

**EXPERIMENTAL INVESTIGATION AND NUMERICAL
MODELLING OF FOUNDATION BEHAVIOUR ON DTU
SOIL USING PLAXIS 2D**

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“EXPERIMENTAL INVESTIGATION AND NUMERICAL MODELLING OF FOUNDATION BEHAVIOUR ON DTU SOIL USING PLAXIS 2D”

submitted as a partial fulfilment of the requirements for the award of the Degree of Master of Technology in the Department of Civil Engineering, Delhi Technological University, Delhi, is an authentic record of the work done by me during the period from 2024 to 2026 under the supervision of

Prof. Kongan Aryan.

The material contained in this dissertation has not been presented elsewhere for the award of any other degree of this or any other institute/University.

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It is hereby certified that the candidate has incorporated all the recommendations suggested by the examiners in his thesis and the statements made by him are correct to the best of my knowledge.

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It is hereby certified that Mr. **RISHAV SHARMA** (24/GTE/09) has conducted the research presented in this dissertation entitled:

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ABSTRACT

This dissertation includes an experimental and numerical study on how foundation systems perform in DTU soil using the PLAXIS 2D software.

The study uses both lab tests and finite element modelling to understand how soil behaves when it's under the load from foundations. Important properties of the soil sample such as moisture content, particle size distribution, specific gravity, compaction characteristic sand shear strength, were tested in the lab.

These properties were then used in numerical simulations in PLAXIS 2D with the Mohr Coulomb model.

A numerical analysis was executed to examine settlement behaviour stress distribution formation patterns, mesh response, and changes in bending moments in the soil and foundation system.

A comparative analysis was also done to look at how different densities of silty sand affect foundation performance. The results showed that soil density has a big impact on settlement and how stress is transferred. Dense soil showed less deformation compared to loose soil, and it also had a better load carrying ability

The contour plots and displacement profiles from PLAXIS 2D helped understand how 2D stress was redistributed in the soil mass.

The study shows that combining experimental investigations with finite element modelling can effectively assess how foundation perform in different soil conditions

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LIST OF SYMBOLS, ABBREVIATIONS AND NOMENCLATURE

Symbol / Abbreviation	Description
C	Cohesion of soil (kPa)
Φ	Angle of internal friction (°)
γ	Unit weight of soil (kN/m³)
γ_d	Dry unit weight of soil (kN/m³)
γ_{sat}	Saturated unit weight of soil (kN/m³)
G_s	Specific gravity of soil solids
e	Void ratio
e_{max}	Maximum void ratio
e_{min}	Minimum void ratio
D_r	Relative density (%)
W	Moisture content (%)
OMC	Optimum Moisture Content (%)
MDD	Maximum Dry Density (g/cm³ or kN/m³)
LL	Liquid Limit (%)
PL	Plastic Limit (%)
PI	Plasticity Index (%)
DST	Direct Shear Test
FEM	Finite Element Method
MC	Moisture Content
PSD	Particle Size Distribution

Symbol / Abbreviation	Description
K	Coefficient of permeability
E	Young's modulus (kPa or MPa)
ν	Poisson's ratio
σ	Normal stress (kPa)
τ	Shear stress (kPa)
Δ	Change in value
PLAXIS	Finite Element Software for Geotechnical Analysis
Mohr–Coulomb Model	Constitutive soil model used in PLAXIS
FEA	Finite Element Analysis

CHAPTER 1

GENERAL INTRODUCTION

Soil plays an indispensable role in any construction project which involves the design of a foundation. As the construction of a building or any other construction progresses, engineers or designers need to make decisions about the stability of the structure. For this reason, construction engineers must know how to design safe and sustainable foundations in the presence of soil.

A foundation carries the load of a structure, therefore, soil and foundation interaction is very important in determining the structural performance, settlement, distribution of stress, and structural deformation. The lack of knowledge of the construction engineer about the behaviour of the soil may lead to excessive settlement which can cause failure of the construction, and failure of the infrastructure.

For this reason, as a branch of civil engineering, geotechnical engineering places great emphasis on the study of soil and the behaviour of foundations. There are several factors that dictate the behaviour of construction soil like moisture content, density, size of particles, shear strength, degree of compaction, and state of stress. Granular soils including sandy and silty soil exhibit a different behaviour based on their compaction. Foundation systems and soil settlement are influenced by these soil characteristics.

Laboratory testing is the only way to obtain the physical and mechanical soil characteristics that are required for design and analysis. The frequent tests used in determination soil characteristics are moisture, grain size, specific gravity, compaction, and direct shear. Parameters obtained through laboratory testing can be used to perform soil response prediction under different loading conditions.

Computational techniques have advanced to the point where numerical modelling is a useful tool in the analysis of critical geotechnical problems. Finite Element Method (FEM) based analysis can be done for detailed study of settlement, stress distribution, deformation patterns and soil-foundation interaction.

Numerical modelling complements experimental cases and improves the analysis of geotechnical behaviour under different conditions. The current study is carried out to perform experimental study and numerical modelling of foundation behaviour on DTU soil using plaxis 2D

Soil samples taken from the DTU campus are experimentally characterized by laboratory tests and the obtained engineering parameters are used for numerical simulation.

The need of this is to assess the impact of soil properties and relative density on the behaviour of foundation, and improve the understanding of soil foundation interaction through the combination of experimental and numerical approaches

1.2 SOIL FOUNDATION INTERACTION

Soil interaction is what happens when the soil and the foundation work together when they are under load from a structure. When a structure puts weight on the foundation it causes stress in the soil underneath, which can make the soil settle, change shape and move the stress around. The way the foundation behaves depends on the properties of soil like how dense it's how strong it is when it is pulled apart how much water it contains and how much it can be squeezed.

What happens to the soil when it is under load is very important for figuring out how well a structure will perform and if it will be stable. If the soil settles much or settles unevenly it can damage the structure cause problems with how it works and make it less safe. So it is very crucial to understand the soil pattern and the foundation interact with each other for design and construction practices.

How much the soil settles and what kind of settlement it is depends on a lot of things like what kind of foundation it's how much weight is on it what the soil is like and if there is water in the soil. Soil that is made up of sand and gravel behaves differently than soil that is made up of clay.

In soil that's sandy or silty how tightly the particles are packed together makes a big difference in how it settles and how much weight it can hold. Soil that is packed tightly together can usually hold weight and settles less than soil that is loose. Understanding how the soil and the foundation interact with each other has become very important in engineering because soil can behave in complex ways when it is

Under different kinds of loads. By doing experiment and using computer models, the ones in PLAXIS 2D we can make accurate predictions about how the soil will settle and change shape. This helps us design foundations that're safer and more efficient.

This study looks at how foundations behave on the soil at DTU using the laboratory tests and computer analysis with PLAXIS 2D. Purpose of this to determine the impact of the properties of the soil and its percentage of denseness it is packed affect the behaviour of the foundation when it is, under load. The soil and foundation interaction is what we are trying to understand and how the soil properties and density conditions affect the foundation systems.

1.3 IMPORTANCE OF EXPERIMENTAL INVESTIGATION

Geotechnical engineering relies heavily on investigations to obtain necessary information concerning physical and mechanical properties and characteristics of soil.

We need these properties accurately to figure out how foundations will perform and how soil will react to different loads. So laboratory testing is crucial to understand the characteristics of soil so to make geotechnical analyses more reliable.

To find out properties of soil we do a lot of laboratory tests. These tests include checking the moisture content, grain size distribution, specific gravity, compaction characteristics, shear strength and density of soil. These properties have an impact on things like how much the soil settles how stress is distributed in the soil and how well foundations work. Therefore experimenting with soil is a step before we do any numerical modelling or design analysis.

Soil behaves depending on things like the conditions at the site what minerals are in the soil how much moisture present in soil and how dense the soil. Because of this we cannot make assumptions about soil properties that always match what happens in real life. That is why it is very important to do investigations on soil from local areas to get realistic engineering parameters and make numerical simulations more accurate. For this study we got soil samples from the DTU site. Did a lot of experiments on them. We did tests to get the information concerning the moisture content, grain size, specific gravity and other soil properties.

We used results of these experiments as input, for modelling using PLAXIS 2D. By combining laboratory investigations with numerical analysis we can better understand how soil and foundations interact.

This approach helps us to reliably assess how foundations will behave in different geotechnical conditions. We think that geotechnical engineering will improve a lot if we use this approach. The soil properties we found out will help us to design foundations and make geotechnical analyses more accurate.

1.4 INTRODUCTION TO NUMERICAL MODELLING

Numerical modelling has emerged as an established approach within geotechnical engineering, facilitating the analysis of intricate soil behaviour and the prediction of soil-foundation system responses under various loading scenarios.

Traditional analytical methods frequently depends upon simplifying assumptions, which can limit their capacity to accurately represent the actual soil behaviour.

Conversely, numerical methods provide enhanced precision and enable more comprehensive investigations into complex geotechnical challenges. Among the diverse numerical methodologies, the Finite Element Method (FEM) is extensively applied for analyzing stress distribution, settlement, deformation, and the overall stability of geotechnical structures.

This method operates by discretizing the soil mass into smaller elements, subsequently evaluating their individual and collective responses to applied loading conditions. Such an approach thereby facilitates the simulation of realistic soil parameters , nature and intricate soil structure interaction phenomena

Utility of numerical modelling is evident in several key areas, encompassing the visualization of deformation patterns, the prediction of settlement characteristics, the analysis of stress states, and the evaluation of potential failure mechanisms.

Furthermore, it facilitates parametric studies through the systematic variation of soil properties and loading conditions.

Consequently, numerical analysis represents a robust technique for investigating foundation behaviour within geotechnical engineering.

The importance of numerical modelling is contingent upon the judicious selection of soil parameters, constitutive

models, boundary plus loading conditons. To enhance reliability of numerical simulations, experimentally determined soil properties are frequently incorporated as input parameters. This features numerical modelling to analyse the behaviour of foundations on DTU soil. Experimentally derived soil properties are integrated into the numerical analysis to evaluate settlement behaviour, stress distribution, and deformation characteristics under varying density condition

1.5 INTRODUCTION TO PLAXIS 2D

The Geotechnical software PLAXIS 2D is an extensive finite element method (FEM) computer program that was created to provide assistance in the analysis.

It is designed to help solve geotechnical engineering problems related to deformation (settlement), stability (seepage), and soil-structure interaction through numerical analysis of soils subjected to different loads, boundary conditions, and time-dependent effects.

By applying FEM techniques, PLAXIS 2D provides the ability to perform a multi range variety of numerical analyses (settlement and distribution of loads through and within soils), providing a computer-based tool for numerically predicting the nature of a soil under the influence of an external load.

One more benefit of the use of PLAXIS 2D is its ability to analyze the impacts of soil parameters on performance of a foundation using parametric analysis technique.

Therefore, parametric studies can be helpful to characterise the impacts of engineering parameters on the performance of the foundation and modification of its interactions with soils.

In the case we will be using PLAXIS 2D, the behaviour of the foundations on the soil from DTU soil (silty sand) will be analysed numerically.

The results obtained from experimental testing, such as the use of laboratory tests, will be used to develop input data for the analysis.

Numerical analyses would be applied for studying the impact of the level of settlement and deformations and calculating the influence of the relative density of soil on the performance of the foundation

We will also get to know about the displacement settlement under the action of load along with stress contour.

1.6 NEED OF PRESENT STUDY AND PROBLEM STATEMENT

While much research has been done on soil/ foundation interaction as well as methods of numerical modelling several variables still remain that have not been evaluated through an experimental numerical integrated approach utilising experimental-measured properties of silty sand to quantify or define site conditions for predicting how foundations will behave under different densities.

Furthermore, additional study is necessary to improve the predictive capability and practical application of locally sourced soils when loading foundations.

Experimental studies provide an accurate representation of soil characteristics whereas numerical modelling allows for detailed modelling and prediction of global and localized deformations, stress distributions, and settlement.

Through the combination of laboratory testing with finite element analysis, the understanding of soil response is enhanced as well as the reliability of geotechnical evaluations.

The current study will investigate the engineering properties of DTU soil which has properties comparable to silty sand via laboratory testing and then utilised as model parameters of DTU soil in PLAXIS 2D modelling so as to calculate effects of various density conditions on the behaviour of a foundation.

Additionally, emphasis will be given to determine how relative density will influence the settlement and deformation characteristics of the foundation.

Integrating the results of this will increase understanding of soil/foundation interaction and offer a foundation for understanding how to better manage the behaviour of the soils. basis for improved prediction of foundation response under varying geotechnical loading conditions.

1.7 OBJECTIVES OF STUDY

- To find out physical as well as engineering properties of DTU soil through laboratory testing.
- To test the moisture content, grain size distribution, specific gravity, compaction and shear strength of soil.
- To create a numerical model of a raft foundation system on DTU soil using PLAXIS 2D.
- To analyse settlement behaviour and deformation characteristics of raft foundation under different soil loading conditions.
- To analyse the variation of stress distribution and stress contours developed beneath the raft foundation under applied loading conditions.
- Compare settlement, deformation, and stress response of raft foundation under varying soil conditions and interpret soil–foundation interaction behaviour.
- To integrate experimentally obtained soil parameters with numerical modelling for improved prediction of raft foundation behaviour.

1.8 EXTENT OF STUDY

The current study is restricted within experimental investigation of foundation behaviour and the numerical modelling of behaviour on DTU soil..

The accepted soil samples are tested in the laboratory to assess engineering characteristics of the soil.

Numerical analysis is performed on PLAXIS 2D to investigate settlement behaviour, deformation characteristics and the distribution of the stresses when loaded by the foundation.

The study mostly focuses on the influence of density conditions and experimentally obtained parameters on soil foundation interaction.

1.9 ORGANIZATION OF DISSERTATION

This phase of dissertation is distributed in six parts covering the experimental and numerical modelling of raft foundation behaviour on DTU soil.

Chapter 1: Introduction

The accepted soil samples are sent to the laboratory where the engineering properties of the soil is tested.

Using PLAXIS 2D a numerical analysis is performed to study settlement behavior, deformation characteristics and the distribution of the stresses under loading by the foundation.

Chapter 2: Literature Review

Previous studies of soil foundation behaviour, tests on soils and raft foundations and numerical modelling using PLAXIS 2D are reviewed. Areas of study that are identified as gaps within previous studies are also mentioned.

Chapter 3: Study Area and Soil Characterization

This chapter describes the collection of DTU soil samples, sample preparation, and determination of physical properties of soil through laboratory testing.

Chapter 4: Methodology

This chapter explains the experimental procedures adopted for evaluating soil properties, these are moisture content, grain size, specific gravity, compaction characteristics, relative density investigation.

The numerical modelling procedure in PLAXIS 2D, modelling assumptions, material properties, along with boundary conditions are also discussed.

Chapter 5: Results and Discussion

Here we get the result and calculations

Settlement behaviour, deformation characteristics, stress contours, and the effect of relative density on raft foundation behaviour are analysed and discussed.

Chapter 6: Conclusions and Future Scope

Here in the chapter summarizes major cases of the study and presents conclusions based on experimental and numerical results.

Instructions for future work are also suggested. The dissertation also includes references and appendices containing additional calculations, observations, and supporting data related to this case.

CHAPTER 2

2.1 LITERATURE REVIEW

ANGGRAINI and SARIFAH (2024)- They investigated the behaviour of raft foundations on clay soil using numerical analysis. Their study showed that increasing raft thickness significantly reduced settlement and improved the bending moment distribution, thereby enhancing the overall performance of the foundation.

BINA ET AL. (2024) – They studied the behaviour of raft foundations on clay shale using numerical analysis. The study found that degradation in shear strength increased foundation settlement and reduced the load-bearing performance of the foundation.

SURESH and DARGA KUMAR (2024) – They investigated the settlement behaviour of pile raft foundations on soft clay and loose sand using PLAXIS 2D numerical modelling. The study showed that pile length, soil cohesion, and angle of internal friction significantly influence foundation settlement and load transfer. The results indicated that increasing pile length improved the performance of the pile raft foundation by reducing settlement and enhancing soil–foundation interaction.

RAO and REDDY (2022)- They highlighted the supremacy of relative density on settlement and deformation nature of granular soils. Their study indicated that increased soil density generally results in improved foundation performance and reduced settlement. They conducted analysis on raft foundation on soil responds in 2022.

KHAN ET AL. (2021) - They studied raft foundations on sand and silty sand in 2021. They used modelling approaches. The study found that the stress is not distributed evenly and that the density of the soil and the loading conditions have an impact on the foundation's performance.

VERMA and CHOUDHURY (2018)- An analysis was performed in 2018 on foundations on sandy soils. They used a program called PLAXIS 2D. The study showed that PLAXIS 2D can predict settlement behaviour and stress distribution accurately and also stress contours beneath raft foundation.

BRINKGREVE ET AL. (2018) – They demonstrated the application of PLAXIS 2D using the Finite Element Method for geotechnical engineering problems. Their study showed that numerical modelling can effectively predict settlement, stress distribution, deformation, and soil–structure interaction in foundation systems.

CODUTO ET AL. (2016) – They explained the settlement mechanisms and soil–structure interaction through analytical approaches. Their study emphasized that soil properties play a significant role in controlling settlement behaviour and the overall performance of shallow foundations

KUMAR and JAIN (2015) - They used the Finite Element Method to study settlement behaviour of raft foundations on soils in 2015. The study showed that numerical modelling is very useful for predicting how the foundation will deform and respond. Their findings showed that numerical methods provide increase in accuracy of deformation behaviour compared to analytical methods

MANDOLINI ET AL (2006) - Mandolini and his team studied raft foundations on different types of soils in 2006, Cohesive and Granular Soils. They used a combination of numerical approaches. The results showed that how stiff the raft is playing a role in controlling settlement and stress redistribution beneath the foundation.

BURLAND ET AL (2006) - Burland and his team did a study in 2006 on raft foundations on soils. They found that these types of foundations can really reduce settlement. Their findings said that if one design the raft correctly it can help spread the load and make the foundation work better and enhance foundation performance.

POULOS (2001) – They investigated the behaviour of soil foundation interaction for different soil conditions using analytical and numerical approaches.

BOWLES (1997) – Bowles presented simplified analytical procedures for foundation design considering bearing capacity and settlement characteristics. This study emphasized importance of soil properties in controlling foundation performance. The study has brought out the criticality of the soil property in regulating the foundation behaviour

2.2 RESEARCH GAP.

The following areas for research have been identified from the literature review.

- Limited work focused specifically on **raft foundation behaviour on silty sand soils** under varying density conditions.
- Most previous investigations considered **generalized soil properties**, whereas studies using site-specific soil parameters remain limited.
- Comparatively fewer studies have integrated **experimental soil characterization with PLAXIS 2D numerical modelling**.
- The influence of **relative density on settlement behaviour, deformation characteristics, and stress distribution** beneath raft foundations has not been sufficiently explored.
- Limited research has analysed **stress contours and deformation patterns** of raft foundations using experimentally obtained soil properties.
- Most studies emphasize settlement analysis, while combined evaluation of **settlement, stress contours, and displacement behaviour** is relatively limited.
- Studies involving **locally available DTU soil** and its application in foundation behaviour analysis are studied

CHAPTER 3

3.1 STUDY AREA



Figure 3.1: Soil Sampling location within DTU campus (Front of CAD LAB)

The soil used in the present investigation was collected from the Delhi Technological University (DTU) campus, specifically from the area located in front of the CAD Laboratory. The selected site represents local ground conditions, and was selected for investigating the performance of raft foundation under different loadings. The soil was sampled manually from a shallow level and taken to the geotechnical lab for tests.

The soil was later identified as silty sand and employed in experimental analysis and numerical modelling.

3.2 SOIL COLLECTION AND SAMPLE PREPARATION



Figure 3.2: Collected soil sample before laboratory processing

After collecting the soil samples were brought to the Geotechnical laboratory for preparation. Visible impurities such as roots, organic matter and oversized particles like stones were removed. The soil was then oven dried into the oven to obtain a representative sample suitable for experimental testing.

The prepared soil sample was then used for further laboratory investigations including moisture content determination, particle size distribution analysis, and other tests. Proper sample preparation was carried out to ensure uniformity and reliability in experimental results.

3.3 PHYSICAL PROPERTIES OF DTU SOIL

The soils collected from the DTU area were identified to be silty sands from the results of the laboratory test and nature of particle composition. Silty sand is made up of majorly sand particles, with the presence of a considerable amount of silt, affecting its settling behaviour and stress distribution.

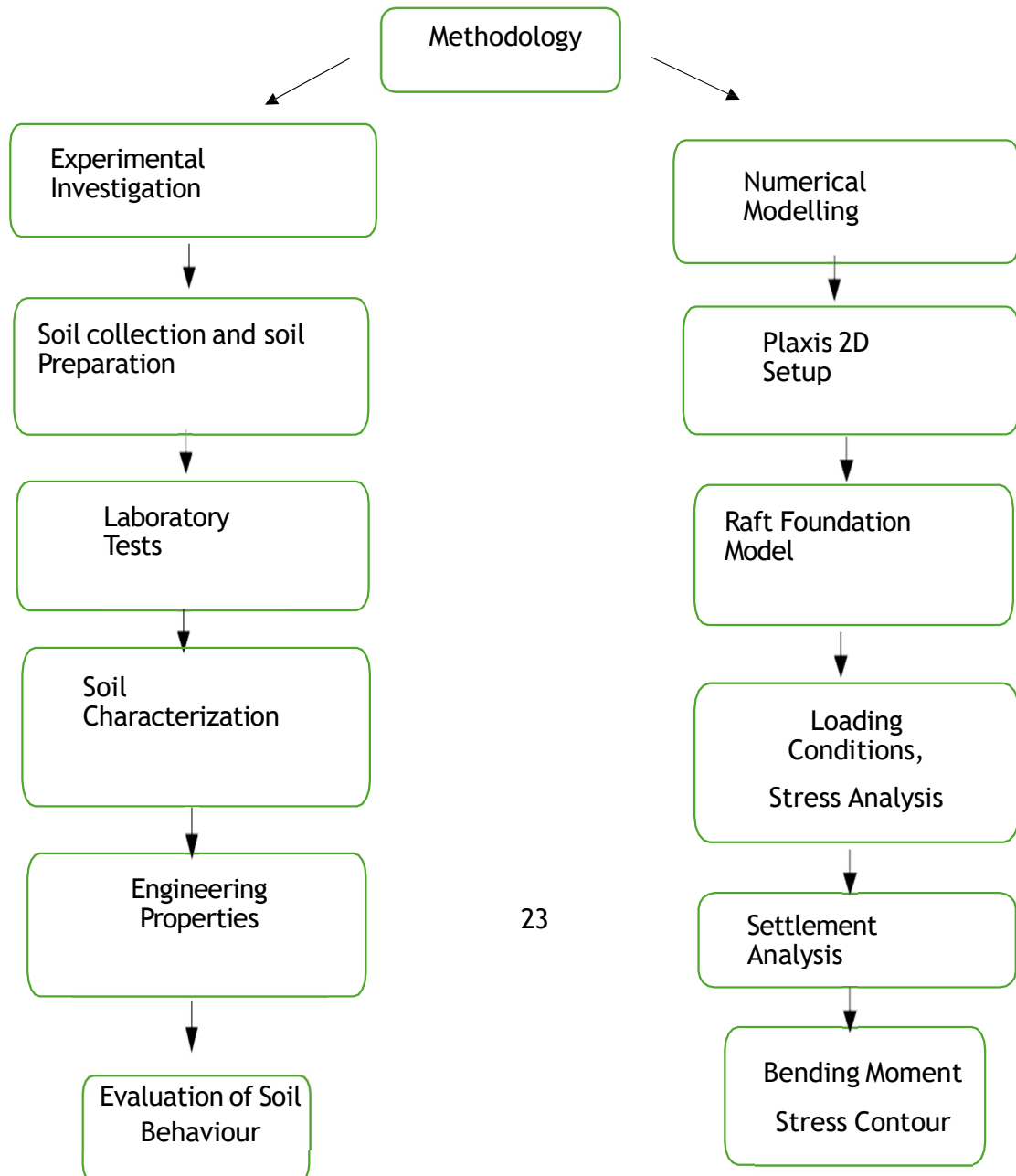
Tests carried out in the laboratory include moisture content determination, particle size determination, and specific gravity tests for determining the respective soil properties.

Soil properties is crucial in predicting the reaction of raft foundation subjected to various loads

CHAPTER 4

METHODOLOGY

In these chapter, various method are explained with a diagram of flow chart in a proper sequence for clarity and clear manner shown in the figure below:



4.1 EXPERIMENTAL INVESTIGATION

Experimental investigations were drafted in order to ascertain the physical and mechanical properties of collected soil samples.

The test results obtained were subsequently used as input parameters for numerical modelling using PLAXIS 2Ds.

The parameters we got were further used as input values for numerical modelling in PLAXIS 2D.

Standard laboratory procedures were adopted for conducting the test

4.1.1 Particle Size Distribution Analysis (Sieve Analysis)

PSD test were performed to ascertain the percentage of different particle sizes of the soil sample from DTU soil collected.

The test assists in establishing soil classification and engineering properties.

The sample of soil collected and was oven-dried and sieved through several standard sieves arranged from largest to smallest sizes of sieve.

The weight retained by each sieve was determined plus further calculations for percentage retained and percentage passing (%) carried out.



Figure 4.1: Collected soil sample before testing



Figure 4.2: Separation of Soil particles using standard Sieve

4.1.2 Water Content Test

The water content test was done in order to know the level of moisture that is contained within the soil

Steps followed included use of the oven drying technique. The Steps are as follows :

This involved the collection of the sample from the ground and putting the soil into a dry moisture can. The initial weight of the can together with the soil was recorded. The sample was then placed in the oven for 24 hours in order to dry up the sample.

The subsequent weight of the dry soil was measured in the can. Moisture content of the soil sample was calculated based on standard procedures



Figure 4.3: Moisture containers used for water content determination

4.1.3 Atterberg Limit Tests

Atterberg limits testing were carried out to investigate the consistencies and the plasticity of the soil samples.

It consists of liquid limit (LL) and plastic limit (PL) representing the moisture contents at different consistencies of soils.

For determination of W_L , the soil sample was made into paste and introduced into the Casagrande apparatus and divided by the standard groove.

The number of blows necessary for closing the groove after traveling a particular distance was recorded.

The $W\%$ that corresponds to about 25 blows were taken as the liquid limit.

On other hand, the plastic limit was determined through manual rolling soil sample into threads until crumbing was achieved at a particular diameter of about 3 mm.

This moisture content was recorded as the plastic limit.



Figure 4.4: Casagrande apparatus used for evaluation of Atterberg limits

4.1.4 Standard Proctor Test

This test is carried out to evaluate the optimum moisture content (OMC) and maximum dry density (MDD) of a soil sample using the Standard Proctor test.

The process starts with taking an soil specimen dried in an oven and blending the soil along with specific amounts of water in the compaction mould, which is filled in layers.

Each layer is compacted using standard methods. After compaction is complete, the combined mass of the mould and compacted specimen is recorded.

Water content of the soil for each compactive effort level is measured, and the dry unit density is calculated from that.

A graph is then drawn showing the co-relation between moisture content and dry density which helps to find the optimum moisture content together with max dry density of the tested specimen.



Figure 4.5: Compaction mould used for SPT



Figure 4.6. Preparation of soil sample in compaction mould



Figure 4.7. Measurement of compacted soil weight

4.1.5 Direct Shear Test

DST was performed out to obtain the shear strength parameters of soil, which include cohesion and angle of internal friction.

Prepared specimen was positioned into the shear box where a normal force was exerted on it. Shear force was applied to the specimen horizontally till the point of failure was reached.

Shear stress at failure obtained at various normal stresses was used to obtain the shear strength properties of the soil material. Values obtained were also used in performing soil behaviour analysis and numerical modelling using PLAXIS 2D.

Co-Relation between shear stress and shear strength is showed using the Mohr-Coulomb criterion.



Figure 4.8: Apparatus used for determination of shear strength parameters

4.2 NUMERICAL MODELLING USING PLAXIS 2D

In this numerical modelling, the PLAXIS 2D program was employed for study the behaviour of raft foundations on DTU soil subjected to various loading situations.

The PLAXIS 2D program, which is establish on the Finite Element Method (FEM), were used for the specimen foundation analysis and evaluation of deformation under various loading situations.

It simulated how soil and foundation interact. The model checked how the foundation deforms under load.

Analysis was conducted and following points were observed:

- Amount of Settlement
- Stress contour
- Stress path
- Bending Moments

4.2.1 Soil Parameters and Material Properties

The various parameters obtained from experiment conducted on DTU soil including shear strength parameters and moisture characteristics, were used as input values in PLAXIS 2D. The soil behaviour was modelled to represent stress-strain response under loading condition.

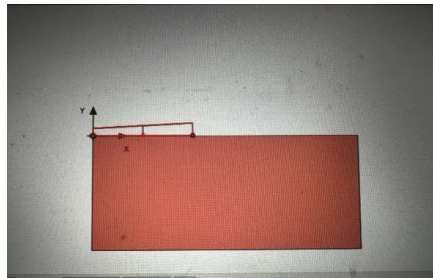
Parameters such as unit weight, cohesion, angle of internal friction, Young's modulus and Poisson's ratio were used in modelling

4.2.2 GEOMETRY AND RAFT FOUNDATION MODELLING

A 2D numerical model were created in PLAXIS 2D to simulate behaviour of raft foundation resting on silty soil

Geometry of the specimen domain and raft foundation was created according to requirement of the model

Figure 4.10: Geometry of Raft Foundation



4.2.3 MESH GENERATION

A deformation behaviour of the raft foundation under applied loading was analysed using PLAXIS 2D. The deformed mesh illustrates settlement distribution within the soil domain and indicates the maximum displacement developed due to loading conditions.

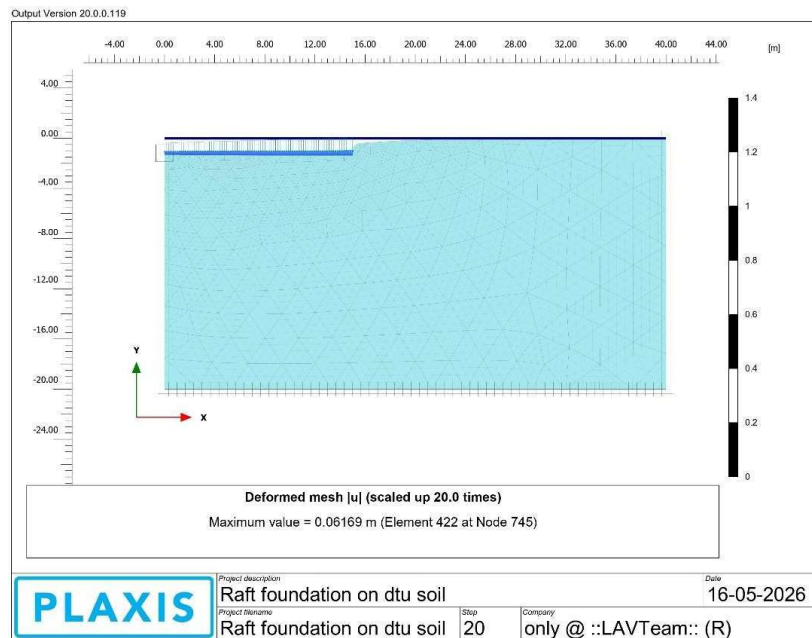


Figure 4.11. Deformed Mesh Generated in PLAXIS 2D

4.2.3. Boundary Condition

Boundary conditions were assigned in PLAXIS 2D so that the realistic interaction between soil and foundation could be modeled.

For bottom boundary, it was fixed horizontally and vertically, whereas lateral boundaries were constrained horizontally.

A line load and a udl was applied over the raft foundation to represent external loading and to study settlement and stress distribution within the soil mass

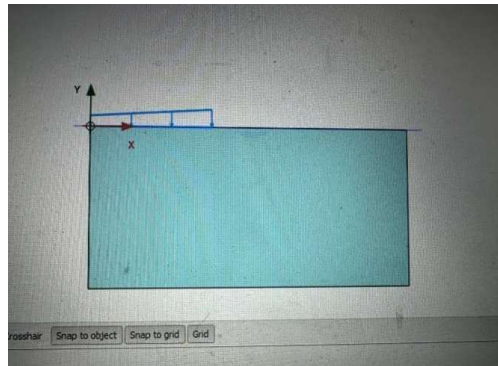


Figure 4.12: Condition and Applied line load in PLAXIS 2D

4.2.5. Material Model (Mohr Coulomb)

The constitutive relationship chosen for analysis in PLAXIS 2D was Mohr- Coulomb model. IT considers the soil behaviour in terms of elasto-plastic behaviour along with input parameters which is determined experimentally

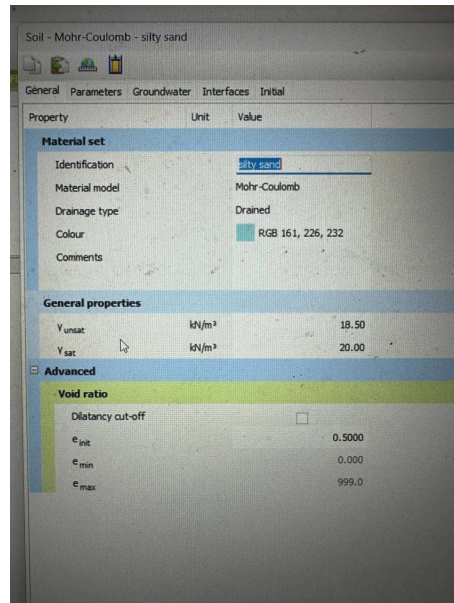


Figure 4.13: General properties of soil model in plaxis 2D

Soil - Mohr-Coulomb - silty sand

General Parameters Groundwater Interfaces Initial

Property	Unit	Value
Stiffness		
E'	kN/m ²	50.00E3
ν' (nu)		0.3000
Alternatives		
G	kN/m ²	19.23E3
E_{oed}	kN/m ²	67.31E3
Strength		
c'_{ref}	kN/m ²	5.000
ϕ' (phi)	°	32.00
ψ (psi)	°	0.000
☐ Advanced		

Figure 4.14 : Stiffness and Strength Parameters Used

CHAPTER 5

RESULT AND DISCUSSION

5.1.1 GRAIN SIZE ANALYSIS RESULT

The GSD was used to ascertain the nature of particle size distribution and soil classification.

The percentages of retention and passing were computed for the different sieves to plot the graph of gradation.

The results obtained from the analysis, the soil has been classified as silty sand, and therefore, it is composed of sand particles mixed with silt.

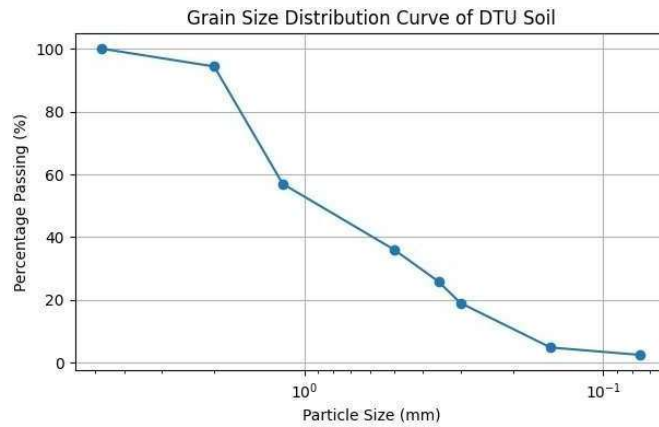
The grain size distribution characteristics influence permeability, density and settlement behaviour of soil under loading conditions.

Sieve Size	Weight retained	%Retained	Cumulative Retained	% Cumulative Retained	% Passing
4.75 mm	0	0.00	0	0.00	100
2 mm	20	5.67	20	5.67	94.33
1.18 mm	132	37.39	152	43.06	56.94
500 u	74	20.96	226	64.02	35.98
355 u	36	10.20	262	74.22	25.78
300 u	24	6.80	286	81.02	18.98
150 u	50	14.16	336	95.18	4.82
75 u	8.4	2.38	344.4	97.56	2.44
Pan	7.2	2.04	351.6	99.60	0.40

Table 5.1- Grain Size Analysis of Dtu soil

Effective Particle Size and Gradation Parameters

The effective particle sizes obtained through the grain size distribution curve are presented below:



Parameter	Value
D_{10}	0.193 mm
D_{30}	0.409 mm
D_{60}	1.232 mm
Cu	6.37
Cc	0.70

Effective particle sizes D10, D30 and D60 were determined using graph of the grain size distribution. Coefficients of uniformity (Cu) and curvature (Cc) were computed to ascertain the degree of gradation of the soil sample.

The computed values were: **Cu = 6.37 Cc = 0.70**

The computed value for the coefficient of uniformity suggests a relatively wide range of particle sizes while the value of the coefficient of curvature is less than one. Thus, this specimen may be classified as poorly graded silty sand., indicating non-uniform gradation characteristics. Such soil behaviour influences compaction, permeability and settlement.

5.1.2 SPECIFIC GRAVITY TEST

This test was done using the pycnometer technique to measure specific gravity of soil solids.

This test gives details about mineralogy and engineering characteristics of the soil. Observations made from the test are detailed below :

Parameters	Value (gm)
Weight of empty pycnometer (W_1)	684
Weight of pycnometer + dry soil (W_2)	994
Weight of pycnometer + soil + water (W_3)	1611
Weight of pycnometer + water (W_4)	1420

$$G_s = 2.6113$$

RESULT AND DISCUSSION

The value for specific gravity for the tested soil sample was determined as 2.60

These results indicate that the tested soil had moderately dense properties and corresponds to the silty sand classification that was obtained through grain size analysis.

5.1.3 PROCTOR TEST RESULT

Standard Proctor Compaction Test was done for establishing the properties of the soil sample concerning its compactness and finding out the optimum moisture content corresponding to mdd.

This experiment was done through change in water content followed by compaction.

Moisture content(%)	Wet density (g/cm ³)	Dry density (g/cm ³)
12	2.62	2.34
14	2.65	2.33
16	2.68	2.31
18	2.74	2.32
20	2.41	2.01

A compaction curve has been drawn for dry density against w% to find out OMC and MDD of the soil sample

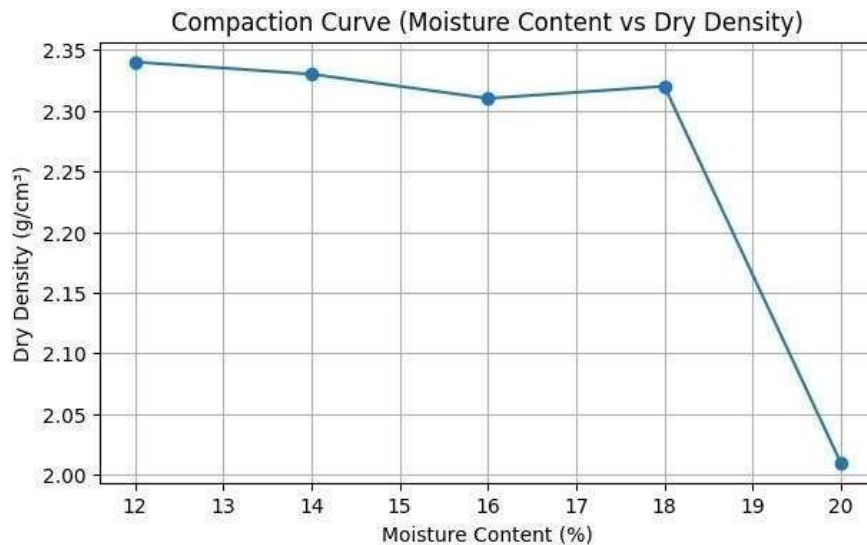


Figure 5.3. Compaction curve for varying dry density readings with moisture

Inferences from graph:

According to the compaction curve, the highest value of dry density (2.34 g/cm³) is obtained at optimum moisture content of 12%. After this, the dry density falls with increase in moisture content.

5.1.4 Shear Strength Parameters Used in Numerical Modelling

The shear strength parameters used in the numerical model were chosen based on the behavior of silty sand and past lab results from similar soil samples.

The Mohr-Coulomb model was used in PLAXIS 2D, and cohesion (c) and angle of internal friction (ϕ) are key factors that influence how soil behaves when stressed.

In this study, the cohesion value was set at 5 kPa and the internal friction angle at 32 degrees.

These parameters indicate that soil has low cohesion and moderate resistance to shearing forces. It also indicate low cohesion and moderate frictional resistance of the soil. The selected parameters were implemented in the numerical simulation to evaluate settlement, stress distribution, and displacement behaviour of raft foundation resting on DTU soil

Parameter	Value
Cohesion	5kpa
Angle of internal friction	32 ⁰
Material Model	Mohr-Coulomb
Drainage Condition	Drained

The selected values were found suitable for representing the behaviour of silty sand under loading conditions and provided stable numerical results during analysis.

5.1.5 Atterberg Limit Test Result

To test the consistency behaviour of the tested sample, an Atterberg limit test was performed. W_L was determined with the Casagrande apparatus through the plot of water content against the logarithmic value of the blow count.

Water contents of 21% and 19% were observed for blow counts of 17 and 24, respectively.

The LL of the tested sample was calculated by interpolation of corresponding flow line at 25 blows as $LL = 18.76\%$.

The low limit shows that the soil possesses low plasticity properties, indicative of its silty sand nature.

Such soils generally show limited volume change and lower compressibility with variation in moisture content.

Number of blows (N)	Water Content (%)
17	21
24	19
25	18.76

Table 5.6 No of blows vs water content

5.1.6 Water Content Test Result

Table 5.7. Water Content Test Observation

Container no.	Weight of container (gm)	Weight of container +wet soil (gm)	Weight of container +dry soil(gm)	Water Content(%)
6	52	182	170	10.16
13	49	182	170	10.16
68	66	204	186	13.00
Average	--	--	--	11.10

The water content test done to find the amount of moisture present on the collected soil sample.

The test was performed to measure the moisture level in the collected soil sample.

Moisture content is important because it affects soil properties like how it compresses and its strength.

The test was carried out using the oven drying method, and readings were taken from three samples

Based on the readings obtained from the experiment, water content of each sample was calculated. Water content of the first, second and third sample was found to be **10.16%, 10.16% and 13.00%**, respectively.

The obtained moisture content indicates that the soil contains relatively low natural water, which is consistent with the behaviour of silty sand.

Lower moisture content generally improves drainage characteristics and reduces excessive deformation under loading.

The measured water content was further considered while analysing compaction behaviour and evaluating soil properties for numerical modelling.



Figure 5.1.6 Container containing soil samples

5.2 Numerical Results

5.2.1 Settlement Analysis

Settlement analysis was also done using PLAXIS 2D to study how the raft foundation settles on silty sand when loaded. This helps determine how much and where the foundation moves under the applied load.

PLAXIS		essential for geotechnical professionals					
Project description	: Raft foundation on dtu soil					Output Version 20.0.0.119	
Company	: only @ ::LAVTeam:: (R)					Step : 20	
Project filename	: Raft foundation on dtu soil					Date : 06-01-2026	
Output	: Calculation results, Phase_1 [Phase_1] (1/20), Table of total displacements					Page : 1	
Soil element	Node	Local number	X [m]	Y [m]	u_x [10^{-3} m]	u_y [10^{-3} m]	u [m]
Clus. 1 - El. 422 silty sand	745	12	11.080	0.000	0.037	-61.691	0.062
	742	1	10.909	0.000	0.036	-61.691	0.062
Clus. 1 - El. 425	742	2	10.909	0.000	0.036	-61.691	0.062
Clus. 1 - El. 399	742	3	10.909	0.000	0.036	-61.691	0.062
Clus. 1 - El. 422	744	6	11.250	0.000	0.037	-61.690	0.062
Clus. 1 - El. 425	727	9	10.739	0.000	0.036	-61.689	0.062
Clus. 1 - El. 422	743	11	11.420	0.000	0.038	-61.688	0.062

Figure 5.7 Settlement Distribution and vertical displacement obtained from Plaxis 2D

The data suggests that the maximum settlement takes place at the point directly below the area where the load is applied, but the settlements slowly decrease with increase in distance from the loaded zone.

This phenomenon occurs due to the stress transfer from the foundation to the subsurface soils and their consequent compaction.

From the numerical simulation, the maximum vertical displacement obtained was approximately:

$$U_y = -61.691 \cdot 10^{-3} \text{ m}$$

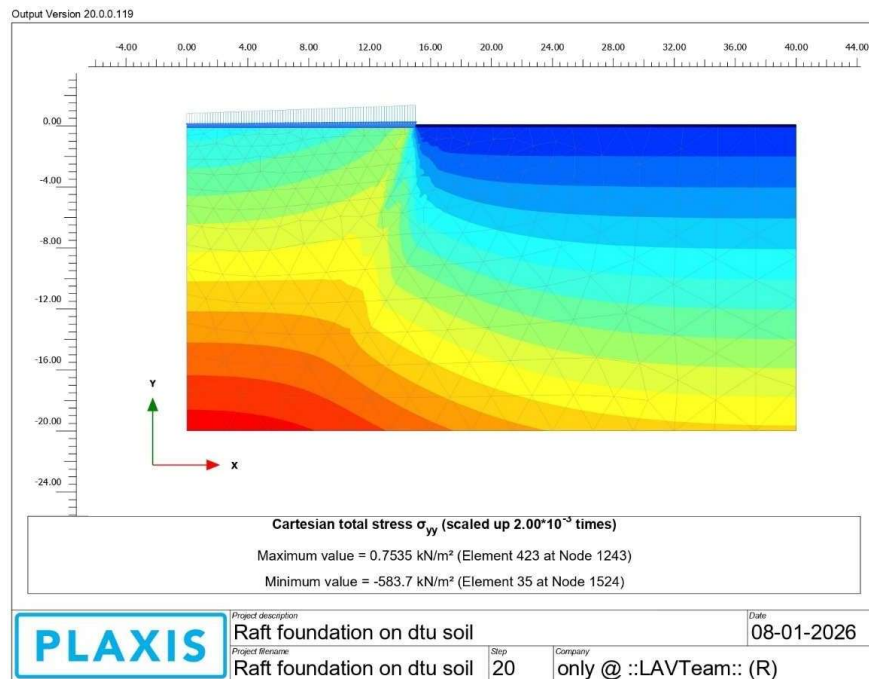
which corresponds to a maximum settlement of approximately:

$$\mathbf{S_{max} = 61.7mm}$$

5.2.2. Stress Distribution

Stress distribution analysis was performed using PLAXIS 2D to examine how stresses change within the soil under the raft foundation when loads are applied.

This analysis helps understand how the load from the foundation moves into the surrounding soil.



Contour plot of vertical stress (σ_{yy}) shows that higher compressive stresses developed beneath the loaded region of the foundations and decreases as the depth and distance from the load zone increase.

The concentration of stress close to the foundations suggests considerable interaction of the raft foundation with the soil layer.

Numerical results obtained from PLAXIS indicate that the maximum vertical stress was approximately: $\sigma_{yy}(\text{max}) = 0.7535 \text{ kN/m}^2$

while the minimum value reached: $\sigma_{yy}(\text{min}) = -583.7 \text{ kN/m}^2$

The negative stress values represent compressive stresses within the soil domain. Higher stress concentration beneath the foundation may contribute to settlement along with deformation behaviour of soil foundation system. The stress contours further indicate gradual dissipation of stresses with depth, demonstrating the load transfer mechanism in silty sand under linear loading condition

5.2.3. Total Displacement

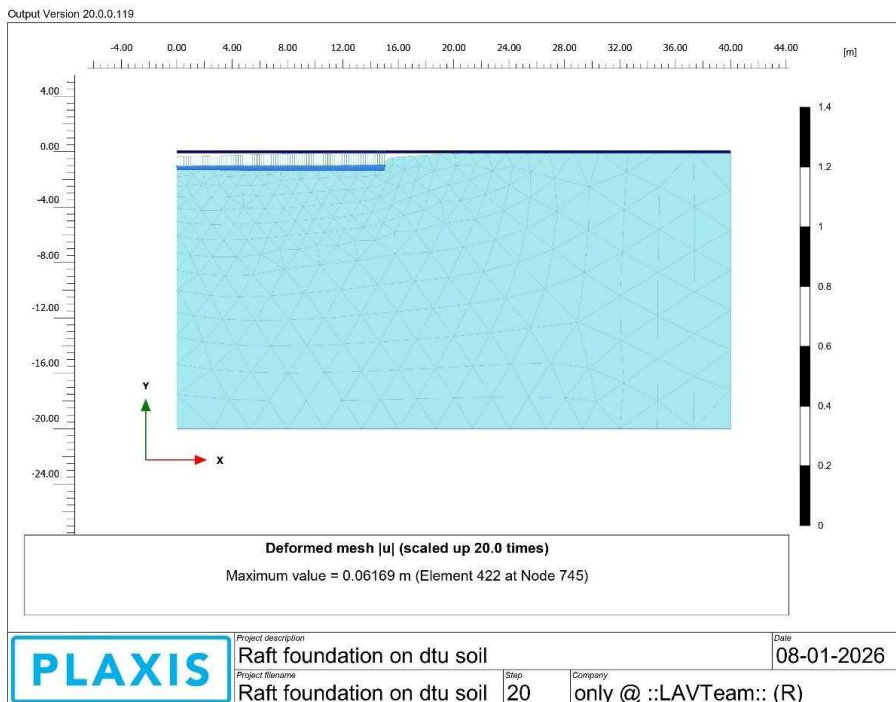


Figure 5.9 Deformed mesh showing total displacement ($|u|$) of raft foundation obtained from PLAXIS 2D analysis

Total displacement behaviour of the raft foundation was analysed using PLAXIS 2D to evaluate deformation within the soil foundation system under applied loading. The displacement contour provides information regarding movement occurring in the soil mass and helps assess foundation performance.

The deformed mesh obtained from numerical analysis indicates displacement concentration near the loaded region of the raft foundation.

The displacement gradually decreases away from the loaded area, showing the transfer of load through the underlying silty sand.

The maximum total displacement obtained from the numerical model was:

$$|U_{\max}| = 0.06169 \text{ m}$$

From the figure above:

The observed deformation pattern indicates settlement of the foundation due to applied loading.

The deformation remains localized around the loading zone, suggesting effective stress redistribution within the soil domain. The contour plot further demonstrates that displacement decreases with depth, indicating lower deformation in deeper soil layers.

This behaviour is consistent with expected response of raft foundations resting on granular soils under loading conditions.

Thus, The maximum displacement calculated from the numerical model is approximately **61.69 mm**, which implies that the settlement characteristic of the raft foundation under load is being experienced.

5.2.4 Bending Moment Distribution Along Raft Foundation

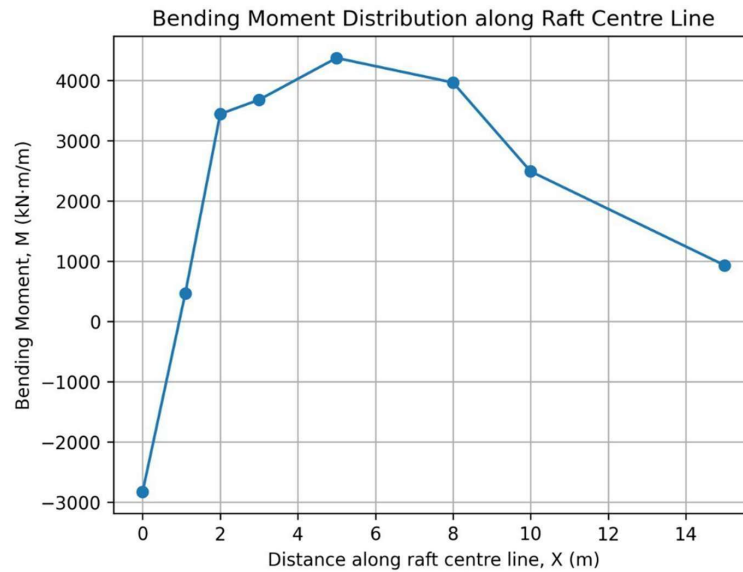


Figure 5.10 Bending moment distribution along Raft foundation

The results show that the bending moment first increased with increasing distance until it reached its highest value at the central part of raft. After that, the bending moment started to reduce towards the raft edges.

Maximum bending moment value $M_{\max} = 4372$ kNm

The variation in bending moment suggests non-uniform load transfer and redistribution of stresses within the raft foundation. Higher bending moments near the centre indicate critical regions requiring attention during structural design.

5.2.5. Horizontal Displacement Distribution (U_x)

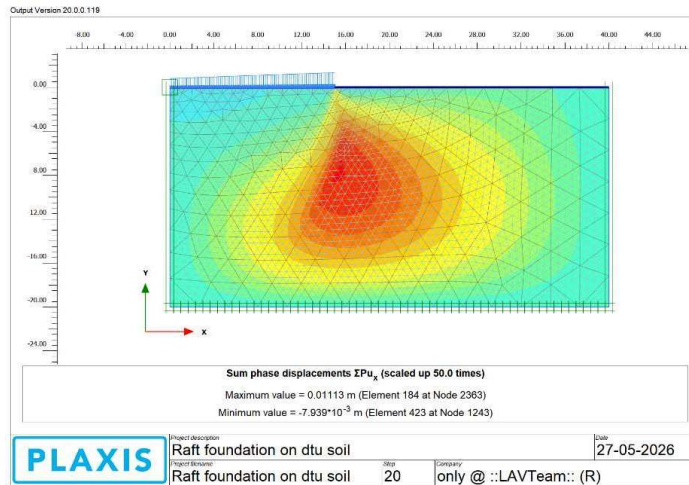


Figure 5.10: Horizontal displacement (U_x) distribution beneath raft foundation under linear loading

The horizontal displacement contour shows the lateral movement of soil around the raft foundation due to the load which is applied.

The higher values of displacement are observed close to the loaded zone, whereas the displacement value reduces as one moves further away from the zone. It can be inferred that the load has been distributed by the soil to other areas as well. It can be stated that there is no abnormal behavior of soil deformation under the given conditions.

Observation:

Maximum horizontal displacement (U_x) obtained from numerical analysis is 11.13 mm.

5.2.6. Effective Stress Distribution (σ'_{yy})

The effective stress contour shows how the applied load from the raft foundation is transferred into the underlying soil.

Higher Compressive forces acting on the soil are higher around the loaded zone and reduce with depth and distance

This response indicates effective stress redistribution within the soil mass. The contour pattern suggests that the soil experiences higher compression near the foundation while deeper layers undergo comparatively lower stress changes.

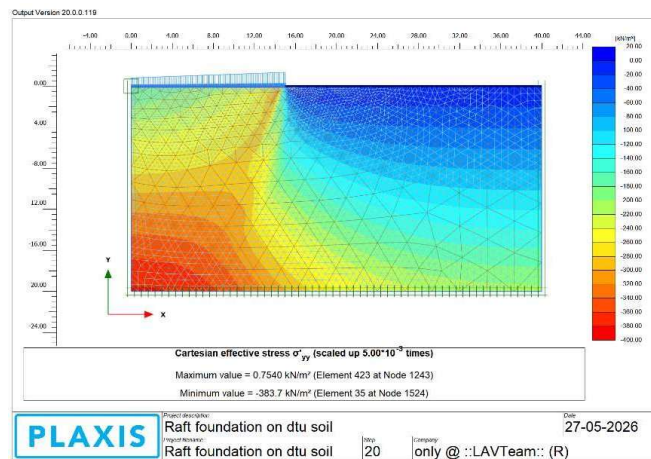


Figure 5.11: Effective vertical stress (σ'_{yy}) distribution beneath raft foundation under linear loading

CHAPTER 6

6.1 CONCLUSION AND RECOMMENDATIONS.

In this investigation, the performance on a raft foundation built on silty sand was examined using laboratory experiments and numerical modelling with PLAXIS 2D

Several lab tests were done to determine the soil's engineering characteristics, including grain size distribution, specific gravity, moisture content, Atterberg limits and compaction tests.

Based on the grain size analysis , the soil was identified as mainly silty sand with a low percentage of fine particles. The Specific Gravity of the soil was measured as 2.60 and the average moisture content of the soil sample was 11.10%

The compaction test showed that the optimum moisture content was 12%, and the maximum dry density was 2.34 grams per cubic centimeter.

Numerical modelling was done to evaluate the settlement, stresses and displacement properties of the raft foundation under loading.

The analysis shows that settlement occurs at the loaded zone, while the amount of settlement reduces as you move away from the loaded zone.

The maximum displacement obtained by numerical modelling is 61.69 mm,, indicating deformation of the soil foundation system under loading.

Stress contours also showed concentration of compressive stresses beneath the raft foundation, followed by gradual stress reduction with increasing depth. Overall, the study shows that combining laboratory testing with numerical modelling provides useful insight into soil–foundation interaction and helps in predicting foundation behaviour under loading conditions.

6.2 Future Scope

- The present work can be extended further by considering advanced soil models to better represent actual field conditions.
- Future studies may investigate the influence of groundwater level, cyclic loading and varying soil conditions on foundation behaviour.
- Further research can also include comparison between different types of foundations and validation of numerical results with field observations.
- Numerical analysis in three dimensions might offer better predictions about settlement and stress response.
- The influence of varying load conditions and relative density on the foundation performance can further be investigated to obtain better understanding about soil-foundation interactions.

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