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# Comparison of foundation by Direct Shear Test in Different soil condition

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**Abstract**

In this paper, we mainly focused on the comparison of foundation in two different locations. Size of foundation depends on bearing capacity of soil. Standard proctor test has been conducted to determine Optimum Moisture Content (OMC) of soil and Direct shear test has been conducted to determine the shear strength parameters in OMC. Bearing capacity of soil is calculated from shear strength parameters using terzaghi's equation. Area of foundation is calculated and it is found that area differ by 34.47% at two locations.

*Keywords*: Foundation, direct shear test, shear strength parameters, bearing capacity.

## 1. Introduction

### *1.1 Background*

i. Foundation

Foundation is a part of a structural system that supports the superstructure of a building and transmits its loads directly to the earth. Foundation design involves the study of both structural system and characteristics of supporting ground. It plays a crucial role in ensuring the stability, safety, and longevity of a structure by distributing its weight evenly and preventing settlement or movement caused by soil instability or subsidence.

ii. Bearing capacity

Bearing capacity is the capacity of soil to support the load that are applied on it. There are different methods to calculate bearing capacity of soil from Plate bearing test, Standard penetration test, Terzaghi's Bearing Capacity Theory, Cone Penetration Test, Vane shear test, Direct Shear test etc. In our context we have used Direct shear test to calculate bearing capacity.

### Scope of research

The outcome of this research help in the following context of the foundation design.

i. Foundation size varies based on soil characteristics; even minor changes can necessitate adjustments.
ii. For small and less significant projects, determining bearing capacity doesn't always require extensive field tests.
iii. Simplified methods can be employed to assess bearing capacity for minor projects.
iv. These methods help save time and resources by avoiding elaborate field testing procedures.

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**Objectives**

The major objective of this project is to compare foundation by direct shear test in different soil location. This will finally give information that the size of foundation differs for minor change in soil characteristics and for small and less important work bearing capacity can be found easily without performing any heavy field test.

**Limitations**

i. The research outcomes may be specific to the chosen topographic scenarios and site location.
ii. All other factors affecting loading condition is kept constant. The only variable for foundation design and comparison is "different soil conditions.
iii. This geotechnical report is based on the data collected from the two pits and from laboratory results and judgement of the author based on the experience.

## 2. Literature review

(Fredlund, 1993) Soil moisture content plays a crucial role in determining bearing capacity, with saturated soils exhibiting lower bearing capacities due to reduced effective stress. Studies have investigated the relationship between soil moisture content and bearing capacity under different conditions.

(Terzaghi, 1943) Terzaghi's seminal work in the 1940s laid the foundation for understanding soil bearing capacity. His theory proposed that bearing capacity depends on the soil's shear strength parameters and is influenced by factors such as the depth of the foundation and the shape of the footing.

(Das, 2007) Several studies have explored the relationship between soil type and bearing capacity. Dense granular soils typically exhibit higher bearing capacities compared to cohesive soils due to their higher shear strength.

(Arora, 2011) Isolated footing is preferred in rocky soil. For gravel and sandy soil combined footing and strap footing is provided. Mat foundation is provided for hard clay. In soft clay having low bearing capacity pile foundation is used. In water logged area pile foundation is used.

(American Society of Agriculture and Biological engineers) Pure clay would have a value of 0º and & would rise with increasing sand content and density to approximately 40° for a compact sandy loam soil. Loose sands range between 25 to 30°. As pure clays are rarely found in top soils the typical value for a 'clay' soil would be in the range 5 to 10°.

(Randolph, 2004.) Soil properties such as cohesion, friction angle, permeability, and compressibility significantly influence the choice and design of foundations. The soil's bearing capacity, which is its ability to support the applied loads without failure, is a critical parameter in foundation design.

## 3. Sample Collection, Preparation and Testing

i. Sample Collection
   Sample is collected at two different locations of Lalitpur and Dhulikhel. Coordinate of lalitpur is 27°38'12"N 85°20'12"E and that of dhulikhel is 27°36'56"N 85°32'32"E. Representative soil sample is extracted by using hand sampling method at depth of 40-50cm from ground surface.
ii. Preparation and testing
   a) Standard proctor test is carried out as per the Indian Standard (IS: 2720 Part VII – 1980).
   b) Direct shear test is carried out at OMC according to IS 2720-13: Methods of test for soils, Part 13: Direct shear test.

***Standard Proctor Test***

Standard proctor test is conducted to determine the optimum moisture content of soil.

| Test Name : Standard Proctor Test | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Location: | Harsiddhi, Lalitpur. | | | | | Harsiddhi, Lalitpur. | | | | |
| Observations | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| Wt. of mould + compacted soil (kg) | 6.408 | 6.408 | 6.408 | 6.408 | 6.408 | 6.408 | 6.408 | 6.408 | 6.408 | 6.448 |
| Wt. of empty mould (kg) | 4.634 | 4.634 | 4.634 | 4.634 | 4.634 | 4.676 | 4.676 | 4.676 | 4.676 | 4.676 |
| Wt of compacted soil (kg) | 1.774 | 1.874 | 1.910 | 1.806 | 1.782 | 1.719 | 1.824 | 1.848 | 1.798 | 1.772 |
| Volume of mould ($m^3$) | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| Wet density ($kg/m^3$) | 1774 | 1874 | 1910 | 1806 | 1782 | 1719 | 1824 | 1848 | 1798 | 1772 |
| Wt of empty container (kg) | 0.039 | 0.047 | 0.051 | 0.040 | 0.046 | 0.042 | 0.046 | 0.040 | 0.049 | 0.047 |
| Wt of container + wet soil (kg) | 0.109 | 0.112 | 0.182 | 0.239 | 0.231 | 0.145 | 0.111 | 0.091 | 0.156 | 0.220 |
| Wt of container + dry soil (kg) | 0.018 | 0.022 | 0.026 | 0.032 | 0.035 | 0.024 | 0.029 | 0.032 | 0.034 | 0.037 |
| Moisture content (%) | 18.136 | 21.501 | 26.463 | 32.194 | 35.219 | 23.718 | 28.898 | 31.682 | 33.772 | 37.391 |
| Dry density ($kg/m^3$) | 1501.664 | 1542.369 | 1510.318 | 1366.176 | 1317.862 | 1389.455 | 1415.076 | 1403.382 | 1344.079 | 1289.747 |

Figure 1. Standard Proctor test for OMC

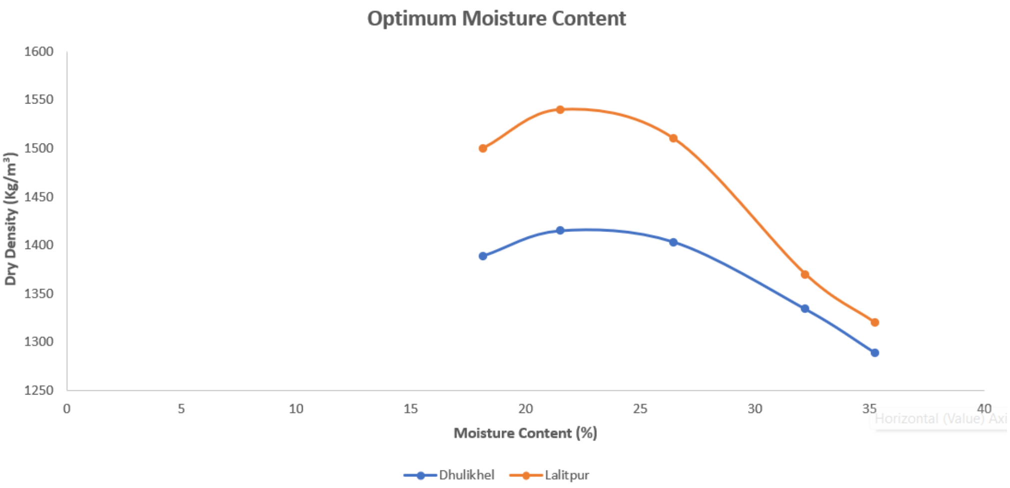


Figure 2: Moisture Density Curve

## DIRECT SHEAR TEST

The direct shear test is a laboratory method used to determine the shear strength parameters of soil specimens. shear strength parameters, cohesion (c) and angle of internal friction (φ). Normal stress is applied at $0.5kg/cm^2$ $1kg/cm^2$ and $1.5kg/cm^2$ and strain rate is applied at 1.25mm per minute.

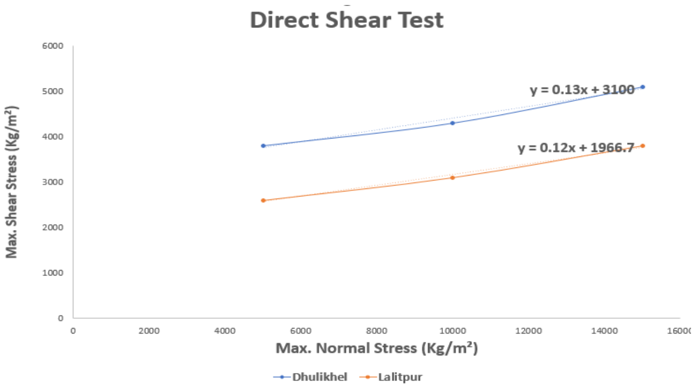


Figure 3: Direct Shear Test Results

Table 1. Shear strength parameters from Direct Shear Test

| | | Dhulikhel | Lalitpur |
|---|---|---|---|
| **S.N.** | **Max. Normal Stress (Kg/m$^2$)** | **Max. Shear Stress (Kg/m$^2$)** | **Max. Normal Stress (Kg/m$^2$)** |
| 1 | 5000.00 | 3800 | 2600 |
| 2 | 10000.00 | 4300 | 3100 |
| 3 | 15000.00 | 5100 | 3800 |
| | | **Result From Graph** | |
| 1 | Angle of Internal Friction F$^0$ | 7.41 | 6.843 |
| 2 | Cohesion C Kg/m$^2$ | 3100.00 | 1966.7 |

## Calculation of Bearing capacity.

The bearing capacity of soil is calculated using the Terzaghi's formula: qf = c'Nc + γDNq + 0.5γBNγ. Here, qf is the ultimate bearing capacity, c' is the cohesion of soil, Nc, Nq, and Nγ are bearing capacity factors, D is the depth of footing, and γ is the unit weight of soil.

As from ϕ value criteria and from density of soil it is predicted that a general shear failure is possible. Hence, bearing capacity factors for general shear failure are as follow,

Table 2. Terzaghi's Equation Parameters

| Parameters | Lalitpur | Dhulikhel |
|---|---|---|
| Φ | 6.84 | 7.410 |
| Nc | 8.146 | 8.4086 |
| Nq | 2.005 | 2.1302 |
| Ny | 0.758 | 0.8374 |
| Sc | 1.1 | 1 |
| Sy | 0.9 | 0.9 |
| (Take) Shape Factor (B/L) | 0.5 | 0.5 |
| unit wt. of soil (KN/m$^2$) | 15.107 | 13.911 |
| (Take) Structural loading (p KN) | 76449.25 | 76449.25 |

Depth of footing is taken as 1.5m.

| S.N. | Initial qu (KN/m²) | Area (m²) =p/qu | Breadth (m) Bf=√(A*S.F) | qu by Terzaghi (KN/m²) |
|---|---|---|---|---|
| | Lalitpur | | | |
| 1 | 150.00 | 509.662 | 15.963 | 300.564 |
| 2 | 300.56 | 254.353 | 11.277 | 276.428 |
| 3 | 276.43 | 276.561 | 11.759 | 278.911 |
| 4 | 278.91 | 274.099 | 11.707 | 278.641 |
| 5 | 278.64 | 274.365 | 11.712 | 278.670 |
| 6 | 278.67 | 274.336 | 11.712 | 278.667 |
| 7 | 278.67 | 274.339 | 11.712 | 278.667 |
| | Dhulikhel | | | |
| 1 | 150.000 | 509.662 | 15.963 | 409.413 |
| 2 | 409.413 | 186.729 | 9.663 | 376.384 |
| 3 | 376.384 | 203.115 | 10.078 | 378.560 |
| 4 | 378.560 | 201.948 | 10.049 | 378.408 |
| 5 | 378.408 | 202.029 | 10.051 | 378.418 |
| 6 | 378.418 | 202.023 | 10.050 | 378.418 |
| 7 | 378.418 | 202.024 | 10.050 | 378.418 |

Figure 2. Calculation of bearing capacity by Trial-and-Error method

## FOUNDATION COMPARISION

Table 3. Foundation Comparison of Lalitpur and Dhulikhel

| Features | Lalitpur | Dhulikhel |
|---|---|---|
| Moisture Content (%) | 21.5 | 29.5 |
| Dry Density(g/cc) | 1.54 | 1.418 |
| Angle of Internal Friction(°) | 6.84 | 7.41 |
| Cohesion (Kg/cm$^2$) | 0.197 | 0.310 |
| Ultimate Bearing Capacity (KN/m$^2$) | 278.667 | 378.418 |
| Factor of Safety | 3 | 3 |
| Safe Bearing Capacity (KN/ m$^2$) | 92.88 | 126.14 |
| Area of Foundation(m$^2$) | 1016.632 | 666.130 |

Area of foundation required for Dhulikhel is 34.47% less than that of Lalitpur.

### Bearing Capacity check from secondary sources.

Calculated bearing capacity of Dhulikhel ward no 6 is 126.14 KN/m2 and bearing capacity obtained from secondary source is 126.53 KN/m2. Hence calculated bearing capacity is within 0.3% difference range than that of secondary source. (Raut, Sep-2020)

## Conclusion

In this article we studied about the shear strength parameter of soil for calculating bearing capacity using Terzaghi’s equation and effect of bearing capacity on foundation design in two different locations. We have observed following outcomes in our experiment.

i. Bearing capacity of Dhulikhel sample is found higher than Lalitpur soil sample.
ii. Approximate Bearing capacity can be calculated by the use of shear strength parameter obtained from direct shear test as it lies in range of bearing capacity obtained from other cumbersome field tests.

iii. For the same structural loading, foundation area requirement for dhulikhel sample is found 34.47 % less than that of harsiddhi, Lalitpur soil sample. Which is directly associated with construction cost of foundation.

**iv.** Direct shear test can be used as alternative for determining bearing capacity of a small and less significant project. As for small works where bearing capacity is unknown, this method can give overview for approximate foundation design for structural integrity in the context of rural areas of Nepal.

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