281.543kPa and lowest value was 39.361kPa at Harihar Bhawan. By settlement criteria, Thapathali, Anamnagar, Bakhundol, Itachhe tol, Harihar Bhawan, Tahachal, Kupondole, Khumaltar, Gwarkho and Kirtipur were found to have weak soils as their Bearing capacity value was less than 100kPa. The soil at Mandikatar and Kumaripati were found to be hard soils with bearing capacity greater than 250kPa.

The net allowable bearing capacity was same as that of settlement method, except for 3 locations.

5.1.4. Liquefaction Potential

The LPI value was found to be the highest at Tahachal with a calue of 50.30 and was the lowest at Kumaripati with a value of 0.00. Bansbari, Bhaisepati, Gahanapokhari, Mulpani, Itachhe Tol, Jawalakhel, Lainchour, Satdobato, Nagpokhari and Kumaripati had very low liquefaction potential as their LPI value was found to be less than 2. Places like Thapathali, Anamnagar, Balkumari, Harihar Bhavan, Kuleswore, Tahachal, Khumaltar, Gwarko and Kupandole had very high potential for liquefaction as their LPI value was greater than 15.

5.2. Similarity of LPI map with other susceptibility maps

5.2.1. UNDP/UNCHS

- Most of our study area lies in area with high or very high potential.
- Place like Tangal, Lainchour, Mandiktar lie in low susceptibility zone.

5.2.2. JICA

- Study area lies in high susceptible zone with high ground water level, ie. Alluvial Land, and Area formed by dry river bed so are mostly high and very high susceptible.

5.2.3. Piya

- Very low susceptibility at Itachhe tol. Bhaktapur.

5.2.4. Subedi

- Most study area has LPI >1
- Itache tol. Has LPI 0.479 (0.3-0.7).

5.3. Relation of depth vs Bearing Capacity

The Shear Bearing Capacity of soil increases with depth whereas the Deflection Bearing Capacity of soil remains about same with respect to depth. ie. force required for 25mm settlement.

5.4. Area Summary

For LPI most of area lies in High Potential Zone ie. 75

5.5. Result from various methods

Most shear methods gave similar results in mean. But the deviation was more in Plasix and least deviation was in Terzaghi. Most deflection methods gave same result except Plasix which gave less capacity than other. The deviation in result was high in methods like Bowels and Teng and less in Plasix and Peck.

5.6. Correlation between methods

The shear methods like Terzaghi, Meyerhof, Hansen and Vesic have high +ve correlation. Plasix shear have no correlation with other results. Bowels, Teng , Meyerhof and Peck have higher correlation. Plaxis settlement have weak correlation with other methods except with Plasix shear. So, these methods which have higher correlation gave similar results.

6.Conclusion

Using the 104 Borehole logs from 31 different locations throughout Kathmandu valley, mapping and zonation of bearing capacity and Liquefaction Potential Index were carried out. By analysis of those maps, following conclusions can be reached:

- The maps produced are powerful tools for the visualization of soil properties which can save time and cost to figure out the preliminary information of the soil required and the bearing capacity and LPI value to be expected.
- The maps can serve as a guidance tools for engineers to figure out the suitability of any type of construction in the area, the need of treatments, type of foundation etc.
- The bearing capacity of the soil depends upon the method used.
- The LPI index map can be used as a hazard map on where liquefaction can be expected and where treatments need to be done.
- Liquefaction potential was found to be strongly influenced by SPT value and the depth of water table.
- The soil deposit of Kathmandu valley was found to be highly heterogeneous with extensively varying soil content and water table depth which means the bearing capacity and LPI value of the soil can change even in small distances.

Bibliography

[1] Dunn, I. S., Anderson, L. R., & Kiefer, F. W. (1980). *Fundamentals of geotechnical analysis*. Jo Wiley & Sons Incorporated.hn Wiley & Sons Incorporated.

[2] Nepal Building Code (NBC-105), (1994). *Seismic design of buildings in Nepal*. Kathmandu: Department of Building, Ministry of Physical Planning and Works, Government of Nepal.

[3] Arora, K. R. (2021). *SOIL MECHANICS AND FOUNDATION ENGINEERING*. STANDARD PUBLISHING.

[4] Danai, R. K., & Acharya, I. P. (2018). *Bearing Capacity Analysis and Zoning of Kathmandu for Shallow Foundations*. Journal of Advanced College of Engineering and Management, 4, 111-117.

[5] Mahato, S.K. (2012). *Bearing Capacity zonation of urban and sub-urban area of Kathmandu and Lalitpur districts* (Master's thesis, Pulchowk Campus, Institute of Engineering, Lalitpur, Nepal).

[6] Jaya Ram Panthi. *Bearing Capacity Mapping of Kathmandu Valley*. PhD thesis. Lalitpur, 2018.

[7] Casagrande Arthur. *Characteristics of Cohesionless Soils Affecting the Stability of Slopes and Earthfills*. In: Journal of the Boston Society of Civil Engineers 23 (Jan. 1936), pp. 257–276.

[8] Allen Hazen. *A study of the slip in the Calaveras Dam*. In: (1918).

[9] F. H. Kulhawy and P. W. Mayne. *Manual on Estimating Soil Properties for Foundation Design*. Itaca, New York: Cornell University, Aug. 1990.

[10] Seed, H. B., & Idriss, I. M. (1971). *Simplified procedure for evaluating soil liquefaction potential*.

[11] Journal of the Soil Mechanics and Foundations division, 97(9), 1249-1273.Seed, H. B., Idriss, I. M., & Arango, I. (1983). *Evaluation of liquefaction potential using field performance data. Journal of geotechnical engineering*, 109(3), 458-482.

[12] Chen, Y. C. (1995). *Effects of fines content on the relationship between maximum shear modulus and liquefaction*, NSC 84-2211-E-011-025.

[13] Sherif, M. A., Tsuchiya, C., & Ishibashi, I. (1977). *Saturation effects on initial soil liquefaction*. Journal of the Geotechnical Engineering Division, 103(8), 914-917.

[14] Seed, H. B., Mulilis, J. P., & Chan, C. K. (1975). *The effect of method of sample preparation on the cyclic stress-strain behavior of sands*. Rep. EERC, (75-18).

[15] Peacock, W. H. and Seed, H. B., *Sand liquefaction under cyclic loading simple shear conditions*, Journal of the Soil Mechanics and Foundations Division, ASCE; 94(SM3): 689-708, 1968.

[16] Tokimatsu, K., & Yoshimi, Y. (1983). *Empirical correlation of soil liquefaction based on SPT N-value and fines content*. Soils and Foundations, 23(4), 56-74.

[17] Gautam, D., Magistris, F.S., Fabbrocino, G., (2017) *Soil Liquefaction in Kathmandu valley due to 25 April 2015 Gorkha, Nepal earthquake*. Soil Dynamics and Earthquake Engineering, 97:37-47

[18] JICA, (2002). *The study on earthquake disaster mitigation in the Kathmandu Valley* (Vol. 1)

[19] JICA, (2018). *The project for assessment of earthquake disaster risk for the Kathmandu valley in Nepal*. Final report, Volume I: Summary. 2-18-2-21.

[20] UNDP/HMG/UNCHS (Habitat), (1994), *Seismic hazard Mapping and Risk Assessment for Nepal*.

[21] Wang, W.S. (1979). *Some Findings in Soil liquefaction*. Water Conservancy and Hydroelectric Power Scientific Research Institute, Beijing, China.

[22] Adhikari, Kalpana & Subedi, Mandip & Pokharel, Bigul & Acharya, Indra & Paneru, Harish & Sharma, Keshab. (2019). *Liquefaction of soil in Kathmandu Valley from the 2015 Gorkha, Nepal earthquake*.

[23] Sakai, H., Fujii, R., & Kuwahara, Y. (2002). *Changes in the depositional system of the Paleo-Kathmandu Lake caused by uplift of the Nepal Lesser Himalayas*. Journal of Asian Earth Sciences, 20(3), 267-276.

[24] Juang, C. H., & Elton, D. J. (1991, August). *Use of fuzzy sets for liquefaction susceptibility zonation*. In Proc. Fourth Intl. Conf. on Seismic Zonation (Vol. 2, pp. 629-636).

[25] Iwasaki, T., Tokida, K. I., Tatsuoka, F., Watanabe, S., Yasuda, S., & Sato, H. (1982). *Microzonation for soil liquefaction potential using simplified methods*. In Proceedings of the 3rd international conference on microzonation, Seattle (Vol. 3, No. 2, pp. 1310-1330).

[26] Youd, T. L., & Idriss, I. M. (2001). *Liquefaction resistance of soils: summary report from the 1996 NCEER and 1998 NCEER/NSF workshops on evaluation of liquefaction resistance of soils*. Journal of geotechnical and geoenvironmental engineering, 127(4), 297-313.

[27] Subedi, M., Sharma, K., Upadhayay, B., Poudel, R. K., & Khadka, P. (2013). *Soil liquefaction potential in Kathmandu Valley. International Journal of Landslide and Environment*, 1(1), 91-92.

[28] Subedi, M., Acharya, I. P., Sharma, K., & Adhikari, K. (2015). *Liquefaction of Soil in Kathmandu Valley From the 2015 Gorkha, Nepal, Earthquake*. Nepal Engineers' Association. Tech J Special Issue Gorkha Earthquake, 108-115.

[29] Bastola, A., & Acharya, I. P. (2016). *Liquefaction Susceptibility Mapping of Kathmandu Valley*. In Proceedings of IOE Graduate Conference (pp. 19-25).

[30] Idriss, I.M., & Boulanger, R.W. (2008). *Soil Liquefaction During Earthquakes*

[31] Idriss, I.M., & Seed, H.B. (1968/7). *Seismic Response of Horizontal Soil Layers*. Journal of Soil Mechanics and Foundation Division, 94(6), 1003-1031.

[32] Das B.M. (2007). *Theoretical foundation engineering*. "J. Ross publishing".

A.Sample Calculation

Notebook URL: `https://github.com/rdmorgnzation/soilbearing/blob/main/notebooks/sample.ipynb`

```python
#Other imports from library
import resources #Must be 1st line
from blcalc import root_dir
from blcalc.excel_load import BoreholeDataSheets
from blcalc.borehole_parser import BoreholeLog
from blcalc.material import LayerSoil, MaterialData
from blcalc.footing import Footing, FootingType, FootingData
from blcalc.assembly import Assembly
from blcalc.solver import Solver, Methods
from blcalc.geocode import GeoCoder
import pandas as pd
from blcalc.soilproperty import SoilProperty
```

```python
filepath = resources.test_data_dir() / "bh1.xls"
```

A.1. Input Files

A.2. Borehole Log

`https://github.com/rdmorgnzation/soilbearing/blob/main/media/media/testdata/bh1.xls`

<REMOVED>

BORE HOLE LOG

Project	:	Soil Investigation of Proposed Rastriya Banijya Bank Building Site
Location	:	Thapathali, Kathmandu
Consultants	:	<Removed>
Bore Hole No	:	BH-1
Diameter of BH, mm	:	100 mm
RL of GWT	:	1.50 m
Date	:	<Removed>
Logged By	:	<Removed>
Checked By	:	<Removed>
Certified By	:	<Removed>

Scale 1=50cm Each	Depth m	Thickness m	Sampiling Depth m	Sampiling Type	Soil Classification	Group Symbol	Soil Symbol	SPT (Field Record) 15 cm	30 cm	45 cm	Value N
	0.00										
		3.00	1.50	SPT	Filling materials including sandy silt with gravels, pieces of bricks etc.	FM		3	2	2	4
	3.00		3.00	SPT				4	3	3	6
			4.50	SPT				4	4	3	7
			6.00	SPT				5	5	4	9
			7.00	UDS							
			7.50	SPT				5	5	4	9
			9.00	SPT				5	6	4	10
			10.50	SPT				5	5	5	10
		17.00	12.00	SPT	Black clayey silt of medium plasticity	MI		5	5	5	10
			13.50	SPT				6	5	5	10
			15.00	SPT				6	5	5	10
			16.50	SPT				5	6	5	11
			18.00	SPT				5	6	5	11
			19.50	SPT				5	5	6	11
	20.00										

A.3. Summary Sheet

https://github.com/rdmorgnzation/soilbearing/blob/main/media/media/testdata/ss.xls

BH. No	Depth m	% of Gravel	% of Sand	Fines Silt	Fines Clay	Atterberg Limits LL	PL	PI	Water Content %	Specific Gravity	Unit Weight Dry gm/cc	Unit Weight Bulk gm/cc	q_u kN/m²	m_v cm²/kg	Direct Shear Angel ø	Direct Shear Cohesion kN/m²
1	0.00-3.00	16.00	31.00	53.00		-	-	-	17.49	-	-	-	-	-	-	-
	3.00-20.00	0.00	5.00	55.00	40.00	40.50	33.04	7.46	33.76	2.511	1.369	1.824	95.00	0.057	32.00	4.50

```
#Parse it first
sheets = BoreholeDataSheets.load_file(str(filepath.resolve()))
```

```
#Parse 1st sheet
keys = list(sheets.keys())
```

```
sheet = sheets[keys[0]]
borehole_log = BoreholeLog(sheet)
```

```
#Attributes obtained from data
pd.DataFrame.from_dict(borehole_log.attributes, orient='index')
```

Out:

	0
project	Soil Investigation of Proposed Rastriya Banijy...
location	Thapathali, Kathmandu
consultants	<Removed>
bore hole no	BH
diameter of bh, mm	100 mm
rl of gwt	1.50 m
date	<Removed>
logged by	<Removed>
checked by	<Removed>
certified by	<Removed>

```
#Parsed values
layer=borehole_log.values
#Here i am removing the last value since we used values <20 only,
# For liquefaction. I am trying to get same result as in report
layer = list(filter(lambda x:x[SoilProperty.depth]<20.,layer))
layer = list(filter(lambda x:x[SoilProperty.depth]%1.5==0,layer))
#just for consistancy
pd.DataFrame.from_records(layer)
```

Out:

SoilProperty.depth	SoilProperty.SPT_N	SoilProperty.GI
1.5	4.0	FM
3.0	6.0	FM
4.5	7.0	MI
6.0	9.0	MI
7.5	9.0	MI
9.0	10.0	MI
10.5	10.0	MI
12.0	10.0	MI
13.5	10.0	MI
15.0	10.0	MI
16.5	11.0	MI
18.0	11.0	MI
19.5	11.0	MI

```
geocoder = GeoCoder()
result= geocoder.fetch_geo('Rastriya Banijya Bank, Thapathali,
                                 Kathmandu')
#Or use google maps to get result
print('Latitude: ', result[0], '(27.655862)')
print('Longitude: ', result[1], '(85.3064456)')
```

Out:
Latitude: 27.6965195 (27.655862)
Longitude: 85.30662 (85.3064456)

A.4. Add datas from summary sheet

```
#Create footing info based on depth
def get_footing(depth=1.5):
    footing = Footing()
    footing[FootingData.Type] = FootingType.Square
    footing[FootingData.Depth] = depth
    footing[FootingData.Width] = 2
    footing[FootingData.Length] = 2
    return footing
#In our case these values were loaded from excel directly
water_depth = 1.5
for i in layer:
```

```
    i[SoilProperty.gamma] = 1.824
    i[SoilProperty.phi] = 32
    i[SoilProperty.qu] = 95
    i[SoilProperty.cu] = 4.5
    i[SoilProperty.G] = 2.511
    if i[SoilProperty.depth]<=3:
        i[SoilProperty.FC] = 53
        i[SoilProperty.water_per] = 0.1749
    else:
        i[SoilProperty.FC] = 95
        i[SoilProperty.water_per] = 0.3376
pd.DataFrame.from_records(layer)
```

_N	SoilProperty.GI	SoilProperty.gamma	SoilProperty.phi	SoilProperty.qu	SoilProperty.cu	SoilProperty.G	SoilProperty.FC	SoilProperty.water_per
4.0	FM	1.824	32	95	4.5	2.511	53	0.1749
5.0	FM	1.824	32	95	4.5	2.511	53	0.1749
7.0	MI	1.824	32	95	4.5	2.511	95	0.3376
9.0	MI	1.824	32	95	4.5	2.511	95	0.3376
9.0	MI	1.824	32	95	4.5	2.511	95	0.3376
).0	MI	1.824	32	95	4.5	2.511	95	0.3376
).0	MI	1.824	32	95	4.5	2.511	95	0.3376
).0	MI	1.824	32	95	4.5	2.511	95	0.3376
).0	MI	1.824	32	95	4.5	2.511	95	0.3376
).0	MI	1.824	32	95	4.5	2.511	95	0.3376
1.0	MI	1.824	32	95	4.5	2.511	95	0.3376
1.0	MI	1.824	32	95	4.5	2.511	95	0.3376
1.0	MI	1.824	32	95	4.5	2.511	95	0.3376

A.5. Values for each layer

```
soil_material = LayerSoil(layer, water_depth, 0)
#Here 0 is for internal purpose (PLAXIS result caching)
pd.DataFrame.from_records(soil_material.get())
```

Out:

er_per	SoilProperty.sat_unit_weight	SoilProperty.vertical_effective_stress	SoilProperty.total_effective_stress	SoilProperty.water_depth	SoilProperty.thickness	So
).1749	20.109596	26.840160	26.840160	1.5	1.5	
).1749	20.109596	42.289554	57.004554	1.5	1.5	
).3376	17.832298	54.323002	83.753002	1.5	1.5	
).3376	17.832298	66.356450	110.501450	1.5	1.5	
).3376	17.832298	78.389897	137.249897	1.5	1.5	
).3376	17.832298	90.423345	163.998345	1.5	1.5	
).3376	17.832298	102.456793	190.746793	1.5	1.5	
).3376	17.832298	114.490241	217.495241	1.5	1.5	
).3376	17.832298	126.523688	244.243688	1.5	1.5	
).3376	17.832298	138.557136	270.992136	1.5	1.5	
).3376	17.832298	150.590584	297.740584	1.5	1.5	
).3376	17.832298	162.624031	324.489031	1.5	1.5	
).3376	17.832298	174.657479	351.237479	1.5	1.5	

y.thickness	SoilProperty.N60	SoilProperty.packing_case	SoilProperty.elasticity	SoilProperty.nu
1.5	4.363333	1	4363.333333	0.3
1.5	6.203635	1	6203.635233	0.3
1.5	7.237280	1	7237.280059	0.3
1.5	9.409680	1	9409.679640	0.3
1.5	8.657378	1	8657.377609	0.3
1.5	8.956403	1	8956.402748	0.3
1.5	8.856863	1	8856.862762	0.3
1.5	8.378496	1	8378.495871	0.3
1.5	7.970111	1	7970.111042	0.3
1.5	7.616156	1	7616.156245	0.3
1.5	8.036077	1	8036.076654	0.3
1.5	7.733046	1	7733.046427	0.3
1.5	7.461899	1	7461.899324	0.3

Sample calculation for 1.5m depth

Saturated Unit Weight (γ_{sat})
= $9.81 * \frac{(1+w\%)*G}{1+w\%*G}$ = $9.81 * \frac{(1+0.1749)*2.511}{1+0.1749*2.511}$ = 20.10959618

Vertical Effective Stress= $\begin{cases} q + (\gamma_{sat} - 9.81) * depth & \text{, for below WL} \\ q + \gamma * 9.81 * depth & \text{, for above WL} \end{cases}$
So, **Vertical Effective Stress** = 0 + 1.824 * 9.81 * 1.5 = 26.84016

Total Effective Stress= $\begin{cases} q + \gamma_{sat} * depth & \text{, for below WL} \\ q + \gamma * 9.81 * depth & \text{, for above WL} \end{cases}$
So, **Total Effective Stress** = 0 + 1.824 * 9.81 * 1.5 = 26.84016

Determining N60
SPT_N = 4.0
Apply dilatracy correction,
Since SPT_N <15 and above GWT no correction is needed,
else, $N = 15 + 0.5 * (SPT\_N - 15)$
So, N = 4.0
And,
Cb = 1
Cs = 1
Eh = 0.55
Cr = 0.7 for depth <3

And, CN = $9.78 * \sqrt{\frac{1}{VerticalEffectiveStress}} \leq 1.7$
= $9.78 * \sqrt{\frac{1}{26.084016}}$ = 1.91492 <1.7 = 1.7
So, $N_{60} = Cb * Cs * Eh * Cr * CN * N/0.6 = 1 * 1 * 0.55 * 0.7 * 1.7 * 4.0/0.6 = 4.3633333$
Packing Case
For sand N60, 4-10, packing case = 2
Starting count from 0(computer) = 2-1=1
Nu
ν = 0.3, for cohesionless soil(assumed)
Elasticity
$E = 10 * N_{60} * 100$ = 10 * 4.3633333*100 = 4363.3333

A.6. Calculation of BC and LPI

For 1.5m, avg_N60 = weighted average N60 from d/2 to 2d

```
soil_material.get_avg_N(1.5)
```

Out:
4.363333333333333

```
footing = get_footing()
assembly = Assembly(footing, soil_material)
solver = Solver(assembly)
results = solver.run()
#print(results)
```

A.6.1. Shear Methods

Terzaghi

$Rw1 = 0.5 * (1 + water\_depth/depth\_footing) = 1$
$Rw2 = 0.5 * (1 + (water\_depth - depth\_footing)/width\_footing) = 0.5$
$q_s = 1.2 * c * N_c + surchage * N_q * Rw1 + 0.4 * \gamma * 9.81 * width\_footing * N_\gamma * Rw2$
$= 1.3 * 4.5 * 44.0357 + 26.840160 * 28.51657 * 1 + 0.4 * 1.824 * 9.81 * 2 * 28.78 * 0.5$
$= 1228.987$
$q_{ns} = (q_s - q)/3 = (1228.987 - 26.84016)/3 = 400.7157$

```
results[Methods.Terzaghi]
```

Out:
400.71581138243215

Meyerhof

$K_p = tan^2(45 + \phi/2)$ = $tan^2(45 + 32/2)$ = 3.2546
sc = $1 + 0.2 * K_p * width\_footing/length\_footing$ = $1 + 0.2 * 3.2546 * 2/2$ =

1.65092
$sq = 1 + 0.1 * K_p * width\_footing/length\_footing = 1 + 0.1 * 3.2546 * 2/2 = 1.32546$
$sy = sq = 1.32546$
$dc = 1+0.2*\sqrt{K_p}*depth\_footing/width\_footing = 1+0.2*\sqrt{3.2546}*1.5/2 = 1.2706$
$dq = 1+0.1*\sqrt{K_p}*depth\_footing/width\_footing = 1+0.1*\sqrt{3.2546}*1.5/2 = 1.1353$
$dy = dq = 1.1353$
$c\_term = cohesion*Nc(phi)*sc*dc = 4.5*35.49026*1.65092*1.2706 = 335.009$
$q\_term = surchage * Nq(phi) * sq * dq * Rw1 = 26.84016 * 23.176776 * 1.32546 * 1.1353 * 1 = 936.0852$
$y\_term = 0.5 * gamma * 9.81 * self.width\_footing * Ny(phi) * sy * dy * Rw2 = 0.5 * 1.824 * 9.81 * 2 * 22.02249 * 1.32546 * 1.1353 * 0.5 = 296.488$
$q_s = 1567.58248$
$q_{ns} = (1567.58248 - 26.84016)/3 = 513.58$

```
results[Methods.Meyerhof]
```

Out:
513.5822200901385

Hansen

$N_c = 35.490260$
$N_q = 23.1767762$
$N_y = 20.78638$
$sc = 1 + N_q/N_c * width\_footing/length\_footing = 1 + 23.1767762/35.49026 * 2/2 = 1.653046$
$sq = 1+width\_footing/length\_footing*tan(\phi) = 1+2/2*tan(32) = 1.624869$
$sy = 1 - 0.4 * width\_footing/length\_footing = 1 - 0.4 * 2/2 = 0.6$
$dc = 1 + 0.4 * width\_footing/length\_footing = 1 + 0.4 * 2/2 = 1.4$
$dq = 1 + 2 * tan(\phi) * (1 - sin(\phi))^2 * depth\_footing/width\_footing = 1 + 2 * tan(32) * (1 - sin(32))^2 * 1.5/2 = 1.20712$
$dy = 1$
$c\_term = cohesion * N_c * sc * dc = 4.5 * 35.49026 * 1.653046 * 1.4 = 369.6023$
$q\_term = surchage * N_q * sq * dq * Rw1 = 26.84016 * 23.1767762 * 1.624869 * 1.20712 * 1 = 1220.1323$
$y\_term = 0.5*gamma*9.81*width\_footing*N_y*sy*dy*Rw2 = 0.5*1.824*9.81 * 2 * 20.78638 * 0.6 * 1 * 0.5 = 111.581953$
$q_s = c\_term + q\_term + y\_term = 1701.31656$
$q_{ns} = (1701.31656 - 26.84016)/3 = 558.158$

```
results[Methods.Hansen]
```

Out:
558.1594404871763

Vesic

$N_c = 35.4902607$
$N_q = 23.176776$
$N_y = 30.2146529$
$sc = 1 + N_q/N_c * width\_footing/length\_footing = 1 + 23.176776/35.4902607 * 2/2 = 1.653046$
$sq = 1 + width\_footing/length\_footing * tan(\phi) = 1 + 2/2 * tan(32) = 1.624869$
$sy = 1 - 0.4 * width\_footing/length\_footing = 1 - 0.4 * 2/2 = 0.6$
$dc = 1 + 0.4 * width\_footing/length\_footing = 1 + 0.4 * 2/2 = 1.4$
$dq = 1 + 2 * tan(\phi) * (1 - sin(\phi))^2 * depth\_footing/width\_footing = 1 + 2 * tan(32) * (1 - sin(32))^2 * 1.5/2 = 1.20712$
$dy = 1$
$c\_term = cohesion * N_c * sc * dc = 4.5 * 35.49026 * 1.653046 * 1.4 = 369.6023$
$q\_term = surchage * N_q * sq * dq * Rw1 = 26.84016 * 23.1767762 * 1.624869 * 1.20712 * 1 = 1220.1323$
$y\_term = 0.5 * gamma * 9.81 * width\_footing * N_y * sy * dy * Rw2 = 0.5 * 1.824 * 9.81 * 2 * 30.2146529 * 0.6 * 1 * 0.5 = 162.19322$
$q_s = c\_term + q\_term + y\_term = 1751.93$
$q_{ns} = (1701.31656 - 26.84016)/3 = 575.03$

```
results[Methods.Vesic]
```

Out:
575.0298611603204

Plaxis

For shear failure in PLAXIS, a large deformation is applied (same result can be obtained by applying large load), so that soil fails by shear. In both cases the soil fails during stagged loading. So we obtain result in plaxis which shows that step failed, but we get result.

```
results[Methods.PlaxisShear]
```

Out:
797.05

Teng

$q_{ns} = 0.11 * N60 * N60 * width\_footing * Rw2 + 0.33 * (100 + N60 * N60) * depth\_footing * Rw1$
$= 0.11 * 4.36333^2 * 2 * 0.5 + 0.33 * (100 + 4.36333^2) * 1.5 * 1 = 61.018$

```
results[Methods.Teng]
```

Out:
61.01840005555556

A.6.2. Settlement Methods

Take 25mm deflection,

Meyerhof

$Rd = 1 + 0.33 * depth\_footing/width\_footing = 1 + 0.33 * 1.5/2 = 1.2475$
$b = water\_depth - depth\_footing = 1.5 - 1.5 = 0$
$Wy = 0.5 + 0.5 * b/width\_footing = 0.5$
$q_s = 8.1 * n60 * ((width\_footing + 0.3)/width\_footing)^2 * Wy * Rd$
$= 8.1 * 4.3633 * ((2 + 0.3)/2)^2 * 0.5 * 1.2475 = 29.154772$

```
results[Methods.MeyerhofDeflection]
```

Out:
29.154772040624994

Bowels

$q_s = 1.5 * Meyerhoff = 1.5 * 29.154772 = 43.732158$

```
results[Methods.Bowels]
```

Out:
43.73215806093749

Peck

$Cw = 0.5 + 0.5 * water\_depth/(depth\_footing + width\_footing) = 0.5 + 0.5 * 1.5/(1.5 + 2) = 0.71429$
$q_s = 10.25 * Cw * n60 = 10.25 * 0.71429 * 4.3633 = 31.94578$

```
results[Methods.Peck]
```

Out:
31.945833333333333

Teng

$Rd = 1 + depth\_footing/width\_footing = 1 + 1.5/2 = 1.75$
$q_s = 35 * (n60 - 3) * ((width\_footing + 0.3)/(2 * width\_footing))^2 * Wy * Rd$
$= 35 * (4.3633 - 3) * ((2 + 0.3)/(2 * 2))^2 * 0.5 * 1.75 = 13.803945$

```
results[Methods.TengDeflection]
```

Out:
13.804282552083333

Plaxis

25mm deflection was applied at the footing depth and the corresponding force was taken as bearing capacity.

```
results[Methods.Plaxis]
```

Out:
40.06205

A.6.3. LPI

Excel sheet: `https://github.com/rdmorgnzation/soilbearing/blob/main/media/media/testdata/lqi.xlsx`

For 1.5m depth, $FC = 94.36$

$delN1 = e^(1.63+(9.7/(FC+0.01))-(15.7/(FC+0.01))*(15.7/(FC+0.01))) = 5.501985976$

$N1cs = N60 + delN1 = 20.23473097$

$MSF = 0.8758$

$Csigma = 1/(18.9 - 2.55 * \sqrt{N1cs}) = 0.134601693$

$Ksigma = 1 - Csigma * log(vertical\_effective\_stress/100) = 0.921469899$

$CRR = exp((N1cs/14.1) + (N1cs/126)^2 - (N1cs/23.6)^3 + (N1cs/25.4)^3 - 2.8/1) * (MSF * Ksigma) = 0.186699144$

$a_g = 0.183$

$SRF = exp(-1.012 - 1.126 * sin(depth/11.73 + 5.133) + 8 * (0.106 + 0.118 * sin(depth/11.28 + 5.142))) = 0.998325105$

$CSR = 0.65*(total\_effective\_stress/vertical\_effective\_stress)*a_g*SRF = 0.118750771$

$FS = CRR/CSR = 0.992381257$

Since, 0.95¡FS¡1.2:

$Fz = 2e6 * exp(-18.427 * FS) = 0.022869488$

$Wz = 10 - data[SoilProperty.depth]/2 = 9.25$

$del\_lpi = Fz * Wz * thickness = 0.317314139$

Adding upto depth of 20 we get, LPI = 21.17671875

```
results[Methods.Liquifaction]
```

Out:
21.17671874695882

B.Table and Calculations

Rastriya Banijya Bank: Thapathali, Kathmandu

Borehole:1				**LPI**:21.18			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	400.72	513.58	558.16	575.03	797.05	61.02
	3.0	541.92	783.32	900.40	917.27	1135.85	104.28
	4.5	657.36	1057.54	1268.90	1285.77	1455.67	167.25
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	43.73	40.06	31.95	13.80	29.15	
	3.0	63.42	51.64	39.54	33.96	42.28	1.50 m
	4.5	84.17	61.72	49.69	56.44	56.11	

Borehole:2				**LPI**:28.43			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	361.88	458.67	504.16	518.97	713.32	61.02
	3.0	486.48	696.16	807.08	821.89	1023.04	94.75
	4.5	586.90	935.09	1131.52	1146.34	1366.96	133.58
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	43.73	36.16	31.95	13.80	29.15	
	3.0	52.40	44.30	32.67	22.03	34.93	1.50 m
	4.5	59.92	52.20	35.37	30.17	39.94	

Borehole:3				**LPI**:28.18			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	413.17	530.26	572.99	590.67	815.45	61.12
	3.0	563.74	815.20	937.30	954.14	1148.95	99.64
	4.5	678.57	1092.96	1307.95	1324.79	1530.37	138.60
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	45.92	37.97	32.58	14.49	30.61	
	3.0	55.85	47.59	35.36	25.77	37.23	1.60 m
	4.5	62.30	53.22	37.24	32.75	41.53	

Borehole:4				**LPI**:26.95			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	417.12	535.87	575.57	594.13	801.37	61.23
	3.0	560.92	811.16	931.39	948.26	1106.70	102.41
	4.5	675.75	1088.39	1301.00	1317.87	1395.57	149.28
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	48.11	38.56	33.22	15.18	32.07	
	3.0	56.61	48.77	36.39	26.60	37.74	1.70 m
	4.5	68.80	56.21	41.63	39.80	45.87	

Summary:

* Means the datas are shown only but not used for further calculation

Depth	Shear	Deflection	LPI	Latitude	Longitude
1.5	556.78	32.33			
3.0	881.97	38.64	26.18	27.655862	85.306446
4.5	1219.91	50.94			

Building Complex: Anamnagar, Kathmandu

Borehole:1				**LPI**:17.96			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	90.35	86.33	104.61	104.61	215.36	209.84
	3.0	438.05	608.77	763.50	776.78	111.02	241.35
	4.5	85.99	104.49	100.26	100.26	148.95	215.91
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	267.86	42.48	145.35	217.45	178.57	
	3.0	121.56	50.47	93.28	96.92	81.04	3.00 m
	4.5	88.37	57.19	61.94	60.98	58.91	

Borehole:2				**LPI**:18.83			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	341.14	441.45	427.08	455.73	105.38	212.41
	3.0	110.15	118.98	127.54	127.54	150.25	226.62
	4.5	106.34	128.89	123.73	123.73	176.62	209.63
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	283.17	59.81	149.83	229.87	188.78	
	3.0	125.98	61.37	90.08	98.24	83.99	3.20 m
	4.5	82.64	64.32	59.15	54.78	55.09	

Borehole:3				**LPI**:19.06			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	320.32	411.62	416.47	439.77	110.51	203.43
	3.0	114.87	124.19	133.23	133.23	156.63	253.10
	4.5	110.42	134.24	128.78	128.78	184.16	243.34
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	229.59	58.46	134.17	186.38	153.06	
	3.0	134.98	70.76	97.11	111.46	89.98	2.50 m
	4.5	107.42	68.43	71.34	81.61	71.61	

Borehole:4				**LPI**:17.17			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	333.22	429.85	432.88	457.05	544.20	226.20
	3.0	499.56	699.67	868.35	883.39	488.90	326.95
	4.5	642.22	996.81	1309.97	1325.25	244.34	285.55
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	245.99	35.11	143.76	202.95	164.00	
	3.0	162.80	40.92	117.13	141.59	108.54	2.50 m
	4.5	123.89	48.16	82.28	99.45	82.59	

Borehole:5				LPI:19.98			
Shear	Depth	Terzaghi*	Meyerhof	Hansen	Vesic	Plaxis	Teng
	1.5	359.37	468.32	467.10	493.09	447.98	276.46
	3.0	528.90	741.57	922.27	937.55	441.02	356.06
	4.5	670.65	1039.91	1373.56	1388.69	210.01	321.70
Settlement	Depth	Bowels	Plaxis	Peck	Teng	Meyerhof	WL
	1.5	278.79	53.13	162.92	236.09	185.86	
	3.0	172.54	61.22	124.13	152.14	115.03	2.50 m
	4.5	136.43	64.94	90.60	113.03	90.95	

Summary:

Depth	Shear	Deflection	LPI	Latitude	Longitude
1.5	226.20	178.57			
3.0	253.10	98.24	18.60	27.697282	85.327457
4.5	210.01	71.61			

Building Complex: Bakhundol Lalitpur

Borehole:1				LPI:7.41			
Shear	Depth	Terzaghi*	Meyerhof	Hansen	Vesic	Plaxis	Teng
	1.5	70.55	67.41	81.68	81.68	87.66	57.16
	3.0	70.55	76.20	81.68	81.68	108.04	111.07
	4.5	70.55	84.99	81.68	81.68	124.10	169.87
Settlement	Depth	Bowels	Plaxis	Peck	Teng	Meyerhof	WL
	1.5	65.60	39.24	45.52	5.52	43.73	
	3.0	67.50	44.17	35.61	3.67	45.00	6.00 m
	4.5	66.75	48.14	35.18	11.53	44.50	

Borehole:2				LPI:6.30			
Shear	Depth	Terzaghi*	Meyerhof	Hansen	Vesic	Plaxis	Teng
	1.5	73.02	69.77	84.55	84.55	90.42	63.11
	3.0	73.02	78.87	84.55	84.55	111.45	116.52
	4.5	73.02	87.97	84.55	84.55	128.06	172.32
Settlement	Depth	Bowels	Plaxis	Peck	Teng	Meyerhof	WL
	1.5	87.46	40.44	60.70	27.61	58.31	
	3.0	81.32	46.29	42.90	18.63	54.21	6.00 m
	4.5	70.47	47.32	37.14	15.56	46.98	

Summary:

Depth	Shear	Deflection	LPI	Latitude	Longitude
1.5	78.27	44.63			
3.0	109.56	44.58	6.86	27.683018	85.310335
4.5	126.08	45.74			

Hindu vidhypeth: Balkumari, Lalitpur

Borehole:1				LPI:17.90			
	Depth	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
Shear	**1.5**	123.77	118.26	143.30	143.30	274.19	420.10
	3.0	673.59	981.96	1164.22	1186.29	282.11	580.96
	4.5	777.64	1235.39	1571.88	1591.65	147.95	368.20
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	324.71	57.85	200.30	287.03	216.47	
	3.0	241.67	69.12	166.91	227.00	161.11	2.20 m
	4.5	155.57	63.22	99.87	133.76	103.71	

Borehole:2				LPI:14.94			
	Depth	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
Shear	**1.5**	116.34	111.16	134.71	134.71	461.97	665.21
	3.0	746.22	1095.26	1297.72	1321.06	233.21	829.83
	4.5	963.01	1565.81	1951.79	1975.40	275.95	627.60
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	459.19	69.00	268.35	418.33	306.13	
	3.0	287.99	83.49	207.19	277.16	191.99	2.50 m
	4.5	214.99	78.75	142.78	198.11	143.33	

Summary:

Depth	Shear	Deflection	LPI	Latitude	Longitude
1.5	347.15	277.69			
3.0	705.39	199.59	16.42	27.671139	85.337935
4.5	497.90	138.27			

DI Skin Health and Referral Center (P). Ltd.: Bansbari, Kathmandu

Borehole:1				LPI:1.26			
	Depth	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
Shear	**1.5**	143.57	137.18	166.23	166.23	309.83	610.09
	3.0	621.03	893.26	1071.55	1091.69	170.80	674.82
	4.5	136.41	165.81	159.08	159.08	459.19	681.34
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	405.89	54.78	247.98	368.28	270.59	
	3.0	262.29	70.24	182.41	249.33	174.86	2.25 m
	4.5	230.61	101.99	148.89	215.02	153.74	

Borehole:2				LPI:3.17			
	Depth	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
Shear	**1.5**	131.19	125.35	151.90	151.90	282.52	160.23
	3.0	718.18	1054.90	1244.81	1268.13	155.29	411.12
	4.5	124.05	150.91	144.76	144.76	203.93	573.96
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	180.40	77.59	110.21	140.48	120.26	
	3.0	194.81	73.47	135.48	176.26	129.88	2.25 m
	4.5	207.75	80.32	134.13	190.27	138.50	

Borehole:3				**LPI:**0.28			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	352.76	455.07	458.27	483.86	697.65	226.20
	3.0	549.08	773.75	950.59	967.58	480.50	344.43
	4.5	649.97	1008.95	1321.92	1338.01	598.22	678.82
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	245.99	38.48	143.76	202.95	164.00	
	3.0	168.72	57.87	121.38	148.00	112.48	2.50 m
	4.5	225.49	96.60	149.75	209.48	150.33	

Borehole:4				**LPI:**0.05			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	387.34	504.66	476.99	511.11	1075.27	240.93
	3.0	934.31	1429.58	1514.73	1565.57	913.52	895.87
	4.5	1666.39	2832.48	3140.74	3205.48	579.36	1188.97
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	327.99	88.96	251.57	270.60	218.66	
	3.0	548.43	135.30	315.65	524.50	365.62	7.00 m
	4.5	527.93	182.36	262.95	502.29	351.95	

Borehole:5				**LPI:**3.09			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	117.58	112.34	136.14	136.14	138.49	103.95
	3.0	117.58	127.00	136.14	136.14	170.38	229.01
	4.5	116.05	140.12	134.61	134.61	1915.91	486.60
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	174.93	62.22	95.84	115.97	116.62	
	3.0	170.05	63.03	97.87	132.09	113.37	4.00 m
	4.5	161.70	92.57	125.28	140.40	107.80	

Borehole:6				**LPI:**1.12			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	100.25	95.79	116.08	116.08	120.15	118.41
	3.0	100.25	108.28	116.08	116.08	147.43	228.87
	4.5	97.27	117.79	113.09	113.09	171.94	442.72
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	196.79	57.39	100.63	138.06	131.20	
	3.0	143.35	66.62	93.51	111.85	95.57	3.50 m
	4.5	157.51	72.49	116.22	135.86	105.01	

Borehole:7				**LPI:**1.26			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	143.57	137.18	166.23	166.23	309.83	610.09
	3.0	621.03	893.26	1071.55	1091.69	170.80	674.82
	4.5	136.41	165.81	159.08	159.08	459.19	681.34
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	405.89	54.78	247.98	368.28	270.59	
	3.0	262.29	70.25	182.41	249.33	174.86	2.25 m
	4.5	230.61	101.99	148.89	215.02	153.74	

Borehole:8				**LPI**:3.17			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	131.19	125.35	151.90	151.90	282.52	160.23
	3.0	718.18	1054.90	1244.81	1268.13	155.37	411.12
	4.5	124.05	150.91	144.76	144.76	203.93	573.97
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	180.40	77.59	110.21	140.48	120.26	
	3.0	194.81	73.47	135.48	176.26	129.88	2.25 m
	4.5	207.75	80.32	134.14	190.27	138.50	

Borehole:9				**LPI**:0.28			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	352.95	455.31	458.52	484.12	698.02	226.20
	3.0	549.19	773.89	950.75	967.75	474.92	344.38
	4.5	650.05	1009.08	1322.06	1338.17	594.11	678.70
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	245.99	38.49	143.76	202.95	164.00	
	3.0	168.70	57.88	121.37	147.98	112.47	2.50 m
	4.5	225.46	96.60	149.73	209.45	150.31	

Summary:

Depth	**Shear**	**Deflection**	**LPI**	**Latitude**	**Longitude**
1.5	226.20	143.76			
3.0	411.12	135.48	1.52	27.737038	85.333544
4.5	573.96	150.31			

Building: Bhaisipati, Lalitpur

Borehole:1				**LPI**:0.20			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	387.96	505.47	477.76	511.93	274.14	240.93
	3.0	1216.59	1875.03	1999.59	2051.66	471.22	1000.54
	4.5	1439.72	2387.86	2907.99	2938.85	474.22	952.59
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	327.99	67.99	179.70	270.60	218.66	
	3.0	447.80	65.79	257.73	432.88	298.54	4.00 m
	4.5	247.64	69.07	191.86	233.46	165.09	

Borehole:2				**LPI**:0.02			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	405.30	530.76	498.93	534.54	287.42	267.30
	3.0	524.24	736.11	877.35	899.80	199.82	357.41
	4.5	182.88	220.63	211.99	211.99	270.55	502.94
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	349.86	55.23	191.68	292.69	233.24	
	3.0	239.74	97.84	137.98	207.56	159.83	4.00 m
	4.5	165.47	106.22	128.20	144.48	110.31	

Borehole:3				**LPI**:0.01			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	190.60	182.12	220.69	220.69	215.93	240.93
	3.0	190.60	205.87	220.69	220.69	261.80	350.46
	4.5	190.60	229.62	220.69	220.69	304.78	446.21
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	327.99	108.97	227.61	270.60	218.66	
	3.0	308.08	113.08	162.54	264.21	205.39	6.00 m
	4.5	249.11	117.13	131.30	209.02	166.07	

Borehole:4				**LPI**:0.01			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	1236.55	1972.52	1550.35	1660.70	360.28	1622.61
	3.0	1586.82	2562.11	2498.22	2584.09	210.57	1801.70
	4.5	190.60	229.62	220.69	220.69	283.54	1231.45
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	940.24	108.55	618.15	889.13	626.83	
	3.0	801.68	98.44	403.73	798.75	534.45	5.50 m
	4.5	410.63	103.21	242.40	392.62	273.75	

Borehole:5				**LPI**:0.03			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	190.60	182.12	220.69	220.69	263.84	1152.13
	3.0	1390.75	2190.63	2186.87	2261.43	455.60	1892.01
	4.5	1978.58	3431.08	3827.67	3888.72	229.61	1465.19
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	787.18	91.41	517.52	734.50	524.79	
	3.0	822.66	103.35	414.30	821.47	548.44	5.50 m
	4.5	452.78	96.12	267.28	438.26	301.85	

Borehole:6				**LPI**:0.00			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	1188.69	1870.22	1481.39	1586.70	348.65	1550.30
	3.0	1253.44	1947.86	1977.29	2044.36	208.69	1253.99
	4.5	188.13	226.64	217.82	217.82	279.64	745.82
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	918.38	108.77	637.32	867.04	612.25	
	3.0	660.27	104.10	348.35	645.61	440.18	6.00 m
	4.5	352.86	111.76	185.98	321.38	235.24	

Summary:

Depth	**Shear**	**Deflection**	**LPI**	**Latitude**	**Longitude**
1.5	318.03	310.34			
3.0	654.49	303.31	0.04	27.648046	85.295963
4.5	375.49	200.44			

Brihaspati Vidyasadan School: Gahanapokhari, Kathmandu

Borehole:1				LPI:0.11			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	146.05	139.54	169.10	169.10	168.83	152.45
	3.0	146.05	157.74	169.10	169.10	933.96	360.63
	4.5	1046.36	1685.00	2069.88	2101.52	753.80	611.38
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	240.53	74.30	158.13	182.24	160.35	
	3.0	314.25	70.58	158.26	270.89	209.50	5.50 m
	4.5	268.46	74.38	158.47	238.66	178.97	

Borehole:2				LPI:0.64			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	153.47	146.64	177.70	177.70	176.66	134.58
	3.0	153.47	165.76	177.70	177.70	214.87	410.14
	4.5	153.47	184.89	177.70	177.70	254.06	619.54
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	218.66	86.87	135.77	160.15	145.77	
	3.0	342.69	107.15	164.36	301.69	228.46	5.00 m
	4.5	227.58	91.24	154.50	203.07	151.72	

Borehole:3				LPI:1.93			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	148.52	141.91	171.96	171.96	171.26	134.58
	3.0	148.52	160.42	171.96	171.96	208.46	248.30
	4.5	145.50	175.90	168.94	168.94	241.29	376.05
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	218.66	68.06	111.81	160.15	145.77	
	3.0	153.70	73.62	100.26	123.06	102.47	3.50 m
	4.5	139.59	90.04	103.00	116.46	93.06	

Borehole:4				LPI:0.00			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	141.10	134.81	163.37	163.37	163.53	118.41
	3.0	141.10	152.40	163.37	163.37	200.54	228.04
	4.5	141.10	169.98	163.37	163.37	2007.17	441.70
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	196.79	79.96	122.19	138.06	131.20	
	3.0	220.70	79.00	105.85	169.57	147.13	5.00 m
	4.5	179.55	75.71	121.89	151.05	119.70	

Summary:

Depth	Shear	Deflection	LPI	Latitude	Longitude
1.5	160.60	145.77			
3.0	211.67	155.98	0.67	27.714253	85.329571
4.5	408.87	145.32			

Green Hill City (P). Ltd. : Mulpani, Kathamndu

Borehole:1				**LPI**:0.28			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	272.60	345.89	340.57	365.52	406.79	91.19
	3.0	571.05	808.95	920.04	950.85	303.81	284.40
	4.5	869.57	1362.16	1676.25	1709.77	165.89	346.95
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	153.06	63.29	206.85	93.88	102.04	
	3.0	264.54	72.07	253.75	217.05	176.36	15.00 m
	4.5	230.56	65.07	182.89	180.25	153.71	

Borehole:2				**LPI**:4.09			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	106.44	101.70	123.24	123.24	126.46	52.90
	3.0	106.44	114.97	123.24	123.24	155.83	112.42
	4.5	106.44	128.23	123.24	123.24	1505.78	208.93
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	43.73	59.67	59.10	-16.57	29.15	
	3.0	71.18	60.52	68.28	7.65	47.45	15.00 m
	4.5	127.22	62.58	100.92	68.35	84.82	

Borehole:3				**LPI**:1.17			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	68.07	65.04	78.82	78.82	85.82	57.16
	3.0	68.07	73.52	78.82	78.82	1504.81	219.16
	4.5	951.70	1507.29	1829.72	1866.37	1959.21	738.49
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	65.60	48.49	88.65	5.52	43.73	
	3.0	212.96	79.63	204.28	161.20	141.98	15.00 m
	4.5	397.54	96.39	315.34	361.09	265.03	

Borehole:4				**LPI**:0.00			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	509.58	700.08	635.76	680.73	873.23	461.28
	3.0	771.36	1134.34	1238.09	1279.48	1108.27	728.36
	4.5	1105.87	1792.28	2124.92	2167.70	1113.87	762.73
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	481.05	74.53	650.10	425.23	320.70	
	3.0	487.40	79.26	467.53	458.40	324.93	15.00 m
	4.5	405.63	84.06	321.75	369.85	270.42	

Borehole:5				**LPI**:0.05			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	68.07	65.04	78.82	78.82	85.47	80.13
	3.0	68.07	73.52	78.82	78.82	105.48	176.04
	4.5	68.07	82.01	78.82	78.82	120.81	273.37
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	131.20	48.28	177.30	71.79	87.46	
	3.0	170.52	52.33	163.57	115.23	113.68	15.00 m
	4.5	182.89	56.49	145.07	128.63	121.93	

Borehole:6				**LPI**:0.59			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	68.07	65.04	78.82	78.82	85.76	80.13
	3.0	68.07	73.52	78.82	78.82	1032.40	137.64
	4.5	596.85	901.37	1164.53	1187.90	1390.95	222.97
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	131.20	42.37	177.30	71.79	87.46	
	3.0	120.77	48.31	115.85	61.36	80.51	15.00 m
	4.5	141.24	59.87	112.03	83.53	94.16	

Borehole:7				**LPI**:2.38			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	73.02	69.77	84.55	84.55	90.95	57.16
	3.0	73.02	78.87	84.55	84.55	113.59	174.27
	4.5	73.02	87.97	84.55	84.55	2076.54	500.20
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	65.60	45.63	88.65	5.52	43.73	
	3.0	168.55	61.50	161.68	113.10	112.37	15.00 m
	4.5	306.94	81.98	243.47	262.97	204.62	

Borehole:8				**LPI**:0.37			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	74.26	70.95	85.98	85.98	92.63	63.11
	3.0	74.26	80.21	85.98	85.98	1391.31	236.15
	4.5	898.96	1412.76	1731.06	1765.69	1674.22	549.19
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	87.46	54.54	118.20	27.61	58.31	
	3.0	227.53	74.19	218.26	176.97	151.69	15.00 m
	4.5	327.62	84.16	259.87	285.36	218.41	

Borehole:9				**LPI**:3.01			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	80.45	76.87	93.15	93.15	99.01	57.16
	3.0	80.45	86.89	93.15	93.15	123.39	149.41
	4.5	80.45	96.92	93.15	93.15	2141.01	469.13
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	65.60	44.78	88.65	5.52	43.73	
	3.0	137.94	65.50	132.32	79.95	91.96	15.00 m
	4.5	293.06	91.51	232.46	247.94	195.38	

Summary:

Depth	**Shear**	**Deflection**	**LPI**	**Latitude**	**Longitude**
1.5	85.76	65.60			
3.0	155.83	120.77	1.33	27.715765	85.386468
4.5	738.49	182.89			

Building Site: Itachhe tol, Bhaktapur

Borehole:1				LPI:0.48			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	95.30	91.06	110.34	110.34	114.91	80.13
	3.0	95.30	102.93	110.34	110.34	141.29	172.89
	4.5	92.62	112.13	107.66	107.66	161.81	292.47
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	131.20	52.08	68.04	71.79	87.46	
	3.0	112.18	64.05	71.19	76.35	74.79	3.60 m
	4.5	111.96	68.78	83.44	86.54	74.64	

Summary:

Depth	Shear	Deflection	LPI	Latitude	Longitude
1.5	103.92	71.79			
3.0	141.29	74.79	0.48	27.672843	85.422608
4.5	161.81	83.44			

Buddha Air (P). Ltd. : Jawalakhel, Lalitpur

Borehole:1				LPI:1.48			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	810.75	1163.98	984.66	1054.10	227.32	976.01
	3.0	483.62	682.40	788.68	815.19	141.89	524.64
	4.5	120.06	144.63	139.00	139.00	189.84	351.01
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	721.58	42.05	490.21	668.23	481.05	
	3.0	400.82	57.73	207.62	364.64	267.21	5.80 m
	4.5	194.36	80.34	106.91	153.20	129.57	

Borehole:2				LPI:0.66			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	120.06	114.71	139.00	139.00	282.95	295.38
	3.0	888.55	1354.71	1438.99	1487.26	144.42	525.48
	4.5	120.06	144.63	139.00	139.00	194.71	479.13
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	371.72	75.85	257.96	314.78	247.82	
	3.0	401.22	71.61	211.68	365.07	267.48	6.00 m
	4.5	262.53	78.54	138.37	223.55	175.02	

Borehole:3				LPI:0.32			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	116.34	111.16	134.71	134.71	137.55	295.38
	3.0	116.34	125.66	134.71	134.71	313.22	580.31
	4.5	738.46	1141.61	1474.11	1495.72	173.99	609.88
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	371.72	71.40	241.67	314.78	247.82	
	3.0	426.23	65.81	212.61	392.15	284.15	5.40 m
	4.5	259.52	74.74	157.16	230.71	173.01	

Borehole:4				**LPI**:0.89			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	121.29	115.89	140.44	140.44	344.92	765.02
	3.0	867.26	1310.86	1401.00	1447.95	317.97	1055.15
	4.5	1193.39	1959.00	2400.82	2431.84	161.27	755.86
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	634.12	65.06	393.73	579.86	422.74	
	3.0	600.75	79.32	288.13	581.15	400.50	5.00 m
	4.5	258.42	76.65	175.43	236.47	172.28	

Borehole:5				**LPI**:0.36			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	116.34	111.16	134.71	134.71	305.06	624.63
	3.0	1074.31	1653.18	1711.13	1768.85	295.16	1030.47
	4.5	1103.30	1792.67	2151.42	2189.61	149.91	786.88
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	568.52	72.21	394.53	513.59	379.01	
	3.0	592.95	78.56	312.83	572.70	395.30	6.00 m
	4.5	364.79	75.81	192.26	334.30	243.19	

Summary:

Depth	**Shear**	**Deflection**	**LPI**	**Latitude**	**Longitude**
1.5	295.38	371.72			
3.0	525.48	312.83	0.74	27.673572	85.311874
4.5	351.01	175.02			

Tamrakar Samaj: Jawalakhel

Borehole:1				**LPI**:14.76			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	118.82	113.53	137.57	137.57	140.22	424.70
	3.0	118.82	128.33	137.57	137.57	170.63	1714.71
	4.5	118.82	143.14	137.57	137.57	190.03	1108.90
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	459.19	90.45	268.35	403.14	306.13	
	3.0	691.21	84.02	359.94	687.80	460.81	4.50 m
	4.5	262.20	66.81	212.82	249.24	174.80	

Borehole:2				**LPI**:12.51			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	132.43	126.53	153.34	153.34	154.54	193.28
	3.0	132.43	143.04	153.34	153.34	188.04	734.70
	4.5	132.43	159.54	153.34	153.34	218.95	584.85
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	284.26	81.82	172.35	226.42	189.51	
	3.0	467.48	66.21	231.29	440.30	311.65	4.80 m
	4.5	202.21	70.93	146.61	179.06	134.80	

Borehole:3				**LPI**:10.05			
	Depth	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
Shear	**1.5**	136.15	130.08	157.63	157.63	158.56	240.93
	3.0	136.15	147.05	157.63	157.63	192.89	767.60
	4.5	136.15	164.02	157.63	157.63	224.51	640.35
	Depth	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
Settlement	**1.5**	327.99	83.19	194.07	270.60	218.66	
	3.0	456.29	66.14	233.44	431.65	304.19	4.60 m
	4.5	196.68	67.92	153.42	176.55	131.12	

Summary:

Depth	**Shear**	**Deflection**	**LPI**	**Latitude**	**Longitude**
1.5	154.54	226.42			
3.0	188.04	359.94	12.44	27.674749	85.312196
4.5	218.95	174.80			

Tangal, Kathmandu

Borehole:1				**LPI**:4.67			
	Depth	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
Shear	**1.5**	719.30	1017.59	889.15	950.36	1394.48	193.28
	3.0	1052.10	1591.56	1777.56	1815.82	1700.15	326.05
	4.5	1369.44	2274.89	2753.78	2784.39	1427.81	515.94
	Depth	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
Settlement	**1.5**	284.26	65.28	145.35	226.42	189.51	
	3.0	189.54	84.93	123.64	161.87	126.36	3.50 m
	4.5	175.09	101.51	129.19	154.90	116.73	

Borehole:2				**LPI**:4.04			
	Depth	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
Shear	**1.5**	604.78	862.06	769.89	822.89	1173.34	172.01
	3.0	931.53	1413.06	1565.04	1604.80	1921.14	341.72
	4.5	1231.39	2022.70	2506.68	2533.18	2136.28	558.94
	Depth	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
Settlement	**1.5**	262.39	56.00	143.76	204.33	174.93	
	3.0	232.35	64.05	133.73	199.56	154.90	4.00 m
	4.5	177.78	82.30	137.74	157.82	118.52	

Borehole:3				**LPI**:3.69			
	Depth	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
Shear	**1.5**	602.84	857.75	771.00	822.98	1191.88	151.65
	3.0	904.76	1359.16	1554.70	1586.69	1483.83	309.85
	4.5	1180.94	1944.06	2398.30	2424.95	1701.00	512.29
	Depth	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
Settlement	**1.5**	234.51	57.39	121.23	177.68	156.34	
	3.0	175.78	86.77	118.03	148.70	117.18	3.40 m
	4.5	175.65	97.57	128.31	155.50	117.10	

Summary:

Depth	Shear	Deflection	LPI	Latitude	Longitude
1.5	818.28	174.93			
3.0	1500.18	133.73	4.13	27.720093	85.326259
4.5	1701.00	129.19			

Harihar Bhavan, Lalitpur

Borehole:1				**LPI**:31.76			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	504.99	606.41	690.43	700.17	909.05	67.50
	3.0	581.97	812.23	882.50	892.24	1229.70	97.02
	4.5	642.21	1015.89	1084.53	1094.77	1400.08	129.27
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	54.67	48.31	39.93	24.85	36.44	
	3.0	55.22	55.08	34.43	25.09	36.82	1.50 m
	4.5	56.06	59.56	33.09	25.99	37.37	

Borehole:2				**LPI**:34.15			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	504.31	623.88	700.75	710.50	890.19	67.50
	3.0	572.59	824.88	875.34	885.09	1100.32	103.07
	4.5	640.67	1046.07	1092.33	1102.09	1271.53	141.83
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	54.67	51.75	39.93	24.85	36.44	
	3.0	62.13	56.29	38.74	32.56	41.42	1.50 m
	4.5	66.68	58.65	39.36	37.50	44.45	

Borehole:3				**LPI**:27.66			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	639.78	813.72	898.36	913.99	1166.51	75.42
	3.0	747.79	1101.13	1173.22	1188.86	1565.30	104.51
	4.5	861.40	1430.64	1523.86	1539.74	1865.40	132.07
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	65.60	45.80	47.92	35.89	43.73	
	3.0	63.66	58.65	39.69	34.23	42.44	1.50 m
	4.5	58.59	54.35	34.58	28.73	39.06	

Summary:

Depth	Shear	Deflection	LPI	Latitude	Longitude
1.5	678.38	43.73			
3.0	862.33	41.42	31.19	27.680471	85.311110
4.5	1080.16	39.36			

Janamaitri Campus: Kuleswore, Kathmandu

Borehole:1				**LPI**:12.98			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	339.40	398.28	442.58	454.76	599.48	80.13
	3.0	456.63	616.30	675.89	691.07	978.72	139.17
	4.5	567.00	855.49	983.11	997.15	1091.47	191.79
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	131.20	78.18	91.05	71.79	87.46	
	3.0	123.14	80.96	64.97	63.92	82.09	6.00 m
	4.5	95.00	81.78	50.07	42.13	63.33	

Borehole:2				**LPI**:14.80			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	211.98	234.15	266.17	275.74	357.44	91.19
	3.0	268.44	342.29	393.12	401.97	564.82	147.39
	4.5	309.84	446.05	539.98	544.92	711.19	196.29
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	153.06	61.12	95.04	93.88	102.04	
	3.0	135.14	63.55	64.82	76.92	90.10	5.00 m
	4.5	72.49	65.42	49.21	35.11	48.33	

Borehole:3				**LPI**:25.17			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	302.48	358.25	387.62	404.84	177.57	70.77
	3.0	372.72	501.92	595.38	603.98	440.83	127.00
	4.5	411.64	620.71	767.00	772.87	399.30	169.43
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	109.33	107.17	55.91	49.70	72.89	
	3.0	66.57	80.28	43.42	28.69	44.38	3.50 m
	4.5	54.67	61.51	40.34	24.49	36.45	

Summary:

Depth	**Shear**	**Deflection**	**LPI**	**Latitude**	**Longitude**
1.5	258.69	91.05			
3.0	440.83	66.57	17.65	27.691730	85.290048
4.5	510.32	50.07			

Amrit Science Campus: Lainchour, Kathmandu

Borehole:1				**LPI**:1.02			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	319.25	411.98	397.69	426.43	677.61	152.45
	3.0	643.54	919.76	1028.41	1063.63	1058.57	329.10
	4.5	815.26	1266.86	1573.49	1606.07	1821.61	481.59
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	240.53	53.80	368.97	182.24	160.35	
	3.0	294.71	62.04	318.03	249.72	196.47	17.50 m
	4.5	298.70	71.84	264.49	254.05	199.14	

Borehole:2				LPI:1.62			
	Depth	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
Shear	**1.5**	343.40	443.16	427.79	458.70	719.36	152.45
	3.0	680.58	970.57	1087.59	1125.03	1107.77	316.10
	4.5	872.79	1354.85	1683.93	1719.35	1860.82	449.30
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	240.53	63.60	342.62	182.24	160.35	
	3.0	286.26	72.13	288.33	240.58	190.84	16.00 m
	4.5	283.86	82.09	235.64	237.97	189.24	

Summary:

Depth	Shear	Deflection	LPI	Latitude	Longitude
1.5	427.63	182.24			
3.0	1031.25	245.15	1.32	27.717759	85.310613
4.5	1534.09	236.81			

Mahendra Ratna Campus: Tahachal, Kathmandu

Borehole:1				LPI:49.49			
	Depth	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
Shear	**1.5**	158.40	171.97	202.26	204.82	234.47	54.21
	3.0	172.78	219.25	239.47	242.04	323.73	109.56
	4.5	187.16	271.12	288.19	290.76	365.27	184.04
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	65.60	42.60	39.29	35.89	43.73	
	3.0	90.20	50.10	48.45	62.96	60.13	0.60 m
	4.5	109.48	54.14	57.36	83.85	72.99	

Borehole:2				LPI:51.12			
	Depth	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
Shear	**1.5**	512.20	655.08	711.27	722.83	835.84	55.38
	3.0	591.72	884.15	899.34	910.91	775.91	110.97
	4.5	671.24	1137.73	1135.25	1146.81	645.54	185.73
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	65.60	49.90	39.77	35.89	43.73	
	3.0	90.20	60.71	48.88	62.96	60.13	0.65 m
	4.5	109.48	65.35	57.76	83.85	72.99	

Summary:

Depth	Shear	Deflection	LPI	Latitude	Longitude
1.5	213.74	43.16			
3.0	278.66	60.42	50.30	27.703457	85.298208
4.5	324.31	72.99			

Bhatbhateni Supermarket & Departmental Store: Satdobato, Lalitpur

Borehole:1				LPI:0.75			
Shear	Depth	Terzaghi*	Meyerhof	Hansen	Vesic	Plaxis	Teng
	1.5	136.15	130.08	157.63	157.63	286.27	1091.72
	3.0	471.96	658.41	807.95	825.37	164.71	592.51
	4.5	133.02	160.89	154.51	154.51	216.90	372.42
Settlement	Depth	Bowels	Plaxis	Peck	Teng	Meyerhof	WL
	1.5	765.31	50.13	391.34	712.41	510.21	
	3.0	279.44	75.86	182.28	259.23	186.30	3.50 m
	4.5	138.55	76.16	102.23	115.33	92.37	

Borehole:2				LPI:0.16			
Shear	Depth	Terzaghi*	Meyerhof	Hansen	Vesic	Plaxis	Teng
	1.5	622.55	880.90	780.76	834.66	286.12	664.96
	3.0	1016.03	1533.06	1725.65	1761.82	164.16	750.84
	4.5	137.75	166.63	160.02	160.02	215.42	714.70
Settlement	Depth	Bowels	Plaxis	Peck	Teng	Meyerhof	WL
	1.5	575.62	76.84	297.58	522.29	383.75	
	3.0	309.06	76.42	207.53	293.04	206.04	3.40 m
	4.5	217.26	85.76	158.71	200.57	144.84	

Borehole:3				LPI:0.23			
Shear	Depth	Terzaghi*	Meyerhof	Hansen	Vesic	Plaxis	Teng
	1.5	1001.16	1494.75	1238.51	1322.54	312.96	1259.14
	3.0	1281.91	1982.98	2174.06	2218.42	180.03	1157.50
	4.5	152.28	184.21	176.89	176.89	1484.92	764.33
Settlement	Depth	Bowels	Plaxis	Peck	Teng	Meyerhof	WL
	1.5	789.37	83.57	412.74	739.74	526.24	
	3.0	378.36	73.40	261.95	369.83	252.24	3.30 m
	4.5	227.93	65.52	164.82	212.12	151.95	

Summary:

Depth	Shear	Deflection	LPI	Latitude	Longitude
1.5	664.96	510.21			
3.0	750.84	252.24	0.38	27.657122	85.320020
4.5	216.90	144.84			

Nepal Mountaineering Association : Naxal, Nagpokhari Kathmandu

Borehole:1				LPI:2.14			
Shear	Depth	Terzaghi*	Meyerhof	Hansen	Vesic	Plaxis	Teng
	1.5	432.33	561.82	554.39	585.39	816.59	62.59
	3.0	636.72	905.87	1089.25	1106.96	1279.45	189.52
	4.5	779.81	1231.50	1553.81	1571.52	1310.33	325.68
Settlement	Depth	Bowels	Plaxis	Peck	Teng	Meyerhof	WL
	1.5	76.53	51.20	41.53	24.16	51.02	
	3.0	96.93	55.60	74.38	70.26	64.62	3.00 m
	4.5	130.81	62.60	91.69	106.94	87.20	

Borehole:2				LPI:1.18			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	569.87	782.05	721.00	767.27	857.82	193.28
	3.0	832.79	1230.16	1408.65	1437.57	1034.65	362.79
	4.5	1060.18	1721.76	2128.70	2151.84	867.55	477.20
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	284.26	71.04	145.35	226.42	189.51	
	3.0	204.30	72.81	133.26	177.86	136.20	3.50 m
	4.5	166.02	71.13	122.50	145.08	110.68	

Summary:

Depth	Shear	Deflection	LPI	Latitude	Longitude
1.5	661.99	73.78			
3.0	1034.34	85.66	1.66	27.713026	85.321666
4.5	1088.94	108.81			

Patanjali Yogpeeth Nepal : Mandikatar, Kathmandu

Borehole:1				LPI:1.04			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	647.80	916.64	801.83	858.35	328.15	716.52
	3.0	904.60	1370.03	1516.92	1555.95	635.86	959.42
	4.5	984.77	1573.71	2006.78	2028.03	340.81	788.10
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	612.25	59.22	335.43	557.77	408.17	
	3.0	437.47	65.15	251.79	421.69	291.65	4.00 m
	4.5	221.15	78.91	171.34	204.78	147.43	

Borehole:2				LPI:2.04			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	137.38	131.26	159.07	159.07	159.81	267.30
	3.0	137.38	148.39	159.07	159.07	630.83	558.98
	4.5	929.48	1488.33	1888.09	1909.33	406.14	634.60
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	349.86	68.49	178.90	292.69	233.24	
	3.0	269.78	66.67	175.98	248.77	179.86	3.50 m
	4.5	200.33	76.79	147.82	182.23	133.55	

Borehole:3				LPI:0.01			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	151.00	144.27	174.83	174.83	174.35	216.26
	3.0	151.00	163.09	174.83	174.83	402.88	516.33
	4.5	677.12	1036.69	1391.63	1405.84	233.33	750.72
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	306.13	84.60	178.90	248.51	204.08	
	3.0	351.29	66.79	182.93	319.68	234.20	4.50 m
	4.5	207.63	87.74	168.53	190.14	138.42	

Summary:

Depth	Shear	Deflection	LPI	Latitude	Longitude
1.5	216.26	248.51			
3.0	558.98	248.77	1.03	27.741145	85.345547
4.5	750.72	168.53			

Mandikhatar, Kathmandu

Borehole:1				**LPI**:0.15			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	141.10	134.81	163.37	163.37	305.94	91.19
	3.0	966.58	1485.45	1565.78	1618.38	374.94	517.18
	4.5	1014.27	1619.74	1948.58	1987.68	207.68	819.37
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	153.06	60.93	139.76	93.88	102.04	
	3.0	397.30	64.03	266.77	360.82	264.86	9.00 m
	4.5	423.92	65.01	242.42	389.65	282.61	

Borehole:2				**LPI**:3.08			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	939.46	1380.06	1143.05	1223.80	535.63	1152.13
	3.0	677.07	975.29	1084.80	1121.04	361.43	838.62
	4.5	878.11	1376.57	1715.10	1745.29	284.11	627.77
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	787.18	69.82	546.27	734.50	524.79	
	3.0	528.37	69.49	278.76	502.77	352.25	6.00 m
	4.5	316.08	76.22	166.59	281.54	210.72	

Borehole:3				**LPI**:3.38			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	143.57	137.18	166.23	166.23	166.39	103.95
	3.0	143.57	155.07	166.23	166.23	204.05	348.88
	4.5	143.57	172.96	166.23	166.23	918.74	1055.59
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	174.93	88.44	127.78	115.97	116.62	
	3.0	307.11	102.54	169.39	263.16	204.74	6.50 m
	4.5	492.93	128.37	236.42	464.39	328.62	

Summary:

Depth	Shear	Deflection	LPI	Latitude	Longitude
1.5	166.39	127.78			
3.0	374.94	266.77	2.20	27.738776	85.345348
4.5	819.37	281.54			

CIWEC Clinic: Lainchaur, Kathmandu

Borehole:1				LPI:4.71			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	625.33	890.74	798.62	852.35	1173.70	267.30
	3.0	1010.34	1556.98	1636.87	1690.59	1349.10	379.56
	4.5	1395.35	2348.27	2680.98	2734.71	870.53	491.58
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	349.86	102.47	293.90	292.69	233.24	
	3.0	325.42	114.91	202.90	282.99	216.95	8.00 m
	4.5	303.15	126.92	162.17	258.87	202.10	

Borehole:2				LPI:7.17			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	853.97	1221.20	1042.54	1114.43	1356.23	152.45
	3.0	1358.46	2122.85	2138.75	2210.64	453.08	271.98
	4.5	1862.95	3197.51	3492.72	3564.61	1269.90	359.85
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	240.53	78.17	184.49	182.24	160.35	
	3.0	255.52	88.63	147.06	207.29	170.35	7.00 m
	4.5	237.94	94.93	118.51	188.24	158.63	

Borehole:3				LPI:1.97			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	725.92	1026.96	897.30	959.08	1308.51	103.95
	3.0	1164.45	1795.47	1851.13	1912.91	1984.93	240.70
	4.5	1602.98	2710.25	3034.32	3096.10	2244.38	450.62
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	174.93	50.28	159.73	115.97	116.62	
	3.0	231.27	80.93	155.29	181.02	154.18	9.00 m
	4.5	284.48	111.36	162.68	238.65	189.65	

Summary:

Depth	**Shear**	**Deflection**	**LPI**	**Latitude**	**Longitude**
1.5	961.11	174.93			
3.0	1349.10	181.02	4.62	27.720400	85.315550
4.5	1269.90	188.24			

Vastukala Pharamarsha Nepal : Kupondole, Lalitpur

Borehole:1				LPI:2.18			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	151.00	144.27	174.83	174.83	174.35	216.26
	3.0	151.00	163.09	174.83	174.83	526.99	675.77
	4.5	1127.54	1839.40	2167.57	2211.28	846.02	1150.34
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	306.13	98.98	257.16	248.51	204.08	
	3.0	466.59	112.38	290.92	435.86	311.06	8.00 m
	4.5	518.04	114.79	277.13	491.58	345.36	

Borehole:2				LPI:3.12			
	Depth	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
Shear	**1.5**	163.37	156.10	189.16	189.16	1085.73	216.26
	3.0	997.39	1531.92	1603.59	1657.54	1011.43	739.65
	4.5	1162.87	1907.21	2236.65	2281.82	876.43	1107.93
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	306.13	101.04	257.16	248.51	204.08	
	3.0	491.75	105.79	306.61	463.11	327.83	8.00 m
	4.5	506.95	110.59	271.20	479.57	337.97	

Summary:

Depth	Shear	Deflection	LPI	Latitude	Longitude
1.5	197.20	248.51			
3.0	707.71	319.44	2.65	27.683757	85.316340
4.5	1129.13	341.66			

Building: Kupondole, Lalitpur

Borehole:1				LPI:15.75			
	Depth	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
Shear	**1.5**	159.32	152.21	184.52	184.52	182.10	166.20
	3.0	154.18	166.97	179.38	179.38	218.16	193.82
	4.5	149.48	182.17	174.69	174.69	248.21	301.07
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	142.13	66.86	101.75	113.21	94.75	
	3.0	128.67	76.59	78.99	104.63	85.78	1.40 m
	4.5	146.52	90.50	85.41	123.96	97.68	

Borehole:2				LPI:10.48			
	Depth	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
Shear	**1.5**	153.47	146.64	177.70	177.70	177.10	226.20
	3.0	151.96	164.25	176.18	176.18	213.83	241.51
	4.5	147.43	178.85	171.66	171.66	244.02	250.72
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	245.99	74.97	143.76	202.95	164.00	
	3.0	130.07	76.09	93.57	106.14	86.71	2.50 m
	4.5	110.48	78.81	73.37	84.93	73.65	

Borehole:3				LPI:5.89			
	Depth	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
Shear	**1.5**	162.14	154.92	187.73	187.73	186.36	248.87
	3.0	160.21	173.20	185.81	185.81	223.91	394.47
	4.5	155.33	188.52	180.92	180.92	256.60	402.46
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	253.65	91.33	150.78	212.20	169.10	
	3.0	186.63	92.31	132.48	167.40	124.42	2.40 m
	4.5	162.46	87.15	106.69	141.23	108.31	

Summary:

Depth	Shear	Deflection	LPI	Latitude	Longitude
1.5	177.10	143.76			
3.0	213.83	104.63	10.71	27.686284	85.314701
4.5	248.21	97.68			

NAST Technology : Khumaltar, Lalitpur

Borehole:1				**LPI**:17.31			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	117.58	112.34	136.14	136.14	138.83	187.75
	3.0	117.58	127.00	136.14	136.14	168.73	206.66
	4.5	112.94	137.02	131.50	131.50	193.38	186.09
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	248.73	63.79	134.97	198.12	165.82	
	3.0	105.71	53.96	81.12	79.76	70.47	3.00 m
	4.5	72.68	53.87	50.95	43.99	48.45	

Borehole:2				**LPI**:15.85			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	118.82	113.53	137.57	137.57	140.18	149.28
	3.0	118.82	128.33	137.57	137.57	169.97	168.72
	4.5	114.46	138.78	133.21	133.21	195.30	179.93
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	216.47	58.81	115.96	164.02	144.32	
	3.0	89.10	51.77	65.94	60.04	59.40	3.10 m
	4.5	67.56	56.77	47.86	38.45	45.04	

Borehole:3				**LPI**:17.23			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	110.15	105.25	127.54	127.54	130.86	89.59
	3.0	110.15	118.98	127.54	127.54	158.84	145.52
	4.5	105.53	128.08	122.92	122.92	182.06	178.68
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	133.93	57.01	72.68	82.14	89.29	
	3.0	69.49	50.98	53.33	40.54	46.33	3.00 m
	4.5	68.22	57.17	47.82	39.17	45.48	

Summary:

Depth	Shear	Deflection	LPI	Latitude	Longitude
1.5	130.86	133.93			
3.0	158.84	60.04	16.80	27.656103	85.327675
4.5	179.93	48.45			

Building: Khumaltar, Lalitpur

Borehole:1				LPI:9.34			
	Depth	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
Shear	**1.5**	101.49	96.97	117.51	117.51	121.71	216.26
	3.0	101.49	109.62	117.51	117.51	148.92	355.16
	4.5	101.49	122.27	117.51	117.51	172.63	319.44
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	306.13	76.61	212.44	248.51	204.08	
	3.0	310.95	73.44	164.05	267.31	207.30	6.00 m
	4.5	188.77	68.58	99.49	143.67	125.85	

Borehole:2				LPI:13.06			
	Depth	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
Shear	**1.5**	97.78	93.42	113.21	113.21	117.31	80.13
	3.0	97.78	105.61	113.21	113.21	143.50	138.32
	4.5	97.78	117.79	113.21	113.21	166.34	201.91
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	131.20	56.11	88.65	71.79	87.46	
	3.0	121.82	62.92	62.81	62.50	81.22	5.75 m
	4.5	98.39	66.74	54.73	50.13	65.59	

Summary:

Depth	Shear	Deflection	LPI	Latitude	Longitude
1.5	113.99	109.92			
3.0	140.91	101.52	11.20	27.648702	85.320339
4.5	169.48	83.48			

Building: Kalopul, Pumori, Kathmandu

Borehole:1				LPI:4.04			
	Depth	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
Shear	**1.5**	568.65	778.42	789.59	819.82	995.63	210.52
	3.0	808.71	1232.72	1360.77	1391.01	1283.38	271.42
	4.5	1048.78	1768.86	2060.30	2090.54	1024.54	316.02
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	180.40	39.72	118.60	151.87	120.26	
	3.0	174.53	46.44	100.45	154.29	116.35	1.00 m
	4.5	158.99	56.48	87.99	137.47	106.00	

Borehole:2				LPI:8.23			
	Depth	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
Shear	**1.5**	437.62	583.39	610.43	633.25	864.43	181.14
	3.0	619.20	919.63	1046.36	1069.18	1145.15	241.90
	4.5	800.79	1315.05	1584.29	1607.11	1296.79	280.54
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	164.00	37.41	107.82	135.30	109.33	
	3.0	161.50	45.48	92.95	140.19	107.67	1.00 m
	4.5	145.94	53.87	80.76	123.33	97.29	

Summary:

Depth	Shear	Deflection	LPI	Latitude	Longitude
1.5	702.48	119.43	6.14	27.711828	85.335359
3.0	1078.44	112.01			
4.5	1160.66	101.64			

Building Site : Gwarkho, Lalitpur

Borehole:1				**LPI**:16.40			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	90.35	86.33	104.61	104.61	109.63	80.13
	3.0	90.35	97.59	104.61	104.61	281.31	318.94
	4.5	1047.23	1685.85	2109.94	2135.96	129.06	339.20
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	131.20	61.22	80.50	71.79	87.46	4.90 m
	3.0	281.57	66.47	137.12	237.23	187.71	
	4.5	139.25	54.58	97.61	109.14	92.83	

Borehole:2				**LPI**:21.67			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	96.54	92.24	111.78	111.78	116.04	80.13
	3.0	96.54	104.27	111.78	111.78	141.92	137.94
	4.5	94.32	114.08	109.55	109.55	163.29	188.36
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	131.20	54.64	69.96	71.79	87.46	3.80 m
	3.0	87.28	54.76	52.63	45.92	58.19	
	4.5	62.99	61.90	47.87	33.49	41.99	

Summary:

Depth	Shear	Deflection	LPI	Latitude	Longitude
1.5	101.89	76.15	19.03	27.666007	85.328472
3.0	139.93	76.88			
4.5	175.82	62.44			

Building: Kumaripati, Lalitpur

Borehole:1				**LPI**:0.00			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	1640.19	2525.46	1944.06	2077.96	292.28	976.01
	3.0	2524.14	4267.29	3858.23	3992.14	514.32	1845.16
	4.5	3408.09	6352.18	6178.12	6312.02	479.33	2151.19
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	721.58	151.54	606.17	668.23	481.05	8.00 m
	3.0	811.85	145.72	506.19	809.76	541.23	
	4.5	732.43	139.84	391.83	723.76	488.29	

Borehole:2				LPI:0.00			
	Depth	Terzaghi*	Meyerhof	Hansen	Vesic	Plaxis	Teng
Shear	1.5	1333.58	2125.37	1692.29	1805.81	450.71	976.01
	3.0	2096.23	3598.51	3344.94	3458.46	523.68	1565.73
	4.5	2858.88	5358.08	5357.89	5471.40	690.11	1805.47
	Depth	Bowels	Plaxis	Peck	Teng	Meyerhof	WL
Settlement	1.5	721.58	141.53	606.17	668.23	481.05	
	3.0	744.06	141.33	463.93	736.35	496.04	8.00 m
	4.5	666.22	135.81	356.40	652.06	444.15	

Summary:

Depth	Shear	Deflection	LPI	Latitude	Longitude
1.5	976.01	606.17			
3.0	1705.44	523.71	0.00	27.670255	85.318625
4.5	1978.33	466.22			

Building: Kupandole, Lalitpur

Borehole:1				LPI:24.78			
	Depth	Terzaghi*	Meyerhof	Hansen	Vesic	Plaxis	Teng
Shear	1.5	94.06	89.88	108.91	108.91	113.20	67.50
	3.0	89.61	97.14	104.46	104.46	134.91	105.96
	4.5	85.05	104.31	99.90	99.90	155.18	149.38
	Depth	Bowels	Plaxis	Peck	Teng	Meyerhof	WL
Settlement	1.5	54.67	44.74	39.93	24.85	36.44	
	3.0	65.17	48.63	40.64	35.86	43.45	1.50 m
	4.5	72.32	53.21	42.69	43.60	48.21	

Borehole:2				LPI:16.40			
	Depth	Terzaghi*	Meyerhof	Hansen	Vesic	Plaxis	Teng
Shear	1.5	106.44	101.70	123.24	123.24	126.62	90.55
	3.0	106.44	114.97	123.24	123.24	154.43	142.95
	4.5	102.88	124.67	119.68	119.68	176.49	187.89
	Depth	Bowels	Plaxis	Peck	Teng	Meyerhof	WL
Settlement	1.5	145.41	53.20	76.03	89.19	96.94	
	3.0	77.10	61.46	53.38	43.57	51.40	3.30 m
	4.5	69.55	65.44	50.30	40.61	46.37	

Summary:

Depth	Shear	Deflection	LPI	Latitude	Longitude
1.5	107.88	53.93			
3.0	127.70	50.01	20.59	27.687034	85.309302
4.5	152.28	49.25			

Nepal Rastra Bank: Thapathali

Borehole:1				**LPI:**1.21			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	353.77	397.00	451.23	462.51	501.83	70.77
	3.0	426.36	555.17	616.22	626.09	921.66	138.71
	4.5	490.37	722.16	826.28	831.91	1094.29	256.28
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	109.33	69.79	63.89	49.70	72.89	
	3.0	108.37	75.72	56.43	56.61	72.25	4.50 m
	4.5	87.84	92.47	71.29	60.41	58.56	

Borehole:2				**LPI:**7.57			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	579.84	719.46	767.47	791.12	590.23	70.77
	3.0	741.72	1053.32	1138.93	1159.63	1040.33	135.53
	4.5	882.11	1397.53	1601.68	1613.51	1915.83	221.55
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	109.33	111.95	63.89	49.70	72.89	
	3.0	103.93	82.96	54.12	51.80	69.29	4.50 m
	4.5	72.31	93.41	58.69	43.60	48.21	

Borehole:3				**LPI:**4.73			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	327.36	387.37	422.20	438.58	44.83	134.58
	3.0	437.69	590.61	674.11	688.43	409.75	178.34
	4.5	531.74	799.79	986.11	994.13	1240.96	256.71
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	218.66	92.03	127.78	160.15	145.77	
	3.0	153.17	73.96	79.76	105.13	102.12	4.50 m
	4.5	88.01	82.36	71.44	60.60	58.68	

Borehole:4				**LPI:**8.25			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	206.81	230.55	259.01	269.50	21.89	103.95
	3.0	273.83	351.77	411.09	420.28	590.23	199.37
	4.5	331.23	478.91	601.60	606.74	768.18	247.48
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	174.93	61.54	102.23	115.97	116.62	
	3.0	172.28	65.43	89.71	125.82	114.85	4.50 m
	4.5	84.18	64.26	68.32	56.44	56.12	

Borehole:5				**LPI:**5.45			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	295.42	345.13	379.49	394.05	527.52	91.19
	3.0	381.14	509.48	595.26	604.35	836.06	182.63
	4.5	439.42	658.26	800.56	807.73	1036.69	286.12
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	153.06	42.49	78.27	93.88	102.04	
	3.0	115.03	78.90	75.03	81.18	76.69	3.50 m
	4.5	110.93	80.33	81.86	85.42	73.96	

Borehole:6				**LPI**:2.30			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	310.36	360.70	398.64	412.94	554.85	424.70
	3.0	394.26	526.04	610.02	618.96	904.12	520.27
	4.5	440.44	660.20	786.89	794.04	1015.84	607.48
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	459.19	83.86	234.80	403.14	306.13	
	3.0	258.18	88.40	168.41	236.20	172.12	3.50 m
	4.5	194.85	93.80	143.77	176.29	129.90	

Summary:

Depth	**Shear**	**Deflection**	**LPI**	**Latitude**	**Longitude**
1.5	381.82	105.78			
3.0	577.35	85.68	4.92	27.690232	85.319926
4.5	761.85	77.14			

Exam Mega Hall Construction Project : Kirtipur, Kathmandu

Borehole:1				**LPI**:8.56			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	282.20	358.07	352.57	378.39	506.38	91.19
	3.0	462.48	641.01	750.46	775.82	960.92	160.08
	4.5	642.09	973.41	1251.28	1276.78	1008.88	203.89
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	153.06	58.47	134.17	93.88	102.04	
	3.0	151.83	60.62	98.31	95.00	101.22	8.50 m
	4.5	121.80	64.23	67.41	62.48	81.20	

Borehole:2				**LPI**:10.13			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	326.13	417.81	409.41	439.29	502.64	103.95
	3.0	457.87	626.91	744.49	768.78	936.96	150.13
	4.5	645.31	972.94	1262.47	1287.15	942.56	184.39
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	174.93	55.13	153.34	115.97	116.62	
	3.0	138.92	58.94	89.95	81.01	92.61	8.50 m
	4.5	98.06	61.99	54.26	36.76	65.37	

Borehole:3				**LPI**:6.85			
Shear	**Depth**	**Terzaghi***	**Meyerhof**	**Hansen**	**Vesic**	**Plaxis**	**Teng**
	1.5	276.38	344.52	342.44	367.72	479.18	70.77
	3.0	431.89	591.78	703.40	726.11	910.86	132.35
	4.5	590.07	886.78	1154.81	1177.24	1186.15	194.75
Settlement	**Depth**	**Bowels**	**Plaxis**	**Peck**	**Teng**	**Meyerhof**	**WL**
	1.5	109.33	51.99	103.82	49.70	72.89	
	3.0	112.20	59.08	78.03	52.07	74.80	9.50 m
	4.5	111.30	68.83	65.70	51.10	74.20	

Summary:

Depth	Shear	Deflection	LPI	Latitude	Longitude
1.5	363.01	103.82	8.51	27.684264	85.295363
3.0	713.39	89.95			
4.5	1008.88	65.70			

C.Figures And Charts

C.1. PLAXIS

Plaxis2d file URL: `https://github.com/rdmorgnzation/soilbearing/blob/main/media/testdata/BHLog.plxzip`

Start a new project with axisymmetry since it is for circular footing.

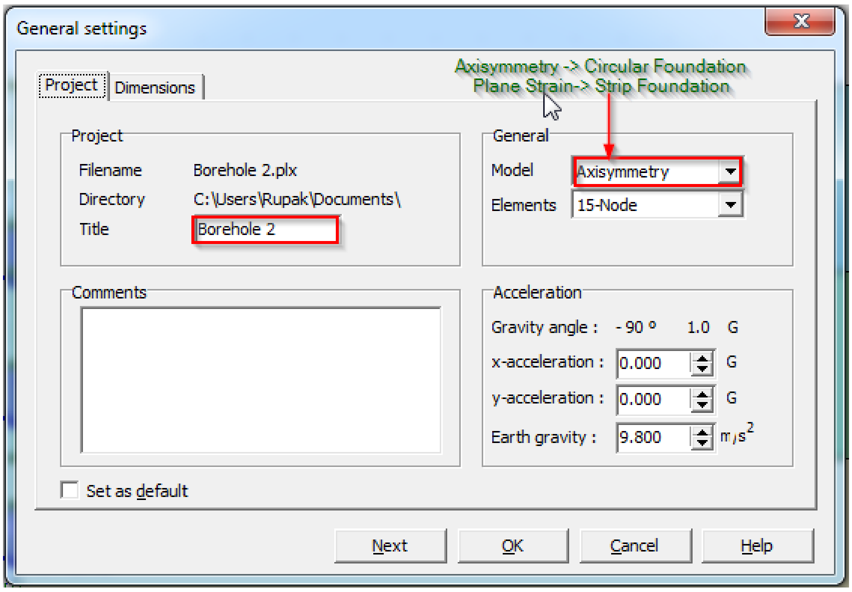


Figure C.1.: Project Options

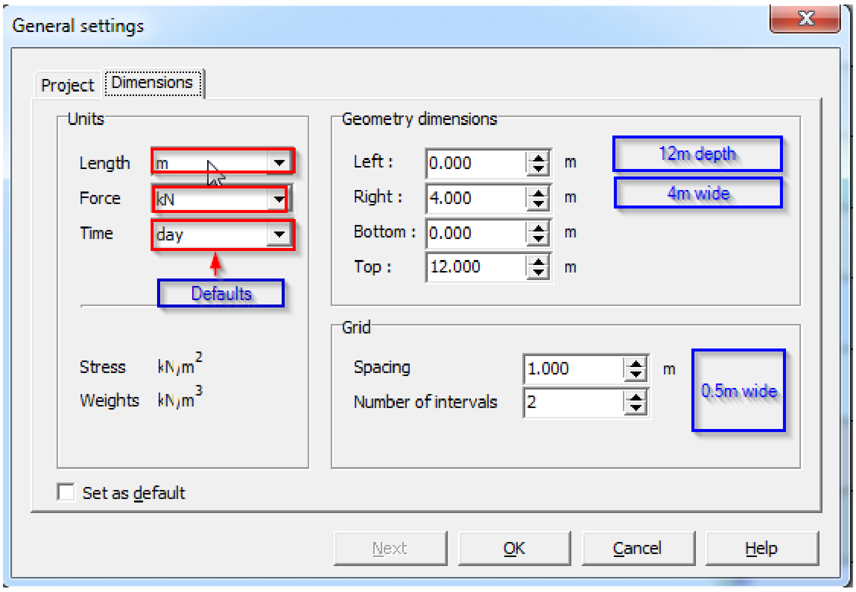


Figure C.2.: Dimension Options

Create a new model for soil with displacements.

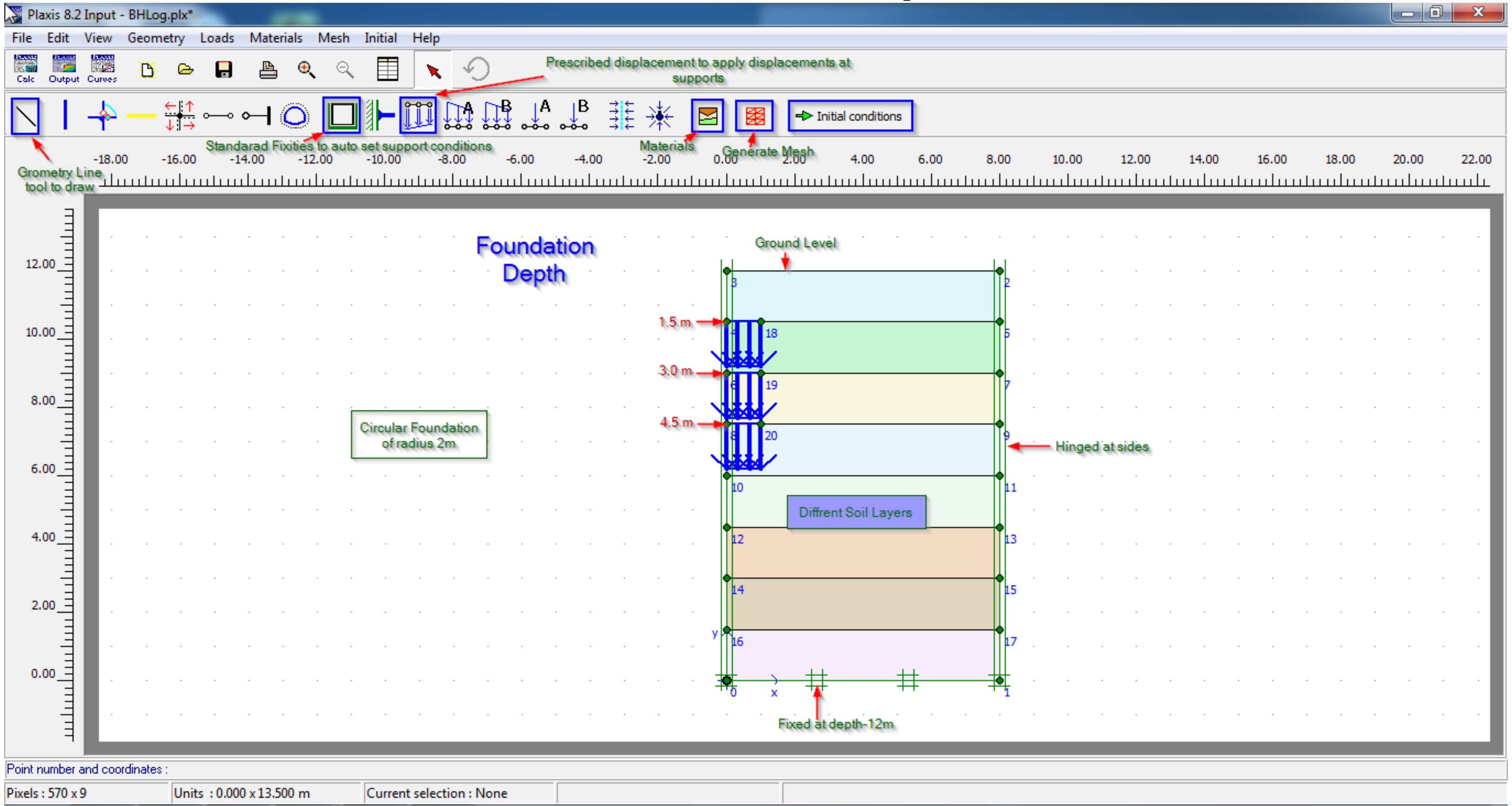


Figure C.3.: Main drawing page

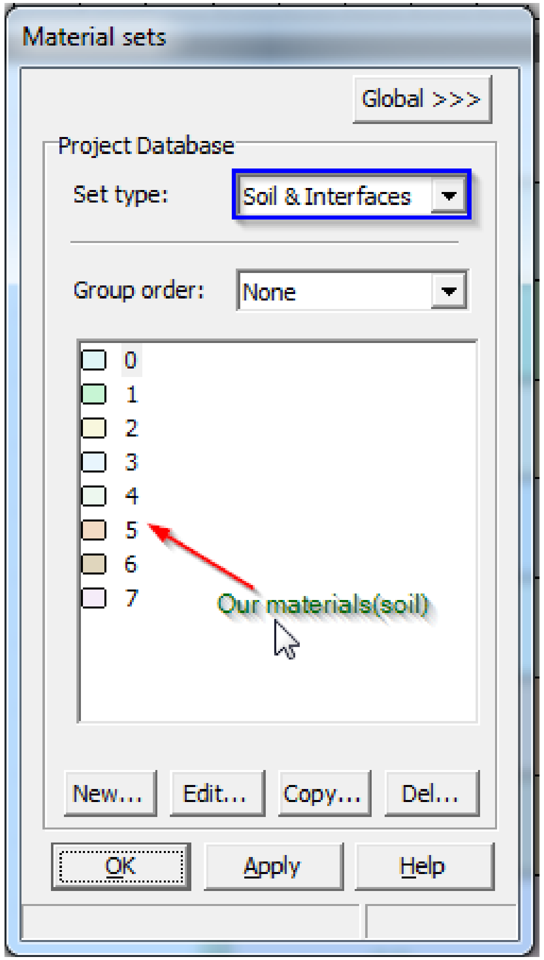


Figure C.4.: Soil List(Materials)

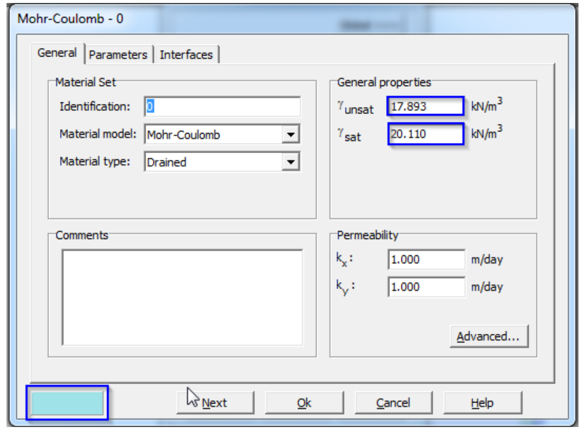


Figure C.5.: General Soil Parameters

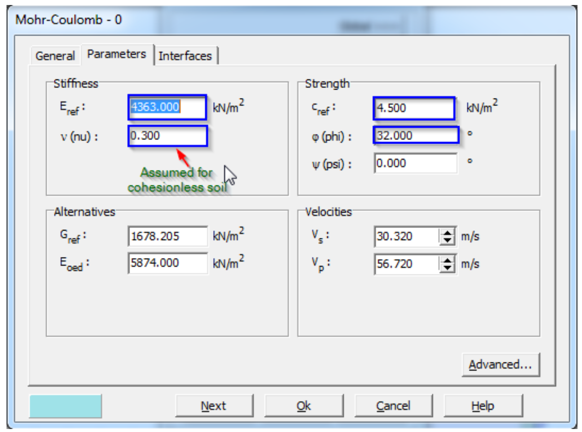


Figure C.6.: Other Soil Parameters

Create materials as in the sample calculation.

Generate Mesh

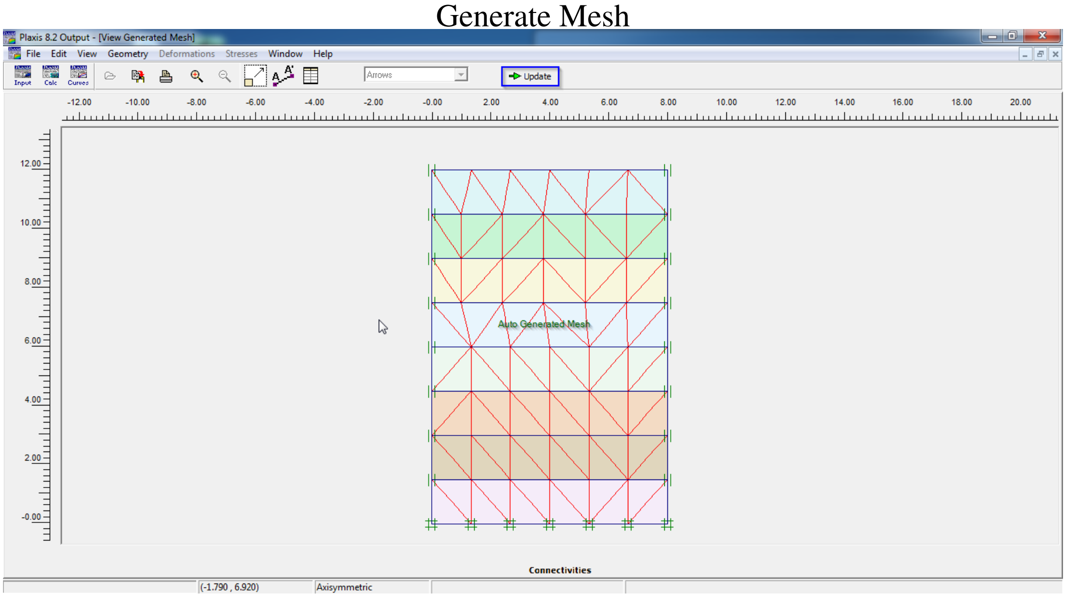


Figure C.7.: Auto generated mesh

Go to initial conditions, and create ground water line.

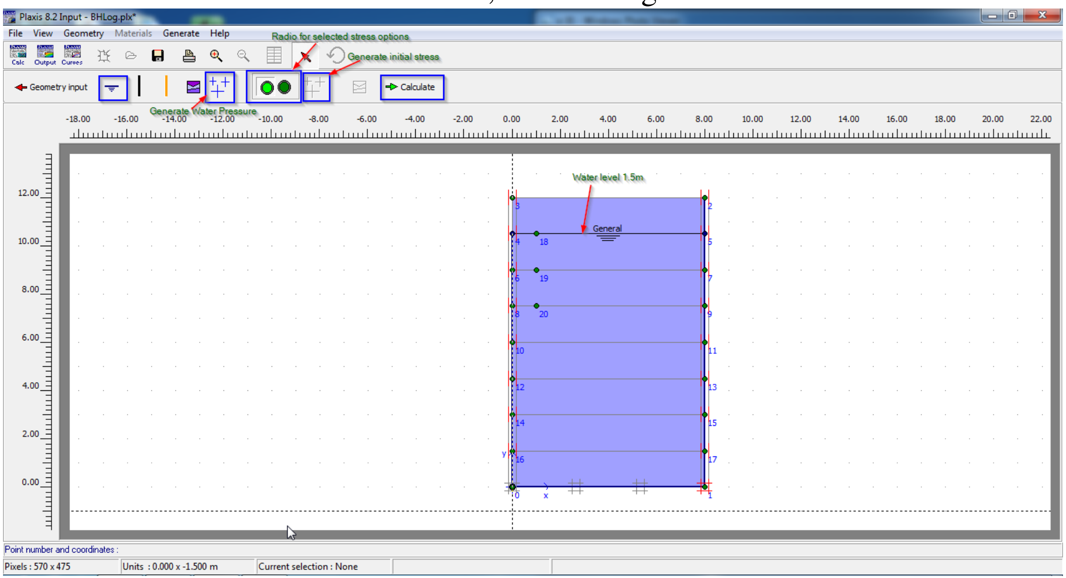


Figure C.8.: Ground Water Options

Go with default options.

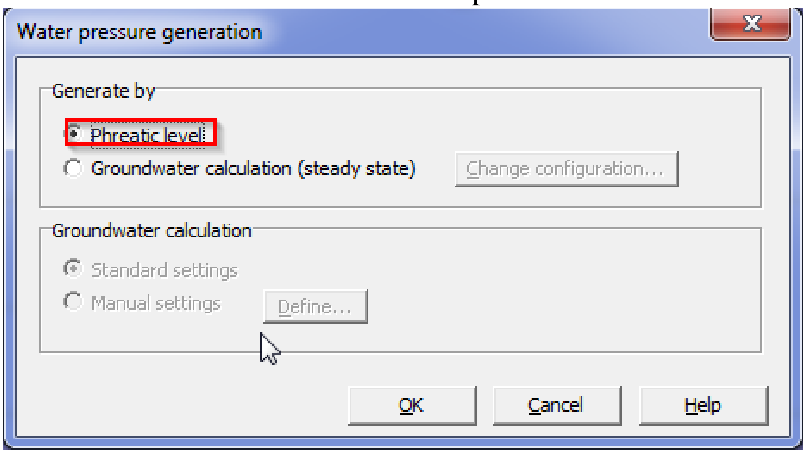


Figure C.9.: Water pressure generation options

Generate pore water pressure.

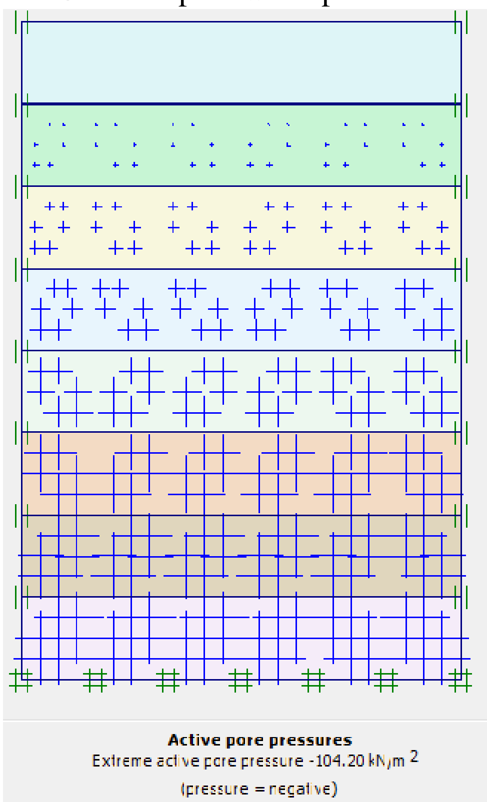


Figure C.10.: Generated pore water pressures

Generate K0 stresses now, but in this sample it will be calculated later. Now go to calculation.

Create calulation steps as in fig.

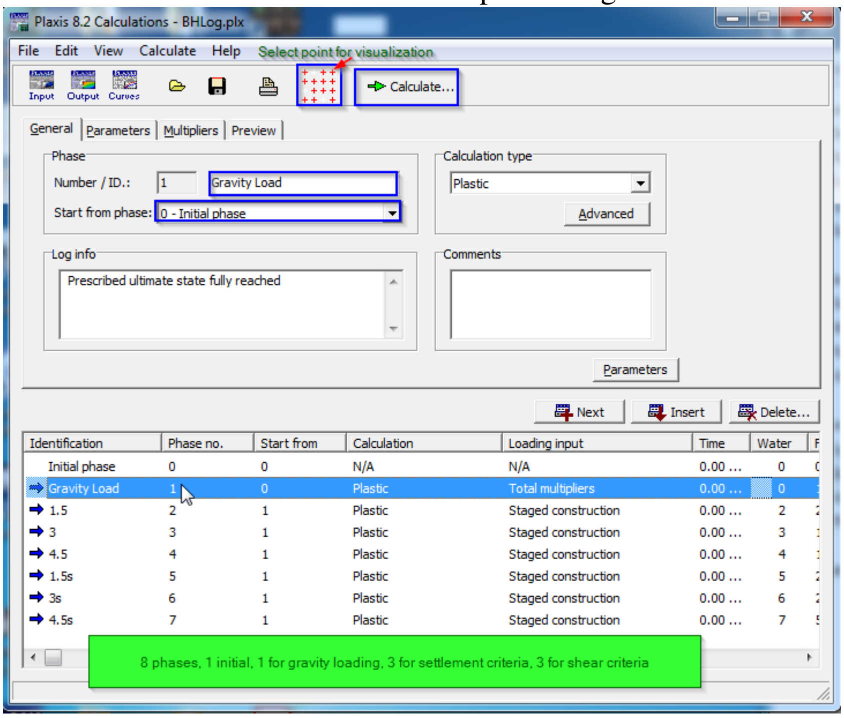


Figure C.11.: Main calculation dialog

For calculating stress due to self wt, set up as follows.

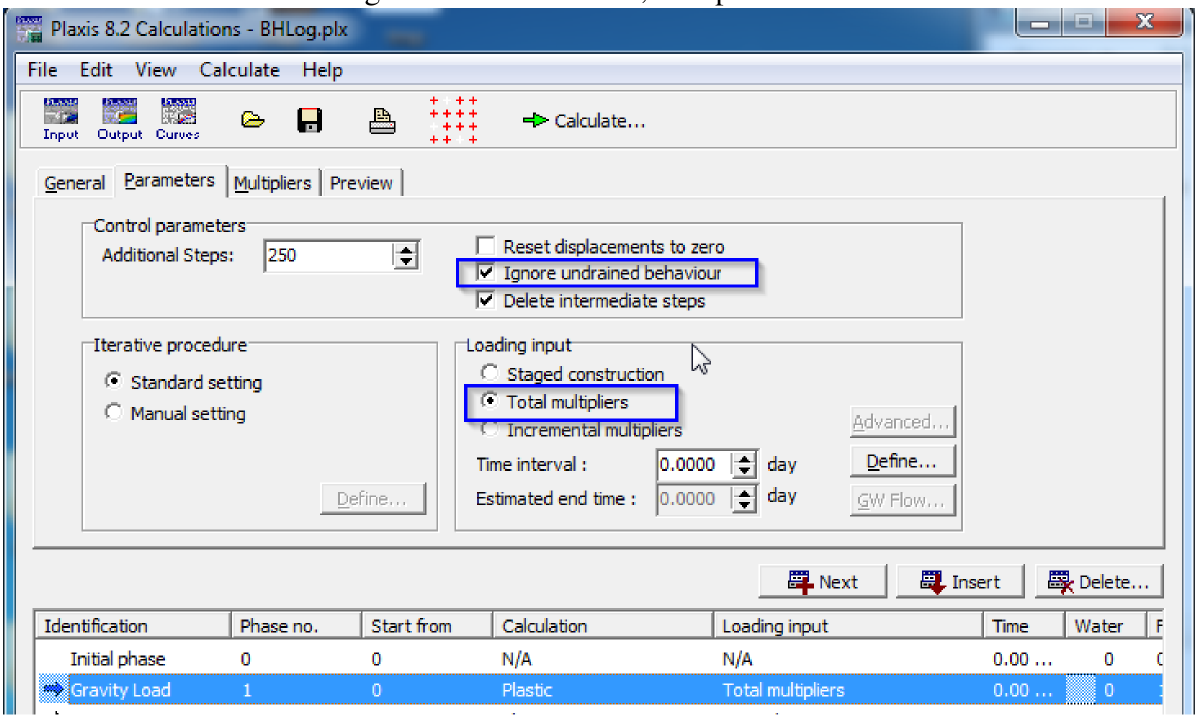


Figure C.12.: Parameters tab

Set MWeight to 1, ie. Self weight.

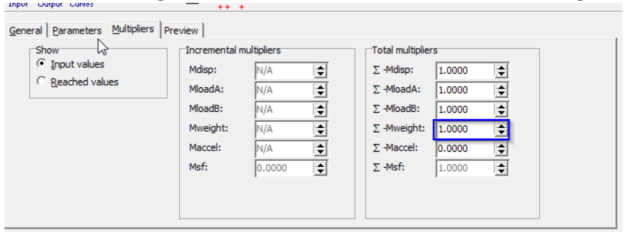


Figure C.13.: Multipliers Dialog

Add new phases for capacity calculation.

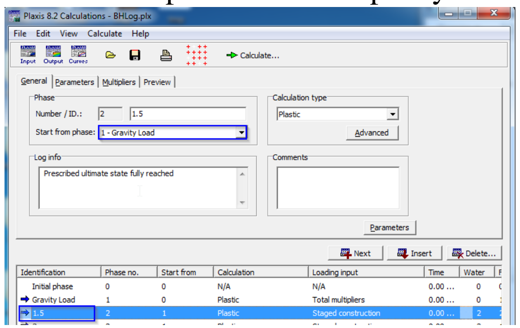


Figure C.14.: New phase

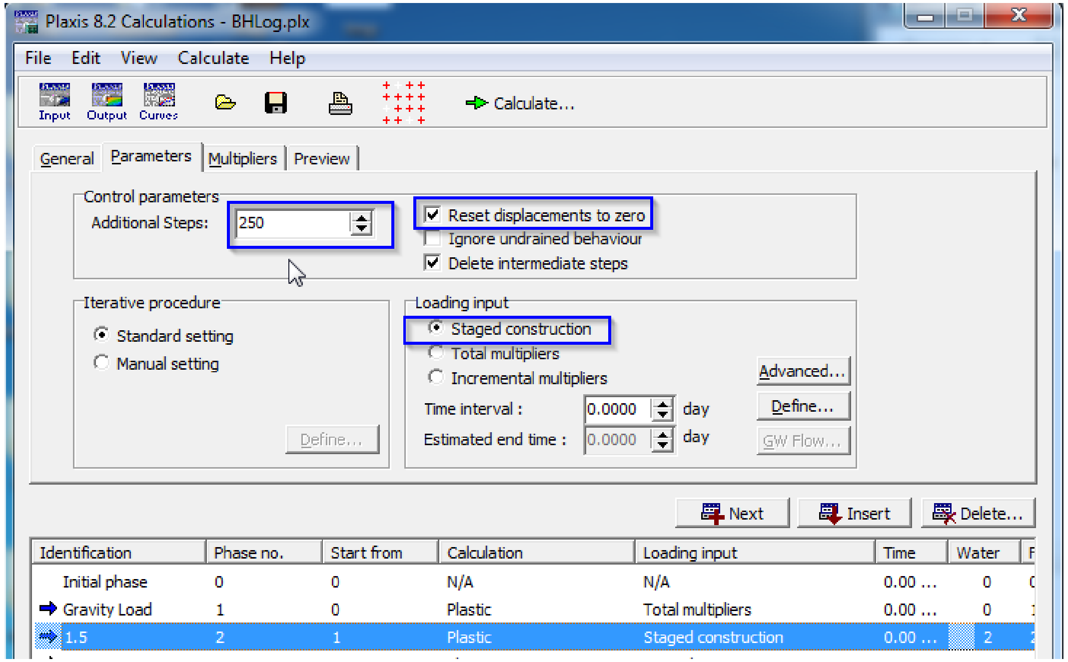


Figure C.15.: Parameters for capacity

Set parameters.

Enable Displacement on required depth.

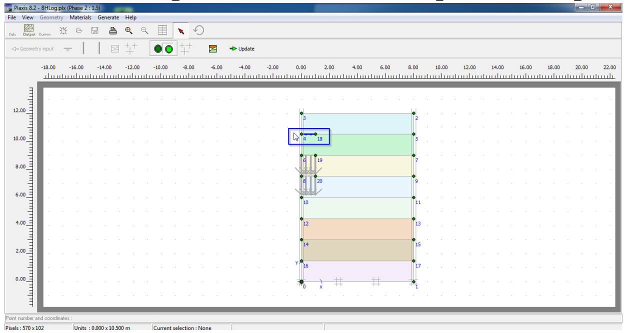


Figure C.16.: Define Dialog

Double click to set displacement value.

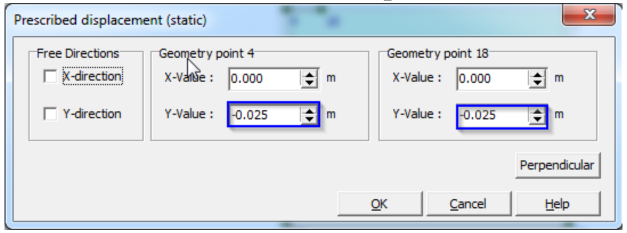


Figure C.17.: Prescribed displacement dialog.

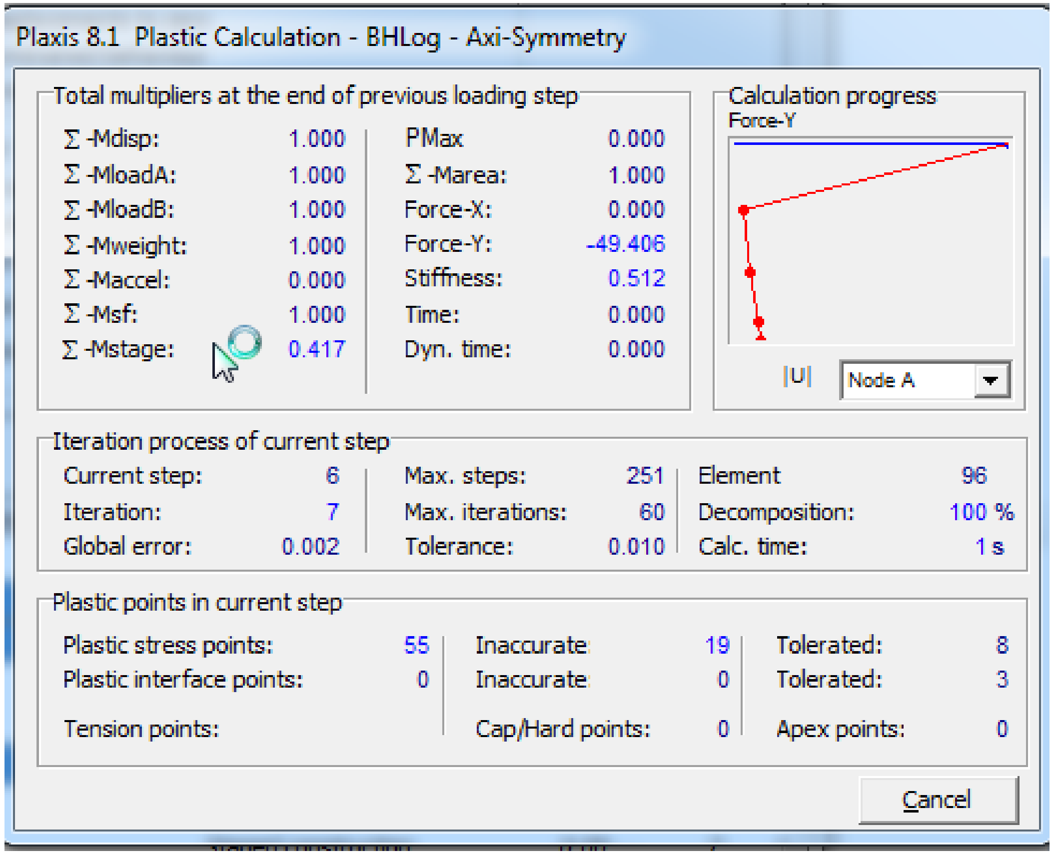


Figure C.18.: Calculation Progress Dialog

After setting all up start calculation.

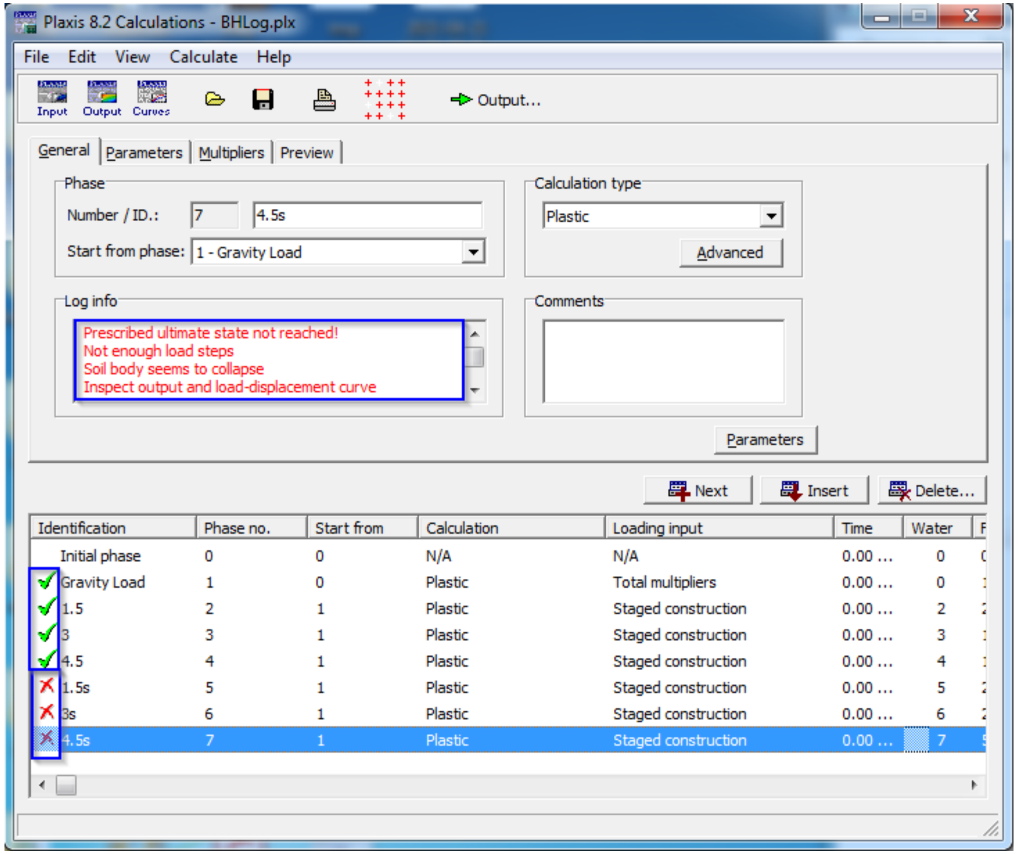


Figure C.19.: Log file

This will not always work as the force will decrease (mostly in shear). If that is case check for output diagram. Here log as in figure is used which is saved in .LAV file.

Check results for capacity. For shear these should fail.

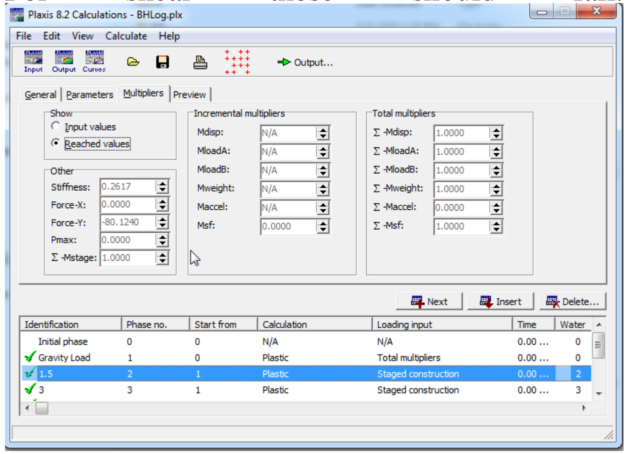


Figure C.20.: Calculation dialog after calculation is complete.

Check multipliers >Reached Values >Force-Y.

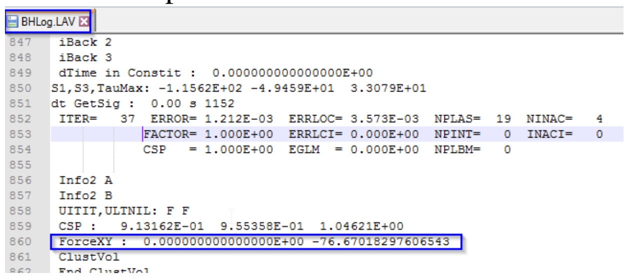


Figure C.21.: Prescribed displacement dialog.

Here our result is -80.1240. So our capacity is $80.1240 * 2\pi/(\pi * 2^2) = 40.062kN/m^2$ for 1.5m displacement.

C.2. GIS

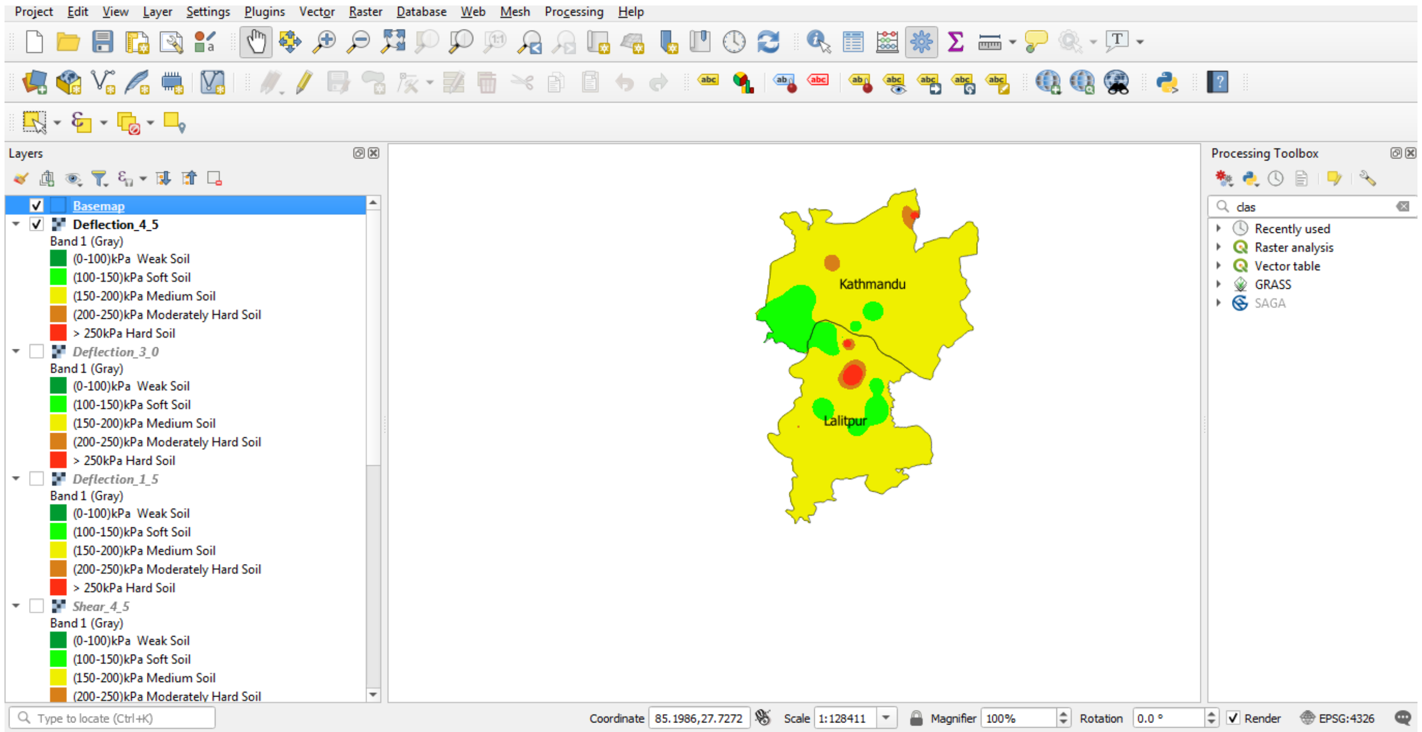


Figure C.22.: GIS Main Screen

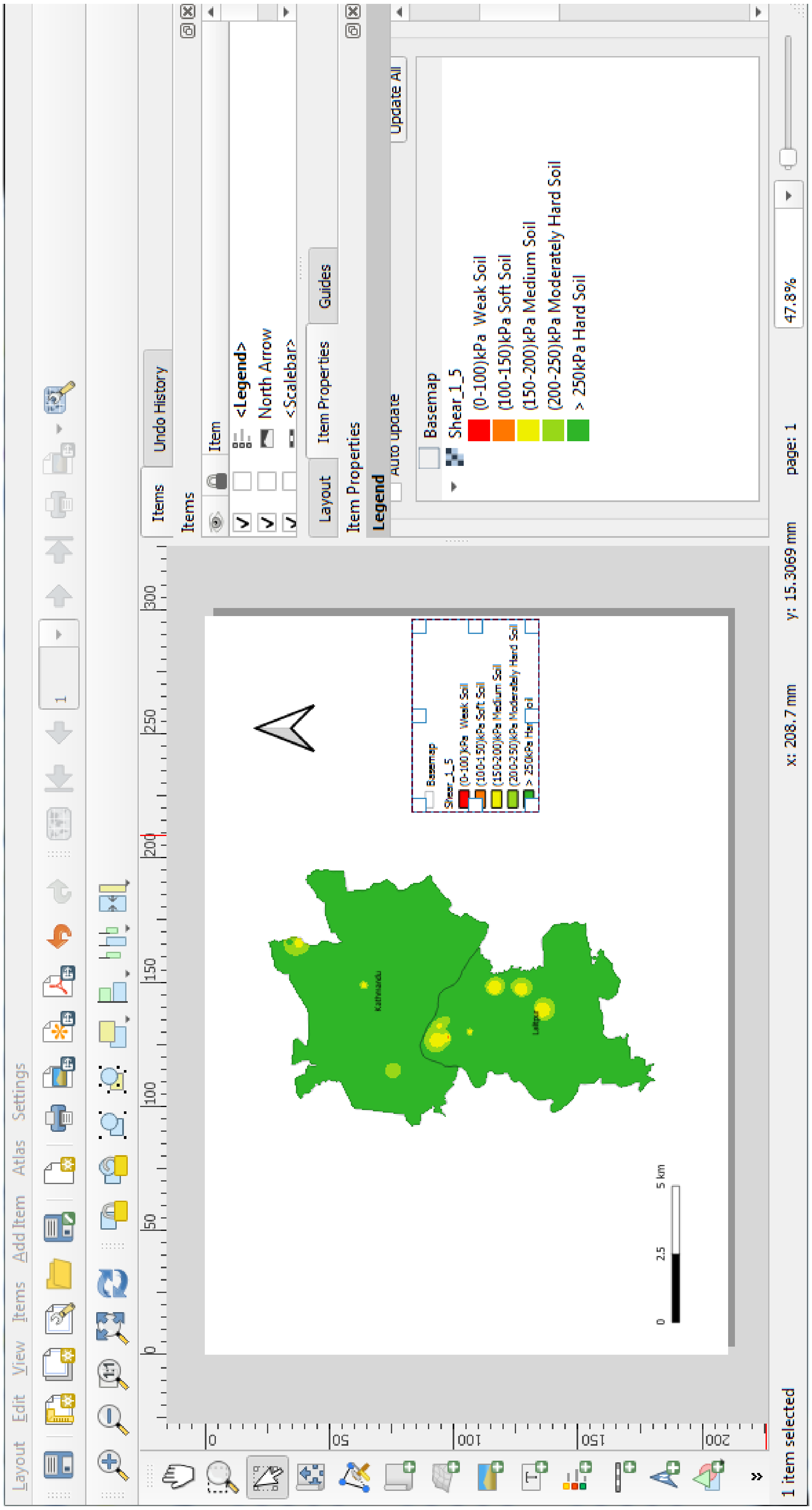


Figure C.23.: GIS Map Layout

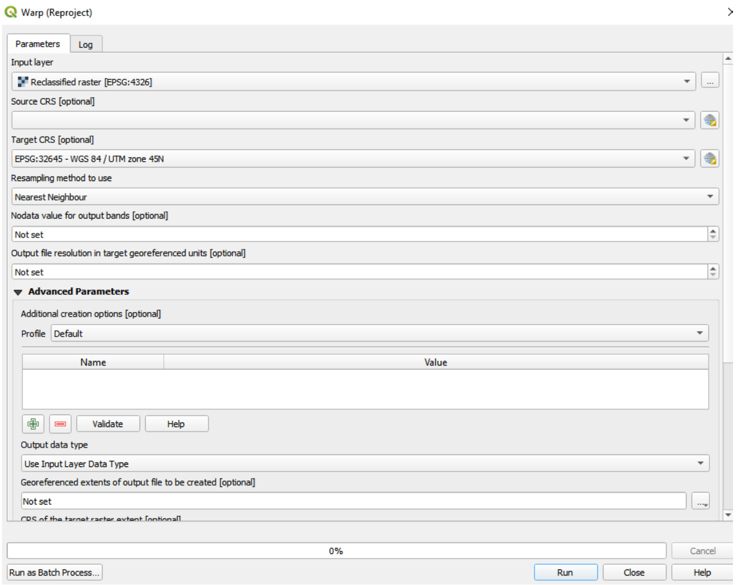


Figure C.24.: Wrap Projection

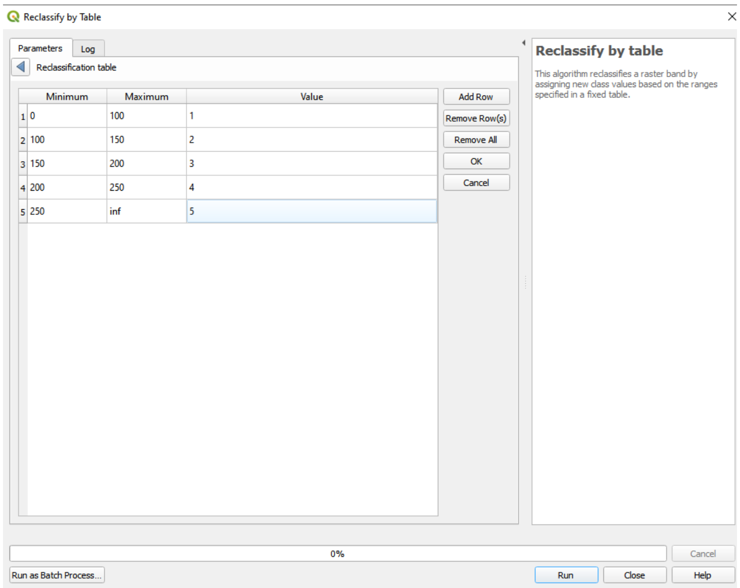


Figure C.25.: Reclassify by table tool

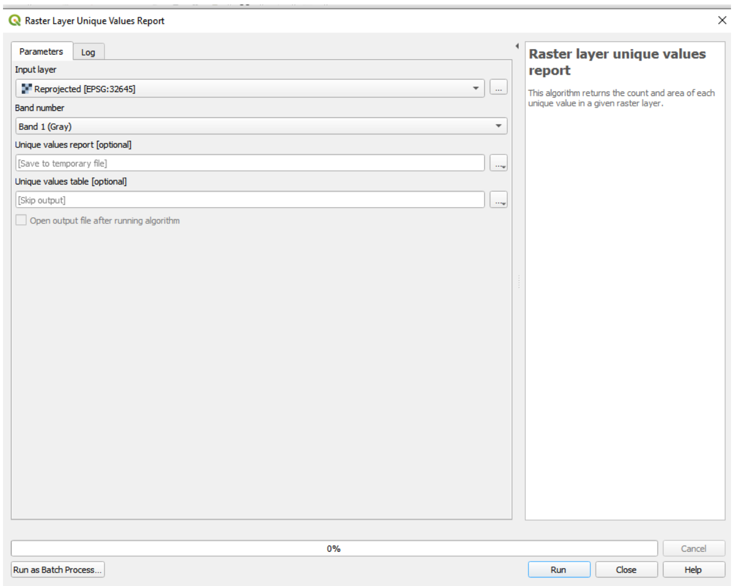


Figure C.26.: Report Tool

Projection: EPSG:32645 - WGS 84 / UTM zone 45N

Width in pixels: 1907 (units per pixel 5.03902)

Height in pixels: 3184 (units per pixel 5.03902)

Total pixel count: 6071888

NODATA pixel count: 2703003

Value	Pixel count	Area (m^2)
1	251	6373.329036588577
2	11866	301298.4954109963
3	34581	878072.0773476876
4	90596	2300390.90597123
5	3231591	82055748.02660684

Figure C.27.: Result From Report

D.Codes

Program link:https://github.com/rdmorgnzation/soilbearing
This file link:https://github.com/rupakbajgain/Zonation-Report

Hansen

```
class Hansen:
    """
    Provide methods to calculate hansen's calculations
    """
    def __init__(self, width_footing, depth_footing, water_depth=0
                                     ):
        """
        calculate same as terzaghi and save
        """
        Terzaghi.water_level_correction(self, width_footing,
                                        depth_footing,
                                        water_depth)
        #Process same as terzaghi for water level correction

    @staticmethod
    def Nc(phi):
        return Meyerhof.Nc(phi)

    @staticmethod
    def Nq(phi):
        return Meyerhof.Nq(phi)

    @staticmethod
    def Ny(phi):
        return 1.5*(Hansen.Nq(phi)-1)*tan(phi)

    def shape_and_depth_factors(self, length_footing, phi):
        """
        Calculate and save shape and depth factors
        """
        self.sc=1+self.Nq(phi)/self.Nc(phi)*self.width_footing/
                                        length_footing
        self.sq=1+self.width_footing/length_footing*tan(phi)
        self.sy=1-0.4*self.width_footing/length_footing
        #depth corrections
        self.dc = 1 +0.4*self.width_footing/length_footing
        self.dq = 1 +2*tan(phi)*(1-sin(phi))**2 * self.
                                        depth_footing/self.
                                        width_footing
        self.dy=1

    def capacity(self, cohesion, phi, gamma, length_footing,
                                     surchage=0):
        """
        Calcutate for provided depth
        """
        self.shape_and_depth_factors(length_footing, phi)
```

```
        c_term = cohesion*self.Nc(phi)*self.sc*self.dc
        q_term = surchage*self.Nq(phi)*self.sq*self.dq
        y_term = 0.5*gamma*9.81*self.width_footing*self.Ny(phi)*
                                                self.sy*self.dy
        return c_term+q_term*self.rw1+y_term*self.rw2
```

LPI

```
class Liquifaction:
    """
    Teng method
    """
    @staticmethod
    def LPI(lay):
        datas = lay.get()
        lpi = 0.
        for  i in range(len(datas)):
            data = datas[i]
            FC = data[SoilProperty.FC]
            delN1 = math.exp(1.63+(9.7/(FC+0.01))-(15.7/(FC+0.01))
                                                  *(15.7/(FC+0.01)))
            N1cs = data[SoilProperty.N60] + delN1
            MSF = 0.8758
            Csigma = 1/(18.9-2.55*math.sqrt(N1cs))
            if Csigma>0.3:
                Csigma = 0.3
            Ksigma = 1-Csigma*math.log(data[SoilProperty.
                                                  vertical_effective_stress
                                                  ]/100)
            if Ksigma>1.1:
                Ksigma = 1.1
            CRR = math.exp((N1cs/14.1)+(N1cs/126)**2-(N1cs/23.6)**
                                                  3+(N1cs/25.4)**3-2.8/
                                                  1)*(MSF*Ksigma)
            a_g = 0.183
            SRF = math.exp(-1.012-1.126*math.sin(data[SoilProperty
                                                  .depth]/11.73+5.133)+
                                                  8*(0.106+0.118*math.
                                                  sin(data[SoilProperty
                                                  .depth]/11.28+5.142))
                                                  )
            CSR = 0.65*(data[SoilProperty.total_effective_stress]/
                                                  data[SoilProperty.
                                                  vertical_effective_stress
                                                  ])*a_g*SRF
            FS = CRR / CSR
            if FS > 1.2:
                Fz = 0.
            elif FS < 0.95:
                Fz = 1-FS
            else:
                Fz = 2e6*math.exp(-18.427*FS)
            Wz = 10 - data[SoilProperty.depth]/2
            lpi += Fz * Wz * data[SoilProperty.thickness]
        return lpi
```

Meyerof

```
class Meyerhof:
    """
    Provide methods to calculate meyerhof's calculations
    """
    def __init__(self, width_footing, depth_footing, water_depth=0
                                                  ):
        """
        calculate same as terzaghi and save
        """
        Terzaghi.water_level_correction(self, width_footing,
                                              depth_footing,
                                              water_depth)
        #Process same as terzaghi for water level correction

    @staticmethod
    def Nc(phi):
        if phi<1e-7:#checked for near value to 2+pi
            phi=1e-7
        return cot(phi)*(Meyerhof.Nq(phi)-1)

    @staticmethod
    def Nq(phi):
        return exp(pi*tan(phi))*(tan(45+phi/2))**2

    @staticmethod
    def Ny(phi):
        return (Meyerhof.Nq(phi)-1)*tan(1.4*phi)

    def capacity(self, cohesion, phi, gamma, length_footing,
                                           surchage=0): #,
                                           inclination_angle=0
        """
        Calcutate for provided depth
        """
        #Passive Earth pressure coff
        Kp = tan(45+ phi/2)**2
        #Shape factors
        sc = 1 + 0.2*Kp*self.width_footing/length_footing
        if phi < 10:
            sq = 1
        else:
            sq=1+0.1*Kp*self.width_footing/length_footing
        sy = sq
        #Depth factors
        dc = 1 +0.2*sqrt(Kp)*self.depth_footing/self.width_footing
        if phi < 10:
            dq = 1
        else:
            dq =1 +0.1*sqrt(Kp)*self.depth_footing/self.
                                                 width_footing
        dy = dq
        c_term = cohesion*self.Nc(phi)*sc*dc
        q_term = surchage*self.Nq(phi)*sq*dq
```

```
        y_term = 0.5*gamma*9.81*self.width_footing*self.Ny(phi)*sy
                                         *dy
        return c_term+q_term*self.rw1+y_term*self.rw2
```

Meyerof Deflection

```
    def capacity(n60, depth_footing, width_footing, water_depth=0
                                         .):
        """
        For 25mm
        """
        Rd = 1 + 0.33*depth_footing/width_footing
        if Rd>1.33:
            Rd=1.33
        b = water_depth-depth_footing
        if b<0:
            b=0
        Wy = 0.5+0.5*b/width_footing
        if Wy>1:
            Wy=1
        if width_footing<1.2:
            return 12.2*n60*Wy*Rd
        else:
            return 8.1*n60*((width_footing+0.3)/width_footing)**2*
                                         Wy*Rd
```

Bowels

```
    def calc_bowels(self):
        return self.calc_meyerofdeff()*1.5
```

Peck

```
    def capacity(n60, depth_footing, width_footing, water_depth=0
                                         .):
        """
        For 25mm
        """
        Cw = 0.5 + 0.5*water_depth/(depth_footing+width_footing)
        return 10.25*Cw*n60
```

Teng

```
class Teng:
    """
    Teng method
    """
    def __init__(self, depth_footing, width_footing, water_depth=0
                                         ):
        Terzaghi.water_level_correction(self, width_footing,
                                         depth_footing,
                                         water_depth)

    def circular_capacity(self, N60):
        return 0.11*N60*N60*self.width_footing*self.rw2+0.33*(100+
                                         N60*N60)*self.
                                         depth_footing*self.rw1
```

```
    def strip_capacity(self, N60):
        return 0.167*N60*N60*self.width_footing*self.rw2+0.277*(
                                         100+N60*N60)*self.
                                         depth_footing*self.rw1
```

Teng Deflection

```
    def capacity(n60, depth_footing, width_footing, water_depth=0
                                        .):
        """
        For 25mm
        """
        Rd = 1 + depth_footing/width_footing
        if Rd>2:
            Rd=2
        b = water_depth-depth_footing
        if b<0:
            b=0
        Wy = 0.5+0.5*b/width_footing
        if Wy>1:
            Wy=1
        return 35*(n60-3)*((width_footing+0.3)/(2*width_footing))
                                         **2*Wy*Rd
```

Terzaghi

```
class Terzaghi:
    """
    Provide methods to calculate terzaghi's calculations
    """
    @staticmethod
    def water_level_correction(self, width_footing, depth_footing,
                                         water_depth=0):
        """
        Provide values that are common to all methods
        """
        dw1 = water_depth
        dw2 = water_depth - depth_footing
        if dw2<0:
            dw2=0
        #save some values
        top_dist_ratio = dw1/depth_footing
        bottom_dist_ratio = dw2/width_footing
        self.width_footing = width_footing
        self.depth_footing = depth_footing
        self.rw1 = 0.5 * (1 + top_dist_ratio)
        self.rw2 = 0.5 * (1 + bottom_dist_ratio)
        if self.rw1 > 1:
            self.rw1 = 1
        if self.rw2 > 1:
            self.rw2 = 1

    def __init__(self, width_footing, depth_footing, water_depth=0
                                        ):
        Terzaghi.water_level_correction(self, width_footing,
```

```
                                      depth_footing,
                                      water_depth)

    @staticmethod
    def Nc(phi):
        if phi<1e-7:
            phi=1e-7
        return (Terzaghi.Nq(phi)-1)/tan(phi)

    @staticmethod
    def Nq(phi):
        return (exp(2*pi*(0.75-phi/360)*tan(phi))) /(2 * cos(45+
                                      phi/2)**2)

    @staticmethod
    def Ny(phi):
        # return 2 * (Terzaghi.Nq(phi) + 1)* tan(phi) / (1+ 0.4*
                                      sin(4*pi))
        # this formula has error of 10%
        # better save table at 1deg interval
        return get_table(t_tables, 'ny', phi)

    def strip_capacity(self, cohesion, phi, gamma ,surchage=0):
        return cohesion*self.Nc(phi) + surchage*self.Nq(phi)*self.
                                      rw1 + 0.5*gamma*9.81*self
                                      .width_footing*self.Ny(
                                      phi)*self.rw2

    def square_capacity(self, cohesion, phi, gamma ,surchage=0):
        return 1.3*cohesion*self.Nc(phi) + surchage*self.Nq(phi)*
                                      self.rw1 + 0.4*gamma*9.81
                                      *self.width_footing*self.
                                      Ny(phi)*self.rw2

    def circular_capacity(self, cohesion, phi, gamma ,surchage=0):
        return 1.3*cohesion*self.Nc(phi) + surchage*self.Nq(phi)*
                                      self.rw1 + 0.3*gamma*9.81
                                      *self.width_footing*self.
                                      Ny(phi)*self.rw2
```

Vesic

```
class Vesic:
    """
    Provide methods to calculate vesic's calculations
    """
    def __init__(self, width_footing, depth_footing, water_depth=0
                                  ):
        """
        calculate same as terzaghi and save
        """
        Terzaghi.water_level_correction(self, width_footing,
                                      depth_footing,
                                      water_depth)
        #Process same as terzaghi for water level correction
```

```python
    @staticmethod
    def Nc(phi):
        return Meyerhof.Nc(phi)

    @staticmethod
    def Nq(phi):
        return Meyerhof.Nq(phi)

    @staticmethod
    def Ny(phi):
        return 2*(Vesic.Nq(phi)+1)*tan(phi)

    def capacity(self, cohesion, phi, gamma, length_footing,
                                                surchage=0):
        """
        Calcutate for provided depth
        """
        Hansen.shape_and_depth_factors(self, length_footing, phi)
        c_term = cohesion*self.Nc(phi)*self.sc*self.dc
        q_term = surchage*self.Nq(phi)*self.sq*self.dq
        y_term = 0.5*gamma*9.81*self.width_footing*self.Ny(phi)*
                                                    self.sy*self.dy
        return c_term+q_term*self.rw1+y_term*self.rw2
```

Material

```python
class Material(Base):
    """
    It is a single soil material for a layer,
    it takes SPT and other previously known material properties,
    and group_indexves the unknown by analytical formulas,
    this contains datas like surchage too
    """
    def is_clayey(self):
        """
        Check first letter and determine if soil is clayey
        """
        group_index = self._data[SoilProperty.GI]
        return group_index[0] not in ['S','G','M']

    def _get_n(self):
        """
        Get n_60 value
        """
        n_60 = self._data[SoilProperty.SPT_N]
        #Apply dilatracy correction
        if _need_dil_correction(self._data[SoilProperty.GI]) and
                                            n_60>15 and self._data[
                                            SoilProperty.depth] >
                                            self._data[SoilProperty.
                                            water_depth]:
            n_60 = 15 + 0.5 * (n_60 - 15)
        if self._data[SoilProperty.depth]<3:
            cr = 0.7
        elif self._data[SoilProperty.depth]<4:
            cr = 0.75
```

```python
        elif self._data[SoilProperty.depth]<6:
            cr = 0.85
        elif self._data[SoilProperty.depth]<10:
            cr = 0.95
        else:
            cr = 1.
        n_60 = 0.55 * 1 * 1 * cr * n_60 /0.6
        #Apply overburden correction
        cor = 9.78*((1/self._data[SoilProperty.
                                            vertical_effective_stress
                                            ])**0.5)
        if cor>1.7:
            cor=1.7
        n_60 = n_60*cor
        return n_60

    def _get_gamma(self):
        """
        Get value of gamma based on soil type
        """
        gamma = None
        if self.is_clayey():
            gamma = 16.8 + 0.15*self._data[SoilProperty.N60]
        else:
            gamma = 16 + 0.1 * self._data[SoilProperty.N60]
        #gamma=_clamp(gamma,10,2.8*9.81)#do we need this
        return gamma

    # Note: The unconfined compressive strength value is two times
                                   undrained shear strength.
                                  The
    # ultimate bearing capacity is approximately six times the
                                  undrained shear strength
                                  where C in
    # CNc is the undrained shear strength. The value of Nc is 5.14
                                   and 5.7 respectively by
    # Meyerhof and Terzaghi.
    # BC Mapping Bhadra 4

    @staticmethod
    def qu(N60):
        """
        Determine Qu from N60
        """
        return 0.29 * N60**0.72 * 100

    def _get_cu(self):
        """
        Get cohesion of soil
        """
        c_undrained=0
        #group_index = self._data['GI']
        if self.is_clayey():
            c_undrained = self.qu(self._data[SoilProperty.N60])/2
            #c_undrained=_clamp(c_undrained, 10, 103)
```

```python
        # Plaxis calculation needs very small c_undrained
        #if c_undrained<0.21:
        #    c_undrained = 0.21
        #use 0.2 as per plaxis recommendation
        return c_undrained#the cu is always 103 check with small
                                          value of n_60, some
                                          mistake maybe

    def _get_packing_state(self):
        """
        Get packing state table column
        """
        # Ok, first determining packing condition as per Table 2.4
                                          ,
        s_phelp = [0,4,10,30,50]
        if self.is_clayey():
            s_phelp = [0,2,4,8,15,30]
        packing_case = 0 # Packing cases as per table
        for i,value in enumerate(s_phelp):
            if self._data[SoilProperty.N60]>value:
                packing_case=i
        return packing_case

    @staticmethod
    def phi(N60):
        """
        Determine phi from N60
        """
        return 27.1 + 0.3*N60 - 0.00054* N60**2

    def _get_phi(self):
        """
        Get phi of soil
        #Many tables are used need to be refactred
        """
        phi = self.phi(self._data[SoilProperty.N60])
        ### Ok let's remove for clay
        if self.is_clayey():
            phi=0 #very small value for plaxis:::@TODO 0.01
        return phi

    def _get_e(self):
        """
        Elasticity
        """
        group_index = self._data[SoilProperty.GI]
        n_60 = self._data[SoilProperty.N60]
        packing_case = self._data[SoilProperty.packing_case]
        elasticity=None
        if self.is_clayey():
            if packing_case==0:#15-40
                elasticity= (15+40)/2 * n_60 * 100
            elif packing_case==1:#40-80
                elasticity= (40+80)/2 * n_60 * 100
            else:#80-200
```

```
                elasticity= (80+200)/2 * n_60 * 100
        else:
            if group_index[1] in ['M','C','P','O']:#with fines
                elasticity= 5 * n_60 * 100
            else: #The OCR condition of cohesionless test cannot
                                                  be determined, assume
                                                   NC sand
                elasticity= 10 * n_60 * 100
        return elasticity

    def __init__(self, input_data):
        """
        Save only use later when required
        """
        Base.__init__(self)
        self._data = input_data
        self._data[SoilProperty.GI] = _group_index_correction(self
                                            ._data[SoilProperty.GI])
        if SoilProperty.N60 not in self._data:
            self._data[SoilProperty.N60] = self._get_n()
        if SoilProperty.packing_case not in self._data:
            self._data[SoilProperty.packing_case] = self.
                                                  _get_packing_state()
        if SoilProperty.gamma not in self._data:
            self._data[SoilProperty.gamma] = self._get_gamma()
        #Check and adjust values of qu, cu and phi as necessary
        if SoilProperty.phi not in self._data and SoilProperty.cu
                                            not in self._data and
                                            SoilProperty.qu in self.
                                            _data:
            group_index = self._data[SoilProperty.GI]
            if self.is_clayey() or group_index[0]=='M':
                self._data[SoilProperty.phi] = 0.
                self._data[SoilProperty.cu] = self._data[
                                                    SoilProperty.qu]
                                                    / 2
        if SoilProperty.cu not in self._data:
            self._data[SoilProperty.cu] = self._get_cu()
        if SoilProperty.phi not in self._data:
            self._data[SoilProperty.phi] = self._get_phi()
        if SoilProperty.elasticity not in self._data:
            self._data[SoilProperty.elasticity] = self._get_e()
        if SoilProperty.nu not in self._data:
            if self.is_clayey():
                self._data[SoilProperty.nu] = 0.45
            else:
                self._data[SoilProperty.nu] = 0.3
        #update data to this dict
        self.set(self._data)
```

Remove Outliers

```
def remove_outliers(x):
    Q1 = np.quantile(x,0.25)
    Q3 = np.quantile(x,0.75)
    IQD = Q3 - Q1
```

```
    minx = Q1 - IQD*1.5
    maxx = Q3 + IQD*1.5
    outx=[]
    for v in x:
        if minx<=v<=maxx:
            outx.append(v)
    return outx
```

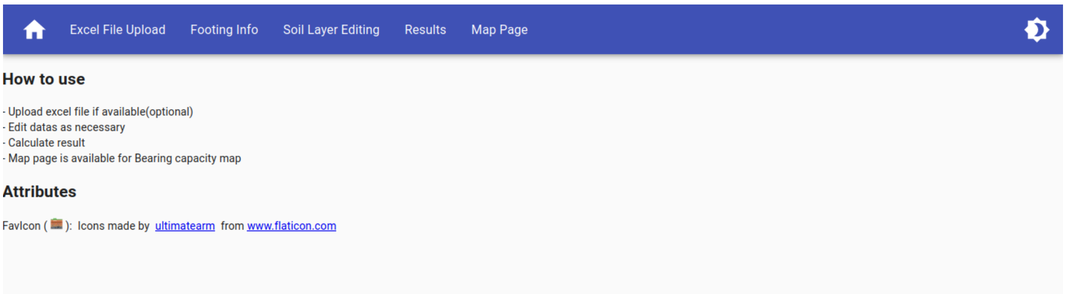
E.Demo

Demo link[1]: `https://bajgain.tech`

E.1. Program Tabs, screenshots and info

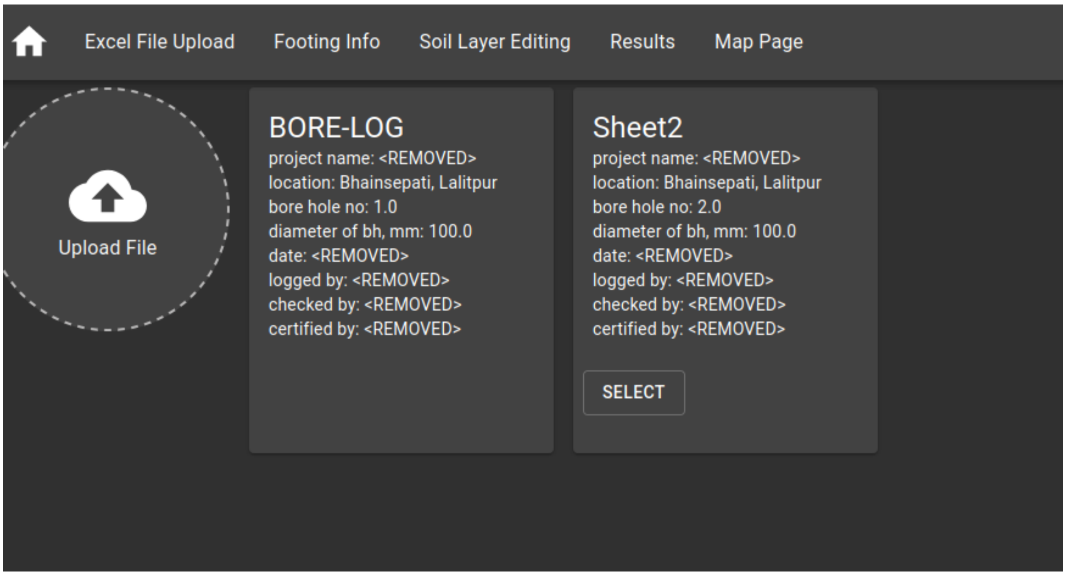
Program has theme selection, so screenshots are diffrent.

E.1.1. Start Screen



General info about program

E.1.2. Upload Tab

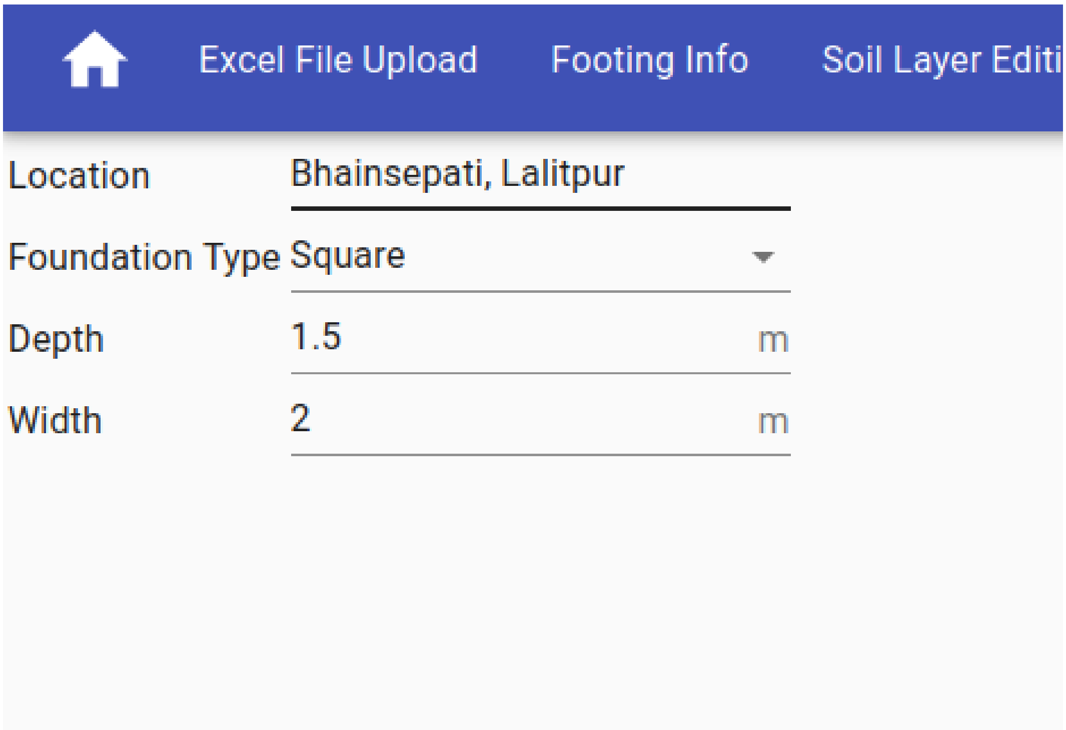


Upload the excel file. (either .xls, or .xlsx)
If more than one sheet is available in file then sheet selection option.

[1]Only available for certain time

- Click and select, or
- drag and drop

E.1.3. Footing info Tab

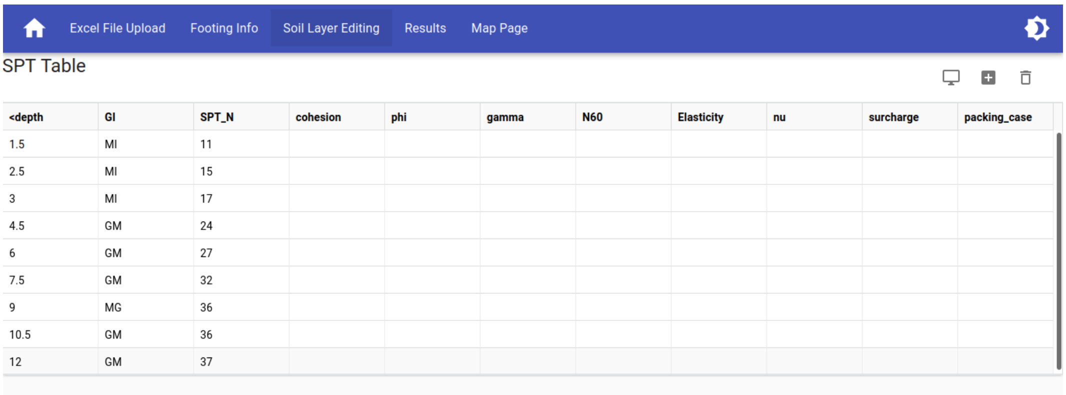


Basic footing info,

E.1.4. Edit Tab

There are 2 modes:-

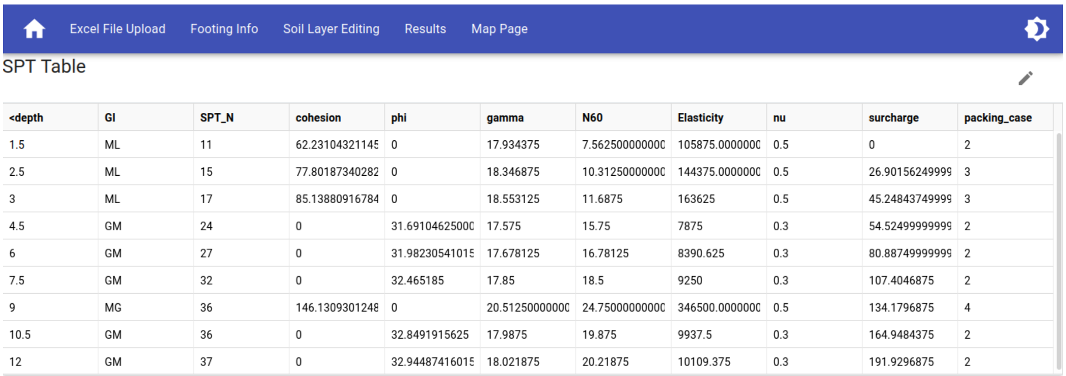
Edit Mode



<depth	GI	SPT_N	cohesion	phi	gamma	N60	Elasticity	nu	surcharge	packing_case
1.5	MI	11								
2.5	MI	15								
3	MI	17								
4.5	GM	24								
6	GM	27								
7.5	GM	32								
9	MG	36								
10.5	GM	36								
12	GM	37								

Actual editing

Preview Mode



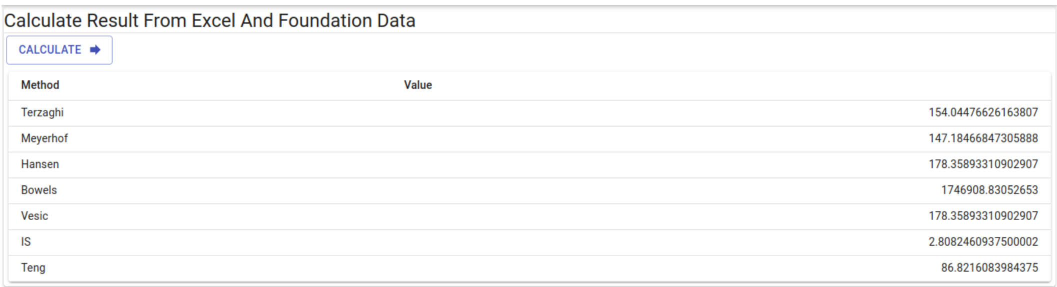
<depth	GI	SPT_N	cohesion	phi	gamma	N60	Elasticity	nu	surcharge	packing_case
1.5	ML	11	62.23104321145	0	17.934375	7.562500000000	105875.0000000	0.5	0	2
2.5	ML	15	77.80187340282	0	18.346875	10.31250000000	144375.0000000	0.5	26.90156249999	3
3	ML	17	85.13880916784	0	18.553125	11.6875	163625	0.5	45.24843749999	3
4.5	GM	24	0	31.69104625000	17.575	15.75	7875	0.3	54.52499999999	2
6	GM	27	0	31.98230541015	17.678125	16.78125	8390.625	0.3	80.88749999999	2
7.5	GM	32	0	32.465185	17.85	18.5	9250	0.3	107.4046875	2
9	MG	36	146.1309301248	0	20.51250000000	24.75000000000	346500.0000000	0.5	134.1796875	4
10.5	GM	36	0	32.8491915625	17.9875	19.875	9937.5	0.3	164.9484375	2
12	GM	37	0	32.94487416015	18.021875	20.21875	10109.375	0.3	191.9296875	2

See program internal interpolations, etc.

E.1.5. Results Tab

There are 2 options:-

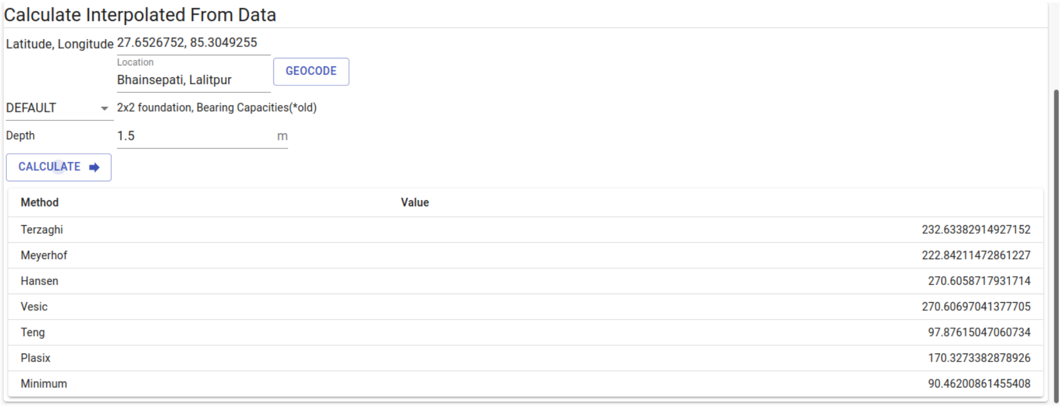
From datas as above



Method	Value
Terzaghi	154.04476626163807
Meyerhof	147.18466847305888
Hansen	178.35893310902907
Bowels	1746908.83052653
Vesic	178.35893310902907
IS	2.8082460937500002
Teng	86.8216083984375

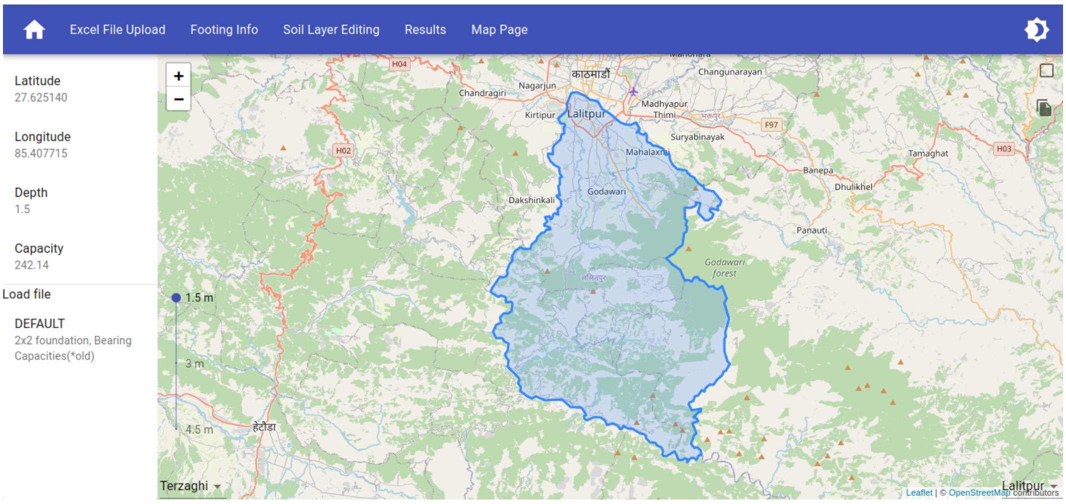
Calculation as per above datas.

Calculate from Interpolation



Datas interpolated by IDW from the project report datas.
Geocode from name, to get latitude and longitude.

E.1.6. Map Tab



Map from datas computed by interpolation.