SOIL EXPLORATION AND GEOTECHNICAL DESIGN OF A FOUNDATION

Bhagyashri Batwalkar[1], Ishika Sonawane[2], John Livinston[3], Tejaswini Narayane[4], Dr. Prasenkumar Saklecha[5]

[1-4]B. E. Student, Department of Civil Engineering, New Horizon Institute of Technology and Management Thane, Maharashtra, India
[5] Professor Department of Civil Engineering, New Horizon Institute of Technology and Management Thane, Maharashtra, India.

Abstract - *Before the actual construction process starts, it is important to conduct a site investigation and soil exploration to acquire vital information about the soil and site conditions. In a construction site investigation is the first and crucial step. These are outlined in the project to ensure that the site is appropriate for the proposed construction and to offer recommendations on the design and construction processes.*

Following soil investigation based on the soil report, further geotechnical design of a shallow foundation was performed; however, the results indicated that the load coming from the structure was less than the results of the shallow foundation, so we opted for the geotechnical design of a pile foundation, which resulted at an end bearing capacity greater than the load coming from the structure. The geotechnical design of the pile consists of recommending the size of the pile and calculating the safe working load of each pile.

***Key Words*: Deep Foundation, Pile Foundation, Shallow Foundation, Bore-hole, Site Investigation, Soil Exploration.**

1. INTRODUCTION

The geotechnical design of a multi-story commercial building includes a thorough site investigation and soil report analysis. After studying the soil report, the appropriate type of foundation was chosen using calculations and information from the site report such as type of soil, depth of bore hole etc.

This involves a detail site investigation study and analysis of soil report our site. After studying the soil report, selected foundation type and site report including site condition, type of soil, and depth of bore-hole and basically, there are two types of foundation: 1. Shallow 2. Deep foundation. For selecting the type of foundation following detailed design steps were involved:

- Study of soil report
- Calculation structural load
- Bearing capacity calculation of shallow foundation.

i. As per IS 6403, 1981 and IRC 78, 2014 - 1: If the soil type is suitable (hard strata) to carry the load and the bearing capacity exceeds the load resulting from the construction, we may use a shallow foundation.

ii. If the foundation's bearing capacity is less than the load from the building, we must use a raft or pile foundation.

For condition 2: Further we have to calculate load carrying capacity of pile foundation.

There are different design methods to calculate bearing capacity and End bearing capacity of soil/ Rock based on site condition.

1.1 Site investigation

The process of acquiring and analyzing information on a site's surrounds, including the geology, topography, hydrology, and environmental conditions, is known as site investigation. The main objective of a site investigation is to find any potential issues or hazards that might impact the construction process or the final structure's stability and safety.

Site investigation is the process of studying about a site's physical and environmental characteristics in order to determine whether it is suitable for a particular civil engineering project. It entails a careful analysis of the geology, hydrology, topography, soil properties, and other elements that potentially influence the site's development or usage.

Drilling, sampling, and geophysical surveys are just a few of the field and lab tasks that site investigations normally involve. The investigation's findings are summarized in a report that offers recommendations for the project's design and construction as well as any possible mitigation strategies to address safety or environmental issues.

1.2 Soil Exploration

A phase of site research called soil exploration focuses primarily on the soil characteristics of the location. In order to assist the design and construction process, soil exploration aims to give thorough information about the soil conditions.

The following steps are commonly included in the soil exploration process:

A) Borehole drilling
Borehole drilling is the process of making holes in the earth to gather soil samples for analysis.

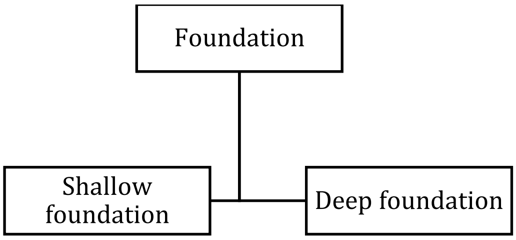
B) Sampling
To ascertain the kind, consistency, and strength of the soil, soil samples are gathered from boreholes at various depths.

C) Testing in the lab
The physical and chemical characteristics of the soil samples, such as density, permeability, shear strength, and compressibility, are examined in the lab.

D) Analysis
The design and construction processes are made more effective by using the information gathered during the soil exploration phase. For instance, it may be used to decide on the necessary kind and depth of foundations, the site's slope stability, and the best building methods.

In conclusion, site investigation and soil exploration are crucial steps in the building process that provide important details about the site conditions and soil characteristics. The stability and safety of the completed structure are ensured using this information, which is also utilized to guide the design and construction process.

1.3 Foundation:
The lowest portion of a building or structure, known as the foundation, is where the weight of the structure is transferred to the ground or rock below. The performance and safety of the entire structure can be greatly impacted by the design and construction of the foundations, which are essential parts of any building or structure.
The several types of foundations frequently used in building construction are as follows:



Shallow Foundation:
When the earth is sturdy enough to sustain the weight of the structure close to the surface, shallow foundations are employed.

Deep Foundation:

When the soil at the surface is unstable or weak and unable to sustain the weight of the structure, deep foundations are employed.
The following category was explored for deep foundation for this project:

- **Pile Foundation:**

Pile foundations are employed when a structure has to be sustained at a deeper level and the soil close to the surface is unstable. They have a long, lean form that might be cylindrical or rectangular.

1.4 Site Details:
NHES Educational Complex near Village Kavesar, Anand Nagar Crossing of Ghodbunder Road in Thane, Maharashtra, to establish a teaching hospital and medical college building. The geotechnical investigation report for all nine completed boreholes at the Thane site is included in this report.

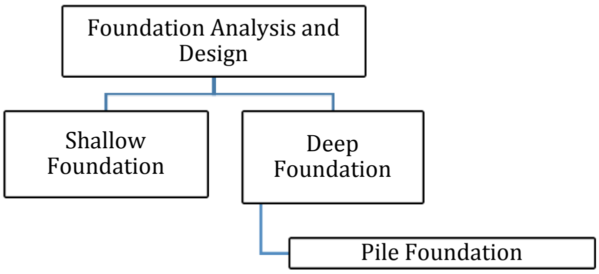
The investigation site is a region of the area known as the "Deccan Traps," a term used in Indian geology. The present researches reveal that the geologic occurrences of various rock types, including the deposits of mafic rocks, are separate from those in the remainder of the Deccan Trap-covered area. Amygdaloidal Basalt, Compact Porphyritic Basalt, etc. In boreholes around Thane regions, a few marker horizons (trachytic, Tachylite beds) have been found. The levels of these, however, do not relate. They have been described in the core logs that are included. According to recent studies, it is not possible to completely rule out the possibility of sub-aqueous volcanic eruptions.

The geologic environment of this area corresponds to the literature review conducted for the Geology of Mumbai region; it shows that the volcanic activity in this area differs from that of the rest of Maharashtra's volcanic province in various ways, which include their association with several evolved rock types like Rhyolites and Trachytes with significant amounts of felsic and basic tuffs, and their being partially or entirely sub-aqueous eruptions as indicated by pillow structures and spilitic compositions

According to the literature research, there are not many defects in the Mumbai region. The area has active earthquake activity.

The document contained includes sections on the lithologic descriptions, as well as their geotechnical relevance. These sections are further supported by microscopic data, which are attached.

2. DESCRIPTION OF PROJECT



2.1 Shallow Foundation:

Bearing capacity & settlement pressure of soil at 3m depth for Shallow foundation area as follow,

i. Bearing Capacity – Using Standard Penetration Test – N Value

For Square and Circular Footing:

$q_{nu=}$ 1/3.0 ($N^2 BW\gamma + 3(100 + N^2) D_f W_q$

$\mathbf{q_{nu=} 0.33 N^2 BW\gamma + 1 (100 + N^2) D_f W_q}$

Where,

N = Standard Penetration test value

q_{nu} = Bearing capacity

Table -1: Bearing Capacity values using N- value

BH	Qnu Kn/m2
BH2	827.04
BH3	1017.36
BH4	1123.5
BH5	1017.36
BH6	1485.84
BH7	1017.36
BH8	918.54
BH9	1017.36

ii. Settlement Analysis- using Teng's Equation

$\mathbf{Q_{np} = 35 (N - 3) \times (B + 0.3 / 2B)^2 \times W\gamma \times R_d}$

Where, $R_d = (1 + D_f/ B \leq 2.0)$ ......Depth Correction Factor

Table -2: Settlement Analysis using Teng's Equation

BH	Q_{np}
BH2	181.125
BH3	221.37
BH4	231.5
BH5	221.37
BH6	301.87
BH7	221.37
BH8	201.25
BH9	221.37

2.2 Pile Foundation

i. Load Carrying Capacity of Pile foundation

Capacity of Piles in Intermediate Geo-Material and Rock

- **Formula**

$$Qu = R_e + R_ef$$
$$Qu = K□□ \times q_c \times df \times Ab + A□ \times Cus$$

Qu = ultimate capacity of pile

R_e = ultimate end bearing

R_ef = ultimate side socket shear

K□□ = Empirical co-efficient (value ranges from 0.3-1.2)

$Q_{c=}$ avg unconfined compressive strength of rock

df = depth factor

= 1+ 0.4 x length of socket / dia of socket

Ab =c/s of base pile

A□ =surface area of socket

Cus = Ultimate shear strength of rock along socket length

K = 1.03

q_c = 6118.29 t/m2

d f = 1+0.4x3x1(3d)/1

=2.2 = 1.2

$Ab = \pi/4x1^2$

$= 0.785\ m^2$

$A□ = \pi d = \pi\ x1x3$

$=9.42\ m^2$

Cus =0.225x√ 9c

Qu = 1 x 6118.29 x 1.2 x 0.785 + 9.42 x 17.59 = 5929.12 ton

= 17.59

- For Diameter = 1m

$\mathbf{Q_{allow} = (R_{e/3}) + (R_{af/6})}$

= 5763.42/3 + 165.69/6

= 1948.75 ton

- For Diameter = 1.2m

$Q_{allow} = (R_{e/3}) + (R_{af/6})$

= 8296.40/3 + 198.76/6

= 2798.59 ton

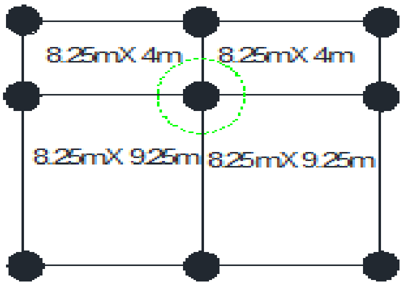
- For Diameter = 0.9m

Qu = 1 x 6118.29 x 1.2 x 0.64 + 7.63 x 17.59
= 4833.05 ton

$Q_{allow} = (R_{e/3}) + (R_{af/6})$

= 4698.84/3 + 134.21/6

= 1588.64 ton



2.3 Load coming from Structure:

Height of building – 75m

No. of floors – 20 floors

Each floor ht. – 75m

Size of each room – 8.25 X 9.25m

Corridor size – 8.25 X 4m

Live Load – 5 kN/m^2

Thickness of Slab - 150mm = .15m

Size of beam – 400 X 450mm

Load Calculation

1. **Wall Load:**

Wall Load = 0.23 x 3.15 x 2.5
= 1.81 t/m
Total Load = Load per m x Total length
= 1.81 x (9.25+5)
Wall load = 25.75 ton

2. **From column:**

Volume of col. = π\4 x 1^2 x 3.75
= 2.94 m^3
Volume of steel = 1% of concrete
= 0.029m^3
Load on Column = 2.94 x 2.5 + 0.029 x 7.8
Column Load = 7.576 ton

3. **Beam Load:**

Qu = 1 x 6118.29 x 1.2 x 1.13 + 11.30 x 17.59
= 8495.16 ton

Volume of col. = 0.4 x 0.45 x 1
= 0.18 m^3
Volume of steel = 2% of concrete
= 0.0036 m^3
Load on Beam = 0.18 x 2.5 + 0.0036 x 7.8
= 0.48 t/m
Total Load on
beam = 0.48 x (8.25 x 2 + 9.25 x 2)
Load on Beam = 16.8 ton

4. **From Slab**:

Slab load S1 = 0.15 x 8.25 x 9.25
= 11.44 m^3
Volume of steel = 2% of concrete
= 0.22 m^3
Total Load on
Slab S1 = (11.44 x 2.5) + (0.22 x 7.8)
= 30.31 ton
Slab load S2 = 0.15 x 8.25 x 5
= 6.18 ton
Total Load on
Slab S2 = (6.18 X 2.5) + (0.12 X 7.8)
= (16.38 + 30.31)/2
Total Slab Load = 23.34 ton

Total Load on Column = 73.45 × 21
= 1542.45 ton

Total Load on Column =

3. OBSERVATIONS

3.1 For Shallow Foundation:

- Based on the subsurface conditions met, competent stratum is not available at shallower depth.
- Silty sand is observed from ground level to the depth varying from 6.5 m to 13.5 m in all boreholes.
- Underlying this layer, completely weathered Basalt is encountered at depth from 6.6 m to 24.0 m.
- Topography of the terrain is seen nearly flat. The site is Deccan trap basically consisting of Basaltic rock.
- Basalt here is not of good quality.

3.2 For Pile Foundation:

- Pile diameter considered in analysis is 1 m and 1.2 m.
- The strata consist of overburden soil followed by weathered rock and at further depths. The relative depths vary from bore to bore.

- For the purpose of assessment of pile capacity, the contribution from weathered rock and overburden is not considered.
- All Borehole samples show veins and abnormally low UCS in some rock samples. Hence it is not considered as representative.
- As the overburden is observed from ground level to the depth varying from 3.00 m to 9.00 m it is not advised to go for shallow foundation. The heterogeneous nature of the strata leads to settlement of unpredictable nature. Instead we recommend to adopt pile foundation to transfer the load to firm strata. With this, settlement will be considerably low

3.1. Results:

I. Shallow Foundation

The results after calculating the Bearing capacity & settlement pressure of soil at 3m depth for Shallow foundation area as follow,

Table -3: Results of shallow foundation

BH	N	q_{nu} kN/m²	q_{ns} kN/m² = $q_{nu}/3$
BH1	-	-	-
BH2	12	827.04	275.68
BH3	14	1017.36	339.12
BH4	15	1123.5	374.5
BH5	14	1017.36	339.12
BH6	18	1485.84	495.28
BH7	14	1017.36	339.12
BH8	13	918.54	306.18
BH9	14	1017.36	339.12

Where,
N = Standard Penetration test value
Q_{nu} = Bearing capacity
q_{ns} = Safe Bearing Capacity

II. Pile Foundation

Table -2: Results of Pile foundation

Sr. No.	Diameter of pile m	End Bearing Capacity Qu ton	Allowable Bearing Capacity Q allow
1	0.9	4833.0.5	1588.64 ton
2	1	5929.12	1948.75 ton
3	1.2	8495.16	2798.59 ton

III. Load from Structure on Foundation

Manual calculation for structure
- Total wall load = 25.75 t
- Load on beam = 16.8 t
- Load on column from slab = 7.576 t
- Total load on slab 1 = 30.31 t
- Total load on slab 2= 6.18 t
- Total load on column= 1800t

Total Load = 1800t (17651.97 kN)

4. CONCLUSION

At the NHES Educational Complex near the village of Kavesar, Anand Nagar Crossing of Ghodbunder Road in Thane, Maharashtra.

Soil Investigation: The geotechnical investigation reports for all nine completed boreholes were studied and we conclude that,
- Silty sand is visible from the surface to a depth ranging from 6.5 m to 13.5 m.
- Fully weathered basalt is found at a depth of 6.6 meters and 24.0 meters under this layer.
- From the ground, up to a depth ranging from 6.5 m to 13.5 m, overburden is visible.
- The land appears to have a relatively level topography.
- The location is essentially a basaltic rock Deccan trap.
- Here, the basalt is of poor grade.

Pile and shallow foundation were considered for the design of foundation

Shallow Foundation

After calculating the bearing capacity of the shallow foundation, it was found to be less than the load coming from the structure, which is 1800 tonnes (17651.97 kN)

Furthermore, based on the subsurface conditions encountered, a competent stratum is not available at a shallower depth. In all boreholes, silty sand was observed from ground level to a depth ranging from 6.5 m to 13.5 m, with completely weathered basalt found underlying this layer at a depth ranging from 6.6 m to 24.0 m. The topography of the terrain is nearly flat, and the site consists of basaltic rock from the Deccan trap, but the quality of the basalt is not good. Considering the overburden and soil condition, it is not recommended to proceed with a shallow foundation.

Pile foundation:

Based on soil report and calculation, A pile foundation is advised since excellent grade rock is not present at shallow depths, according to field and laboratory research. A pile foundation can transfer the load of the structure to a deeper and more competent stratum, thus ensuring the stability and safety of the structure.

The pile diameters were selected as 0.9m, 1.0 m and 1.2 m., as per IRC 78, the allowable pile capacity were observed to be 1588 tonnes (158822 KN), 1948 tonnes (19409 kN) 2798 tonnes (27879 kN) respectively.

Finally, a single pile with diameter 1m having load caring capacity of 1948 ton was suggested for the proposed structure

As per IRC 78, the material to be used for the construction of pile foundation shall be M30 grade Reinforce cement concrete

5. REFERENCES

Indian Standard, IS: 2720 Part 4 (1995, Reaffirmed 2015). "Grain size analysis of soil" BIS, New Delhi.

[1] Indian Standard, IS: 2720 Part 3 (1980, Reaffirmed 2016). "Determination of specific gravity" BIS, New Delhi

[2] Indian Standard, IS 2720 Part 5 (1985, Ref. 2015)). "Liquid Limit and Plastic Limit Test" BIS, New Delhi

[3] Indian Standard, IS 2720 Part 6 (1972, Ref. 2016). "Shrinkage Limit Test" BIS, New Delhi

[4] Indian Standard, IS: 12070-1987, code of practice for design and construction of shallow foundations on rocks

[5] Indian Standard, IS: 13365 (Part 1): 1988, Quantitative classification system of rock mass-Guidelines.

[6] Indian Standard, IS: 6403: 1981, Code of practice for determination of bearing capacity shallow foundations.

[7] Indian Road Congress, IRC 78: 2014, Standard Specifications and coder of practice for road bridges.

[8] Dr.s.k.tiwari, m.k.kumawat, (2020) "Guidelines for Planning Soil Investigation of Building Project"

[9] Harry G. Poulos, (2018) "Tall building foundation design method and application"

[10] Vedprakash Maralapalle, Analysis and Design of foundation for G+5 residential building"

[11] A.R.Arora, "Soil Mechanics and Foundation Design"

[12] MJ Tomlinson, "Foundation Design and Construction"

[13] H.g. Poulos, E.H. Davis "Pile Foundation Analysis and Design"