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NUMERICAL SIMULATION OF STATIC PILE LOAD TEST ON STRATIFIED SOIL DEPOSITS

By

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Abstract

Static pile load tests on foundations are carried out to examine and determine load-displacement behaviors. The test covers the direct measurement of pile head displacement in the response to incremental load. For this study, finite element simulations of field pile load-settlement were done using commercial packages PLAXIS 2D v8.6 and PLAXIS 3D, 2013. For both axisymmetric and three-dimensional models, two material models were used i.e., linear elastic for pile and Mohr-Coulombs for soils. Input parameters of numerical modeling were estimated using different correlations techniques based on SPT N values of soil and Unified compressive strength (UCS) of rock core samples.

Finally, a comparison between axisymmetric and three-dimensional model was done, it has been observed that the result of three-dimensional model is better as compared to the axisymmetric model results.

KEYWORDS: Static pile load test, Finite element analysis, PLAXIS, Material models, SPT, Axisymmetric

Chapter One

Introduction

1.1. General

The settlement of the pile foundation is a controlling factor of its design because the primary purpose of the pile foundation is to limit the deformation of the structure it supports [1, 2]. In the past, there have been various techniques such as experimental techniques, analytical techniques and numerical techniques which have been adopted by researchers to predict the actual settlement behaviour of pile foundations.

Static load test on a pile is one of the methods for determining the load-carrying capacity of a pile. It can be conducted on a driven pile or cast-in-situ pile on a working pile or a test pile, and on a single pile or a group of piles [3].

Nowadays, the numerical simulation of structures is one of the most popular approaches widely used in geotechnical and structural analysis [4]. Numerical analysis provides immediate and suitable solutions for various field problems which can be used for similar type of field problems that arise in the future as well. During the past few years, there has been an obvious trend towards developing finite element techniques as they give very reliable and accurate solutions to complex engineering problems.

In this research, finite element method based programs PLAXIS 2D and 3D, which are commercially available and widely used in geotechnical engineering were used to carry out the research. Then discussed and compared field load test with numerical simulation of such a test in similar conditions. Finally, differences and difficulties in the results interpretation with their possible reasons are discussed.

1.2. Statement of the Problem

Pile load test can represent reasonable results, but such tests are expensive and time consuming. Generally, client or the contractors are not that much interested to conduct this test due to its high cost and time consumption. Numerical modeling software simulation of pile load test reduces time and costs, increases efficiency and reliability when compared to standard field load tests. It allows to perform numerous analyses for various soil conditions and pile types.

1.3. Objective of the Study

1.3.1. General objective

The main objective of the present study is to conduct finite element analysis for static pile load test using both axisymmetric and three dimensional analyses. Finally, the results of two models compared with the result of pile load test.

1.3.2. Specific objectives

- To determine input parameters for numerical simulation.
- To validate the FEM model with actual pile load test results.
- To compare load settlement results of axisymmetric and 3D model.
- To compare the effect of mesh size change on the model output results.

1.4. Method

In order to effectively achieve the objectives of this study, the following methods have been employed.

- Review previous studies, thesis, journals, books and papers related to my study area.
- Collection of soil investigation and actual pile load test reports are done from highly experienced institutions.
- Correlations are used to estimate input soil and rock parameters for numerical modeling using SPT - N value and uniaxial compressive strength (UCS) of rock core samples based on the available experimental data.
- The finite element analysis was performed using PLAXIS 2D version 8.6 and PLAXIS 3D, 2013. For both investigations, two primary finite element material models were incorporated they are Linear elastic and Mohr-Coulomb model.
- Finally, discussed about the comparison of field test and finite element analysis based on the output of PLAXIS 2D and 3D results.

1.5. Scope of the Study

Due to time constraints and unavailability of the pile load test and soil investigations data, this study is aimed at covering only analyzed the comparison of vertically loaded static pile load test compared with finite element analysis of single pile (PLAXIS 2D and 3D) when pile are loaded stage wise loading and unloading at the pile head on two ongoing projects for different area.

Chapter Two

Literature Review

2.1. Review of Static Pile Load Test

Static load tests on foundation piles are generally carried out in order to determine load – displacement characteristic of the pile head. For standard (basic) engineering practices this type of test usually provides enough information. However, the knowledge of force distribution along the pile core and its division into the friction along the shaft and the resistance under the base can be very useful. Such information can be obtained by strain gage pile instrumentation [5].

The relevant theoretical analysis of static pile load test is based on analysis of the single pile under the axial compression. With the advent of computers, more sophisticated methods of analysis have been developed to predict the settlement and load distribution in a single pile [6].

According to [7] three types of loading procedures for a static load test are:

- The Quick Load Test,
- The Incremental Static Load Test, and
- The Constant Rate of Penetration Test.

Measuring pile movement adjustments made to instrumentation or to data recorded in the field procedure clearly indicate and explain by [8].

Standard Measuring Procedures

Take reading of time, load, and movement, and record them before and after the application of each load increment or the removal of each load decrement.

Reading for constant rate of penetration loading

Take readings of time, load and settlement and record at least every 30s or at sufficient intervals to determine the rate penetration being achieved.

Reading for quick load test method

Take readings of time, load, and settlement, and record immediately before and after the application of each load increment and at intermediate time intervals as specified.

Chapter Three
Methodology

3.1. General

A geotechnical site investigation is the process of collecting information and evaluating the conditions of the site for the purpose of designing and constructing the foundation for different structure such as a building, dam, bridge etc.

3.2. Review of Geotechnical Site Investigation

Based on the availability of geotechnical sub-surface investigation and pile load test report there are two ongoing project sites were adopted for this research study for different locations, namely:

- Megech Dam Intake Pile Works
- Amhara Credit and Saving Institute (ACSI)

3.3. Material Parameters

In this research, the material parameters used in the modeling are divided into soil, rock and structural parameters.

3.3.1. Soil parameters

Laboratory and in situ tests are conducted to estimate the strength and elastic properties of soil. There are various methods for evaluation of soil in-situ properties of soil. The most popular and common methods relate in situ soil indices, such as the standard penetration test (SPT) or the cone penetration test (CPT). The Standard Penetration Test (SPT) is still one of the most popular and economical means to obtain subsurface information of soil.

When laboratory data is not available, it is a common practice to estimate the shear parameters from the SPT results. There are many charts, tables and empirical relationships are available in the literature between the SPT N value and the angle of internal friction (φ) and undrained cohesion (c_u) by different researchers like [9-13].

Gibbs and Holtz (1957) showed that overburden pressure could significantly affect the SPT blow count. Schmertmann (1975) considered overburden pressure to develop a relationship between

N_{60} and internal friction angle (φ) .This correlation can be mathematically approximated as follows (Kulhawy and Mayne, 1990) where σ' is the effective overburden pressure and P_a is the atmospheric pressure [10, 11].

$$\varphi' = \tan^{-1}\left[N_{60}/\left(12.2 + 20.3\frac{\sigma'}{P_a}\right)\right]^{0.34} \quad (3.1)$$

Correlating C_u to N_{60} presented by, [9] is one of the more commonly used methods of estimating C_u for all clay types.

$$C_u = 0.06P_a\, N_{60} \quad (3.2)$$

Different soil types of modulus of elasticity equations by several test methods based on the adjusted SPT N_{55} value specified in [14].

Gravelly sand

$$E_S = 1200(N + 6) \quad (3.3)$$

$$= 600(N + 6) \ \ldots\ldots\ldots\ldots\ldots.. \ N < 15 \quad (3.4)$$

$$= 600(N + 6) + 2000 \ldots\ldots\ldots\ldots\ldots. \ N > 15 \quad (3.5)$$

Silts, sandy silt, or clayey silt

$$E_S = 300(N + 6) \quad (3.6)$$

Thus correcting for field procedures, and on the basis of field observations, it appears reasonable to standardize the field SPT number as a function of the input driving energy and its dissipation around the sampler around the surrounding soil [15].

$$N_{60} = \frac{N\, C_E C_B C_S C_R}{0.60} \quad (3.7)$$

where:

C_E = Energy Correlation Factor

C_B = Borehole Diameter

C_S = Sampling method

C_R= Road Length Correlation

Corrections to SPT (Modified from Skempton 1986) as listed by Robertson and Wride (1998).

3.3.2. Rock parameters

In designs and numerical modelling of underground openings, excavations, and foundations on rocks, Mohr–Coulomb shear strength parameters, cohesion (C), angle of friction (φ), unit weight

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(γ), modulus of elasticity (E), Poisson's ratio (μ), are key parameters required in numerical simulations and designs.

In this research, uniaxial compressive strength of rock core samples are available on soil investigation report. Then based on the given uniaxial compressive strength of the rock core samples indirect tensile strengths of the given rock samples were obtained by using different correlation techniques.

There are several empirical correlations reported in the literature that relate the compressive strength (σ_c) and tensile strength (σ_t) [15]. Some of the correlations between σ_c _ σ_t correlations are given below in Table 3.1.

Table 3.1. σ_c _ σ_t correlations

No	Correlation	Reference
1	$\sigma_c = 10.5\ \sigma_t + 1.2$	[16]
2	$\sigma_c = 3.6\ \sigma_t + 15.2$	[17]
3	$\sigma_c = 2.84\sigma_t - 3.34$	[18]
4	$\sigma_c = 12.4\sigma_t - 9.0$	[19]
5	$\sigma_c = 10\ \sigma_t$	[20]

In the absence of any measurements, σ_t is sometimes assumed to be a small fraction of the uniaxial compressive strength σ_c. A wide range of values from 1/5 to 1/20 have been suggested in the literature, and 1/10 is a good first estimate that is $\sigma_c = 10\ \sigma_t$ it is noted that [15].

After finding of indirect tensile strength (σ_t), Mohr–Coulomb shear strength parameters, cohesion (c), and friction angle (φ), was estimated. Cohesion and friction angle of intact rock can be estimated and given by, [21].

$$\varphi = \sin^{-1}\left(\frac{\sigma_c - 4\sigma_t}{\sigma_c - 2\sigma_t}\right) \tag{3.8}$$

$$C = \frac{0.5\sigma_c\sigma_t}{\sqrt{\sigma_t(\sigma_c - 3\sigma_t)}} \tag{3.9}$$

It was also shown that approximately $C = 1.82\ \sigma_t$

3.3.3. Structural parameters

Static pile load test results and test pile specifications was obtained by MIDROC FOUNDATION specialist private limited company.

3.3.3.1. Megech Dam Intake Pile Works

Table 3.2. Physical description of test pile

Pile type	Date of pile casting and testing	Concrete Strength	Length of pile (m)	Diameter of pile (mm)	Maximum working load (kN)
Preliminary	21/01/2019 G.C	C- 30	29.20	1000	11,250.00

Table 3.3. Physical description of test pile

Pile type	Date of pile casting and testing	Concrete Strength	Length of pile (m)	Diameter of pile (mm)	Maximum working load (kN)
Working	06/02/2019 G.C	C- 30	29.20	1000	7,500.00

3.3.3.2. Amhara Credit and Saving Institute (ACSI)

Table 3.4. Physical description of test pile

Pile type	Date of pile casting and testing	Concrete Strength	Length of pile (m)	Diameter of pile (mm)	Maximum working load (kN)
Working	25/03/2019 G.C	C- 30	46.00	1000	3,222.00

3.4. Input Parameters for Numerical Modeling

In this research, input parameters of numerical modeling i.e. cohesion (c), and internal friction angle (φ), and modulus of elasticity of soil (E), were estimated using the above correlations techniques based on adjusted SPT N values of soil and Unified Compressive Strength (UCS) of rock core samples if, cohesion and internal friction angle is not specified in the geotechnical investigation report.

Unit weight of soil (γ), was calculated based on the specific gravity of the given soil formation and also appropriate value of Poisson's ratio of soil and rock (μ) and modulus of elasticity of rock (E) was adopted from several approved sources like, [14, 22, 23].

According to PLAXIS 3D, 2013 reference manual the interface properties are calculated from the soil properties in the associated data set and the strength reduction factor by applying the following rules:

$$C_i = R_{inter} C_{soil} \quad (3.10)$$

$$tan\ \varphi_i = R_{inter} tan\varphi_{soil} \leq tan\ \varphi_{soil} \quad (3.11)$$

The friction angle of the soil-pile interface is taken as eq. (3.12):

$$\delta' = \frac{2}{3}\varphi' \quad (3.12)$$

The evaluation of adhesion between pile and soil, indicated as C_a, plays a prominent role in the calculation of the side resistance of piles in clays carried out in terms of total stresses (referred as ''α method''). Many national design provisions and recommendations suggest estimating C_a by means of the undrained cohesion (C_u) reduced by a coefficient, namely α, which represents the percentage of C_u mobilized by the pile–soil adhesion mechanism [24]. Recently [25] has formulated graphically and analytically relationships between α and C_u.

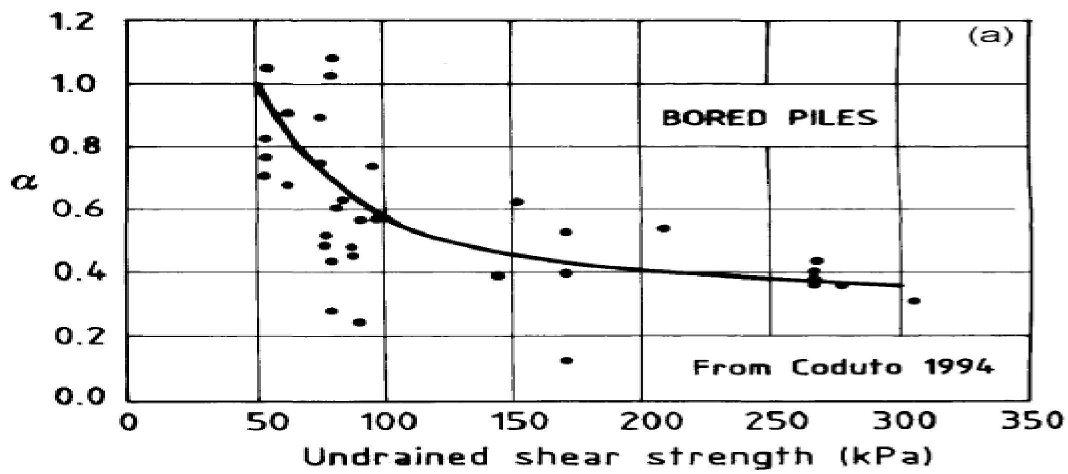

Figure 3.1. Undrained shear strength versus α for bored piles adopted from [25].

Table 3.5. Analytically relationships between α and C_u for bored pile [25].

Bored piles	$\alpha = 1$	for $C_u \leq 51$ kPa
Bored piles	$\alpha = 0.32 + 250{C_u}^{-1.5}$	For $C_u > 51$ kPa

As an attempt to improve the result of the analysis the value of the angle of the dilatancy, ψ, for clays are ($\psi \approx 0$) and for non-cohesive soils (sand, gravel) with the angle of internal friction φ > 30° the value of dilation angle was estimated as $\psi = \varphi - 30°$.

3.4.1. Megech Dam Intake Pile Works

Table 3.6. Summary of soil input parameters

Soil type	Dense light brown silty clay with gravels				Dense light brown to dark brown silty clay with gravel & boulders			Concrete pile
Material (Depth)	1.8	3.2	4.7	6.0	7.5	9.0	11.7	29.20
Model	MC	MC	MC	MC	MC	MC	MC	LE
Adjusted N values	10.26	12.90	34.36	34.36	23.28	26.83	51.33	-
Unit weight, γ (kN/m^3)	11.3	11.3	11.3	11.3	11.5	11.5	11.5	25
	16.6	16.6	16.6	16.6	16.7	16.7	16.7	25
Friction angle (φ)	13	15	-	-	-	-	-	-
Choesion, C_u (kN/m^2)	61.6	77.4	206.2	206.2	139.7	161.0	308.0	-
Poisson's ratio, (μ)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2
Dilatancy angles (ψ)	-	-	-	-	-	-	-	-
Modulus of elasticity, (E) (kN/m^2)	4,400.0	5,115.0	10,635.0	10,635.0	7,785.0	8,700.0	15,000.0	3.1e+7
$R_{interface}$	0.83	0.68	0.40	0.40	0.47	0.44	0.36	1.0

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Table 3.7. Summary of rock input parameters

Material (Depth)	Rock input parameters					
	26.50	26.95	27.50	30.40	35.50	38.55
Model	MC	MC	MC	MC	MC	MC
Unit weight, γ (kN/m^3)	21.08*	20.59*	18.24*	29.22*	23.92*	23.14*
Uniaxial compressive strength, σ_c (MPa)	7.40*	11.80*	10.10*	16.30*	13.90*	11.80*
Tensile strength, σ_t (MPa)	0.74	1.18	1.01	1.63	1.39	1.18
Friction angle (φ)	48.59	48.59	48.59	48.59	48.59	48.59
Choesion, C (kN/m^2)	1,398.50	2,230.00	1,909.00	3,080.41	2,626.85	2,229.99
Poisson's ratio, (μ)	0.27	0.27	0.27	0.27	0.27	0.27
Dilatancy angles (ψ)	18.59	18.59	18.59	18.59	18.59	18.59
Modulus of elasticity, (E) (MPa)	815	1,120	950	4,260	2,112.5	1,120
$R_{interface}$	1.0	1.0	1.0	1.0	1.0	1.0

The entry * indicates directly taken from the soil investigation report.

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3.4.2. Amhara Credit and Saving Institute (ACSI)

Table 3.8. Summary of soil input parameters

Material (Depth)	Adjusted N values	Soil type	Unit weight, γ (KN/m^3)		φ	C_u (kN/m^2)	μ	Ψ	R_{int}	E (kN/m^2)
			Sat	Dry						
2.00	4.68	silty, gravel clay	17.37	12.14	6	28.05	0.30	-	1.0	3,330.00
4.00	38.95		17.37	12.14	-	233.75	0.30	-	0.39	14,550.00
6.00	43.54		17.51	12.28	-	261.25	0.30	-	0.38	16,050.00
8.50	45.83	high plastic clayey silt	17.37	12.14	-	275.00	0.30	-	0.37	16,800.00
10.50	27.50		17.37	12.14	-	165.00	0.30	-	0.44	10,800.00
13.80	45.83		17.37	12.14	-	275.00	0.30	-	0.37	16,800.00
14.50	21.08		17.37	12.14	-	126.50	0.30	-	0.50	8,700.00
16.40	45.83		17.37	12.14	-	275.00	0.30	-	0.37	16,800.00
20.50	45.83	high plastic sandy silt	17.37	12.14	44.12	-	0.30	14.12	0.58	16,800.00
22.50	16.5		22.65	20.63	30.11	-	0.30	0.11	0.62	7,200.00
24.65	45.83		22.65	20.63	38.75	-	0.30	8.75	0.60	16,800.00
26.10	45.83		17.37	12.14	38.35	-	0.30	8.35	0.60	16,800.00
28.00	45.83		19.38	15.38	37.85	-	0.30	7.85	0.60	16,800.00
30.00	45.83		17.51	12.28	37.55	-	0.30	7.55	0.61	16,800.00
32.00	45.83	clayey/sandy silt with gravel	17.37	12.14	-	275.00	0.30	-	0.37	16,800.00
35.00	45.83	high plastic /clayey silt	17.37	12.14	-	275.00	0.30	-	0.37	16,800.00
37.50	45.83		17.37	12.14	-	275.00	0.30	-	0.37	16,800.00
39.00	45.83		17.37	12.14	-	275.00	0.30	-	0.37	16,800.00
46.00	-	Concrete pile	25.00	25.00	-	-	0.20	-	1.0	3.1e+7

Table 3.9. Summary of rock input parameters

Material Depth	Rock input parameters (crushed basalt)								
	Unit Weight γ (kN/m^3)	Uniaxial compressive strength, σ_c (MPa)	Tensile strength , σ_t (MPa)	Friction angle (φ)	Cohesion, C (kN/m^2)	(μ)	Ψ	R_{int}	Modulus of Elasticity, (E) (MPa)
42.20	27.84*	62.22*	6.22	48.59	11,758.47	0.27	18.59	1.0	83,000
44.30	27.94*	60.84*	6.08	48.59	11,497.68	0.27	18.59	1.0	81,000

The entry * indicates directly taken from the soil investigation report.

Chapter Four

Finite Element Analysis for a Single Pile

4.1. General

Selecting an appropriate constitutive model has a significant influence on the accuracy of the solutions. In this research, for both axisymmetric and three-dimensional models, two material models were used i.e., linear elastic for pile and Mohr-Coulombs for soils.

4.2. Geometry

The model consists of two materials: the pile and the soil. The length of the pile, L, defines the rest of the geometry. The distance between the surfaces h, is 2.5L. This limit will be used in every analyzed case, and has special importance because the proximity of the layer has great influence in the pile settlement results.

In order to compare Plaxis' results with [26] it is required that this distance must be greater than 2L, so it does not influence the proportion of load that reaches the pile base.

The distance between the symmetry axis and the vertical outer boundary should be equal or higher than 2L, since in pile settlement analyses performed with closer limits, results have been affected by it [27].

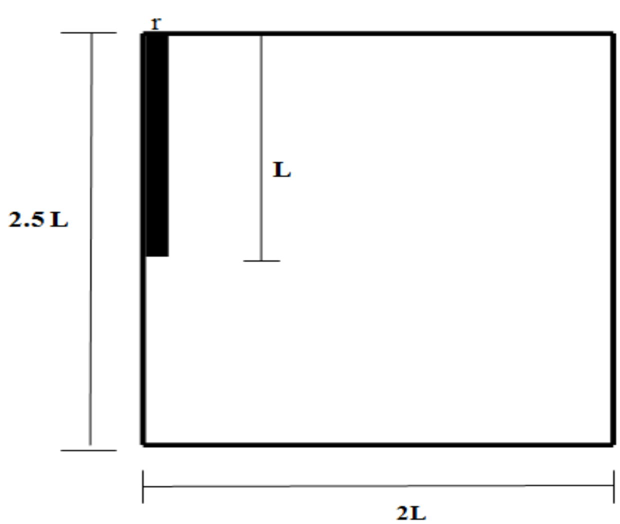

Figure 4.1. Geometry of the model (PLAXIS 2D).

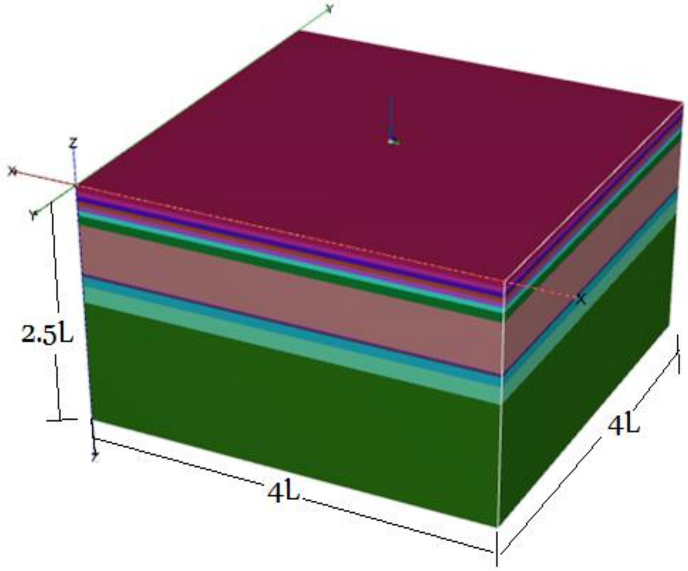

Figure 4.2. Rectangle and soil block (PLAXIS 3D)

The acceptance of geometry of the model was assured by varying horizontal and vertical boundaries in terms of pile length (L) for the same applied load and the following result obtained.

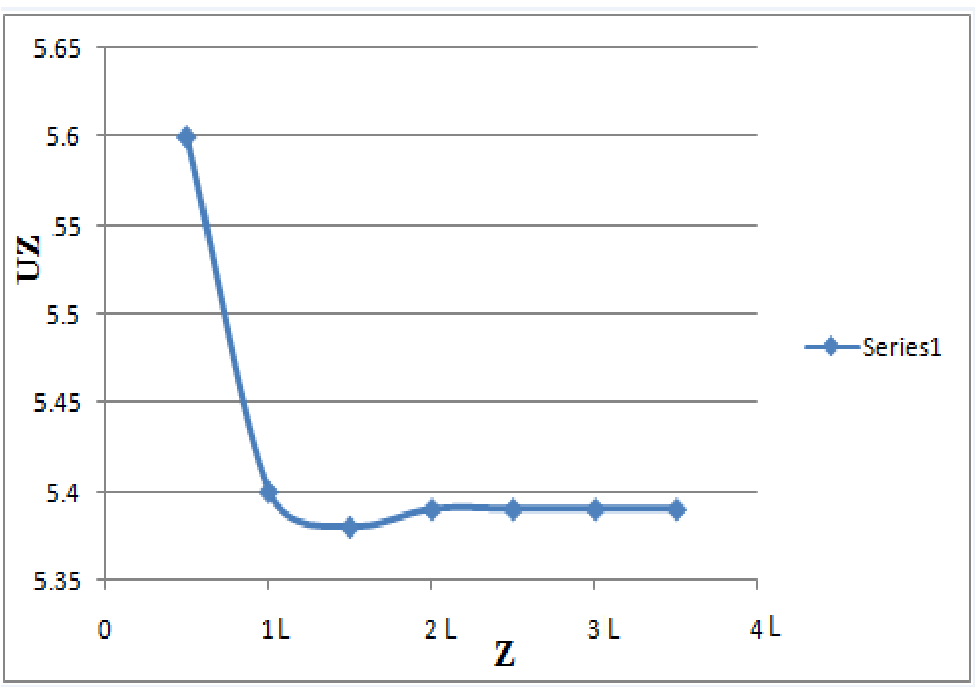

Figure 4.3. Settlement versus horizontal boundary in terms of L

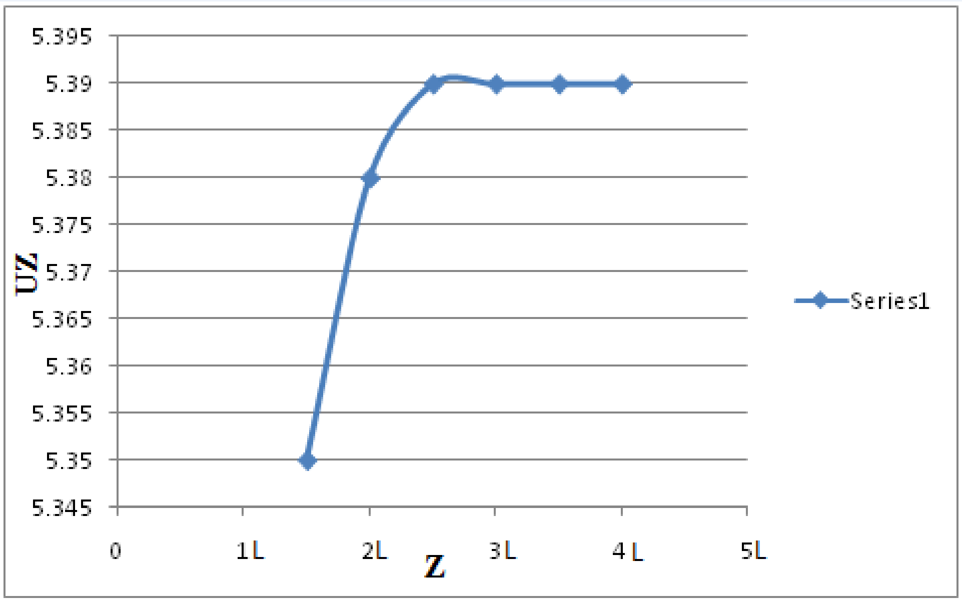

Figure 4.4. Settlement versus vertical boundary in terms of L

From figure 4.3 and 4.4 it is concluded that the distance between the symmetry axis and the vertical outer boundary, should be equal or higher than 2L and the distance between the surface and the rigid layer, should be equal or higher than 2.5L. It is observed that pile settlement results have been affected when analyses performed with closer limits.

4.3. Mesh convergence study

Here, one of the models is selected and compare the effect of mesh size changes on the model output results .The mesh size is very coarse, coarse, medium, fine and very fine.

Table 4.1. Effect of the mesh size changes on the 100% and 200% of the working load displacement (PLAXIS 3D)

Maximum displacement for 100% of the working load	**Maximum displacement for 200% of the working load**	**Mesh size**
2.08	4.06	Very coarse
2.31	4.52	Coarse
2.52	4.92	Medium
2.63	5.12	Fine
2.69	5.24	Very fine

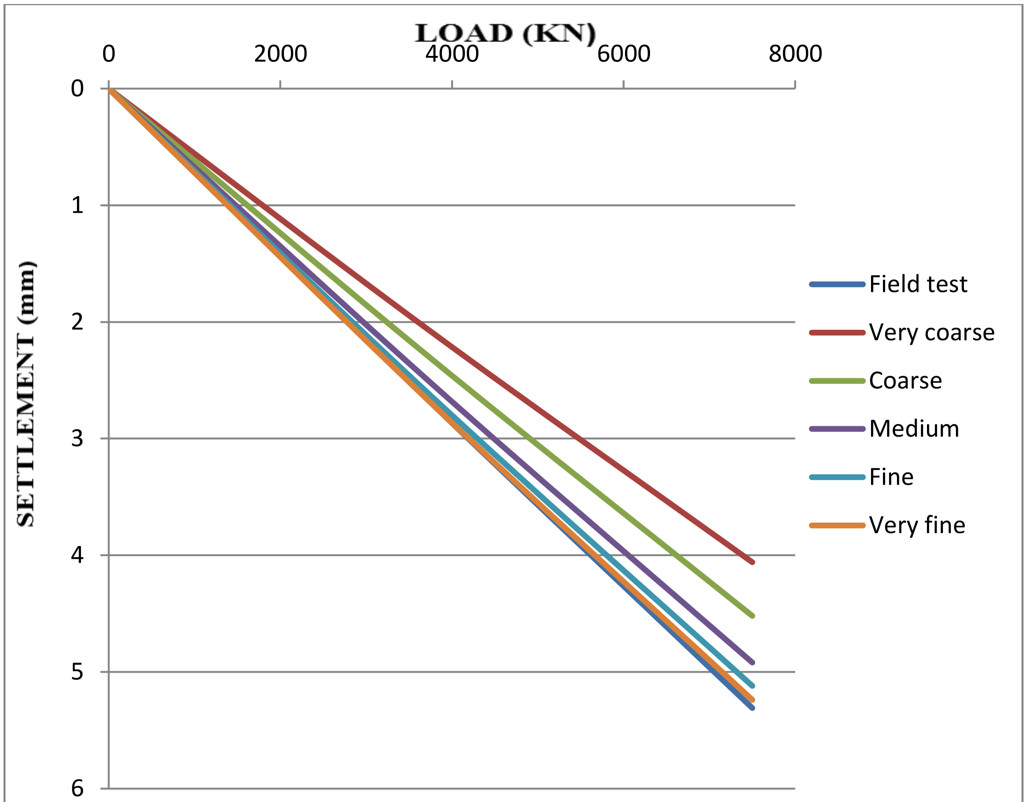

Figure 4.5. Effect of the mesh size changes

Very fine mesh size has better accuracy compared to field test, but has longer computational time.

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Chapter Five

Results and Discussions

5.1. Finite Element Analysis of a Single Pile Using PLAXIS 2D

5.1.1. Megech Dam Intake Pile Works

The working pile length is 29.20m .Due to this the geometry dimension of the model is 73m X 58.4m.

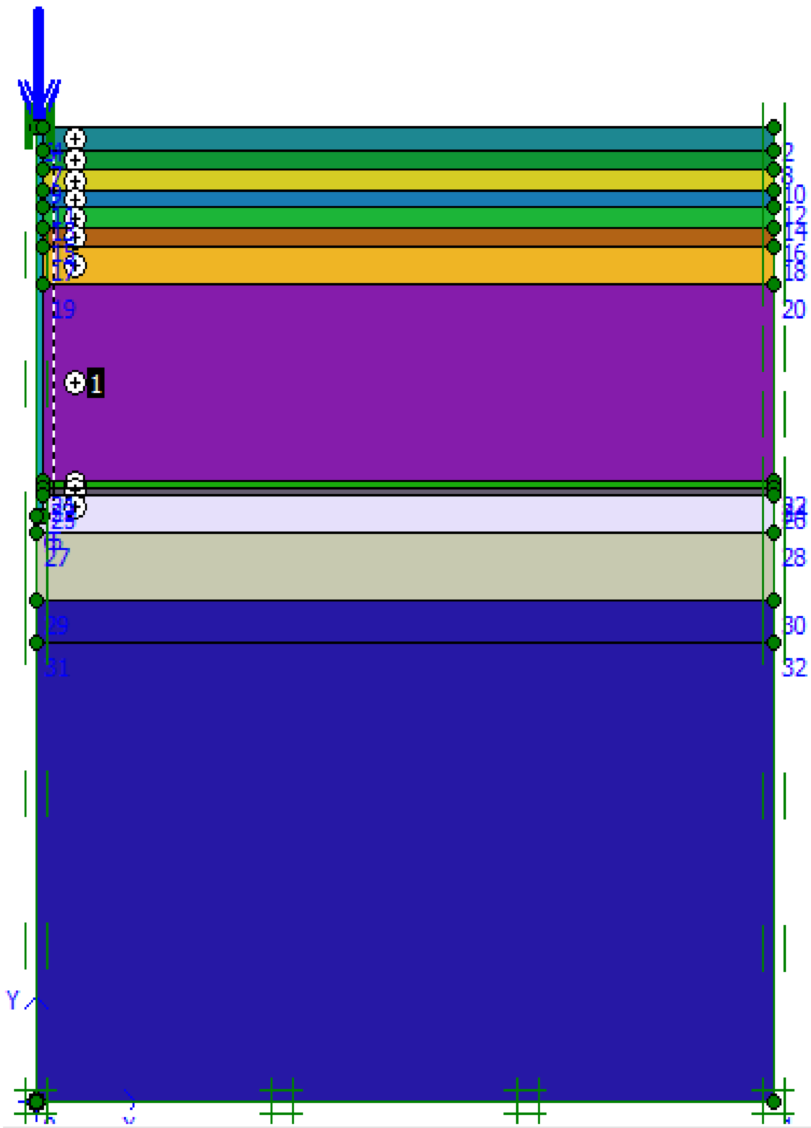

Figure 5.1. Geometry of the model, L=29.2m.

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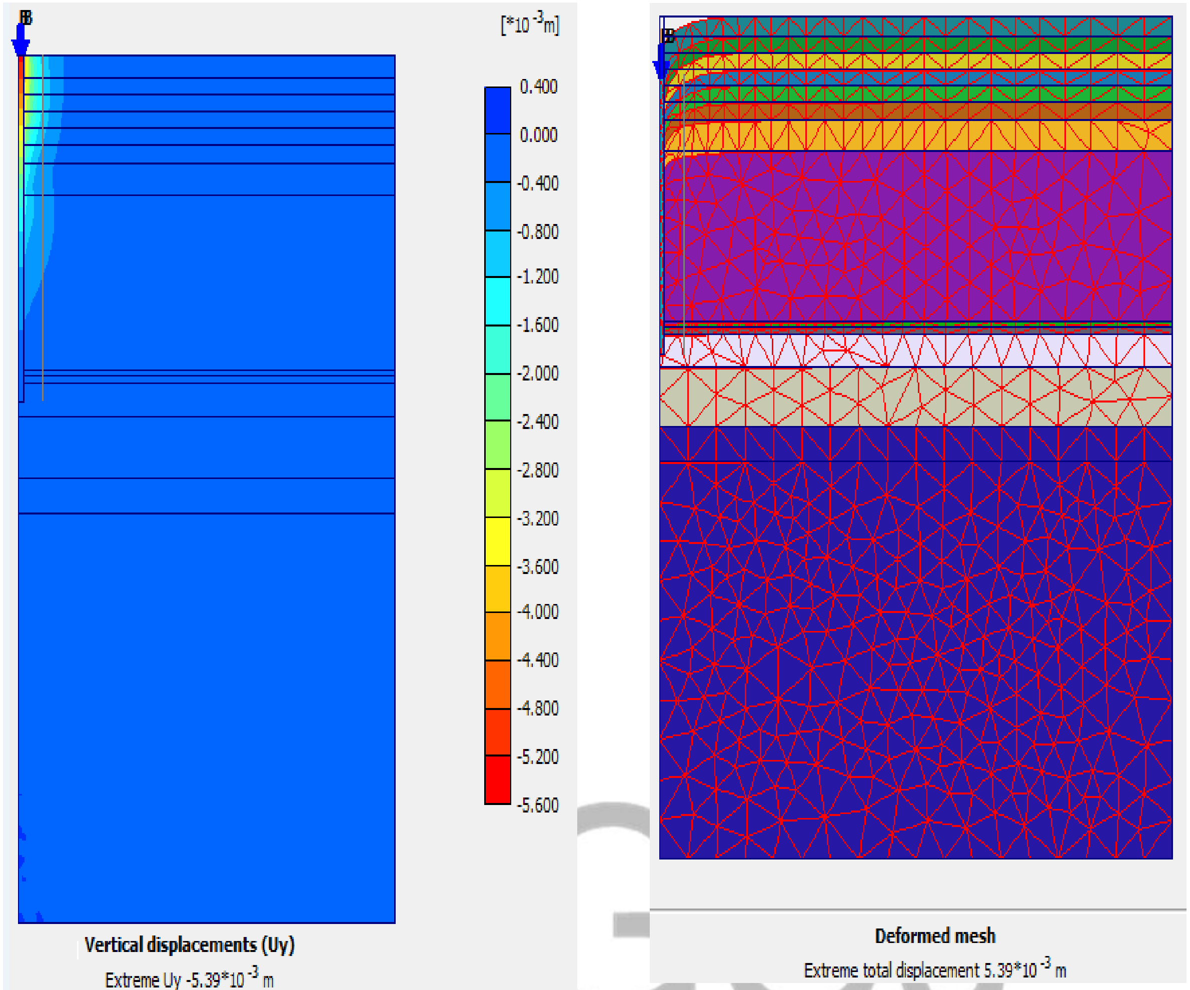


(a) (b)

Figure 5.2. (a) Settlement contours of soil and (b) Deformed mesh for maximum test load (200% of the working load)

5.1.1.1. Comparison of field test and 2D analysis

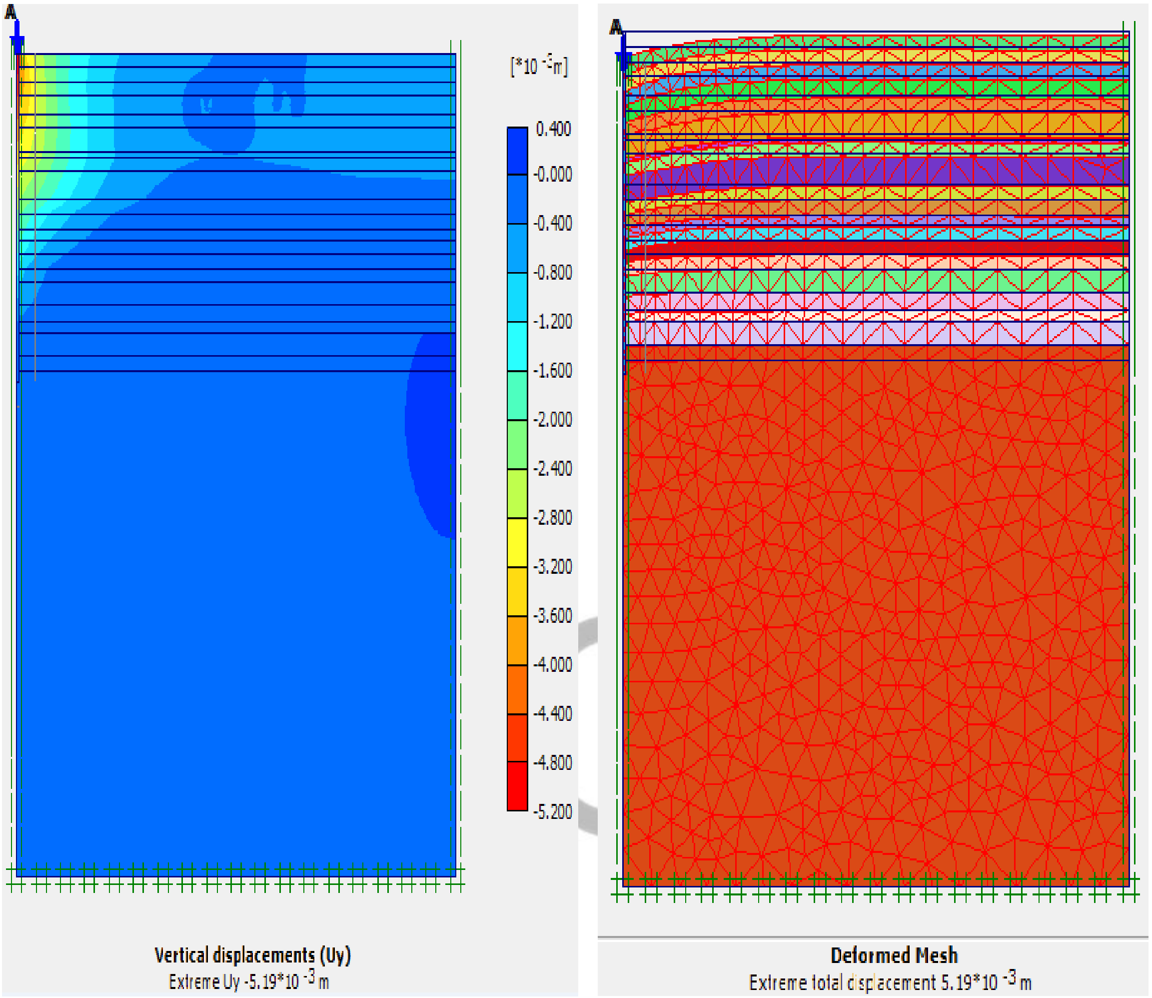
The vertical settlement corresponding to maximum test load 7,500 kN (200% of the working load) has been presented in the following table.

Table 5.1. Comparison of vertical settlement data corresponding to maximum test load of 7,500 kN

Methods	**Vertical settlement (mm)**
Field test	5.31
PLAXIS 2D analysis	5.39

5.1.2. Amhara Credit and Saving Institute (ACSI)

The working pile length is 46m. Due to this the geometry dimension of the model is 115m X 92m.



(a) (b)

Figure 5.3. (a) Settlement contours of soil and (b) Deformed mesh for maximum test load (200% of the working load)

5.1.2.1. Comparison of field test and 2D analysis

Table 5.2. Comparison of vertical settlement data corresponding to maximum test load of 3,222 kN

Methods	Vertical Settlement (mm)
Field Test	4.40
PLAXIS 2D Analysis	5.19

5.2. Finite Element Analysis of a Single Pile Using PLAXIS 3D

5.2.1. Megech Dam Intake Pile Works

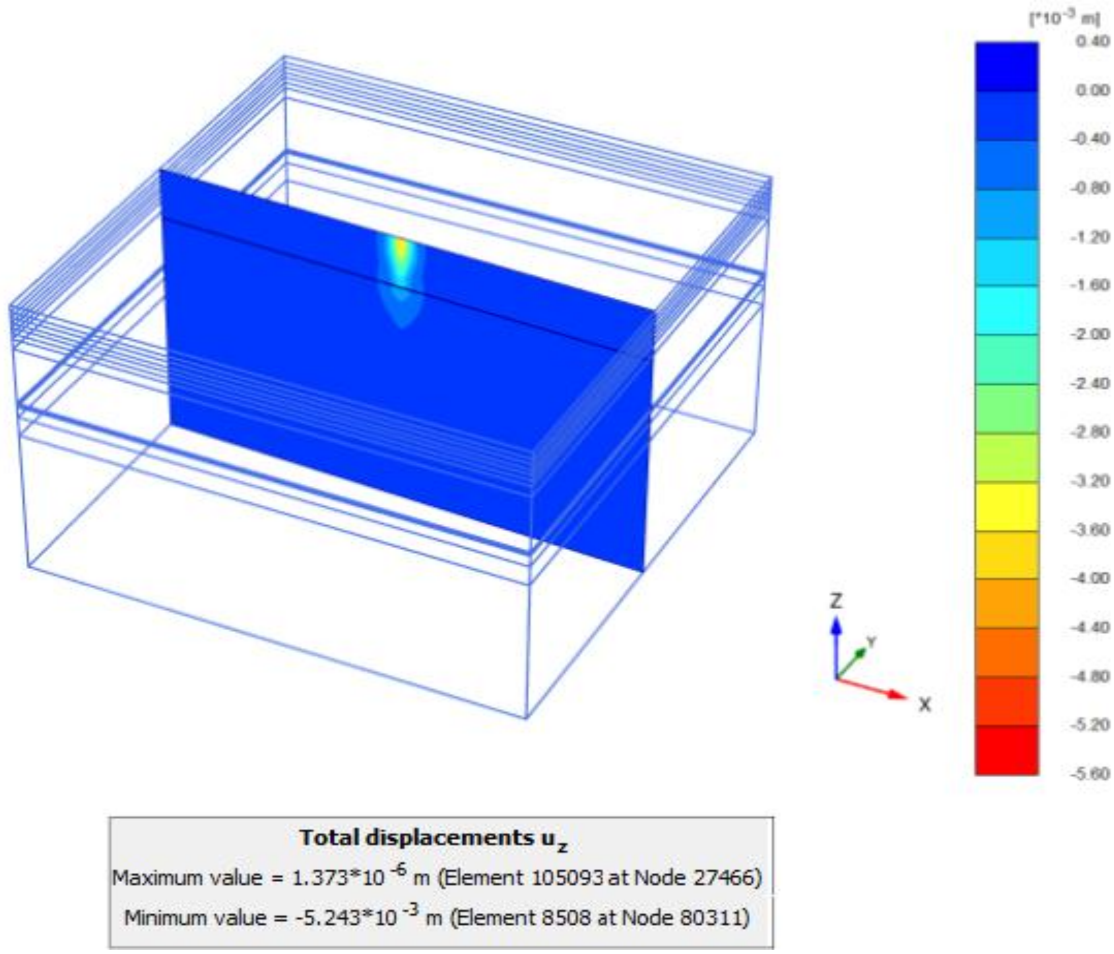


Figure 5.4. Settlement contours of soil (cross section) for maximum test load

5.2.1.1. Comparison of field test and 3D analysis

The vertical settlement corresponding to Maximum Test Load 7,500 kN (200% of the working load) has been presented in the following table.

Table 5.3. Comparison of vertical settlement data corresponding to maximum test load of 7,500 kN

Methods	Vertical settlement (mm)
Field test	5.31
PLAXIS 3D analysis	5.24

5.2.2. Amhara Credit and Saving Institute (ACSI)

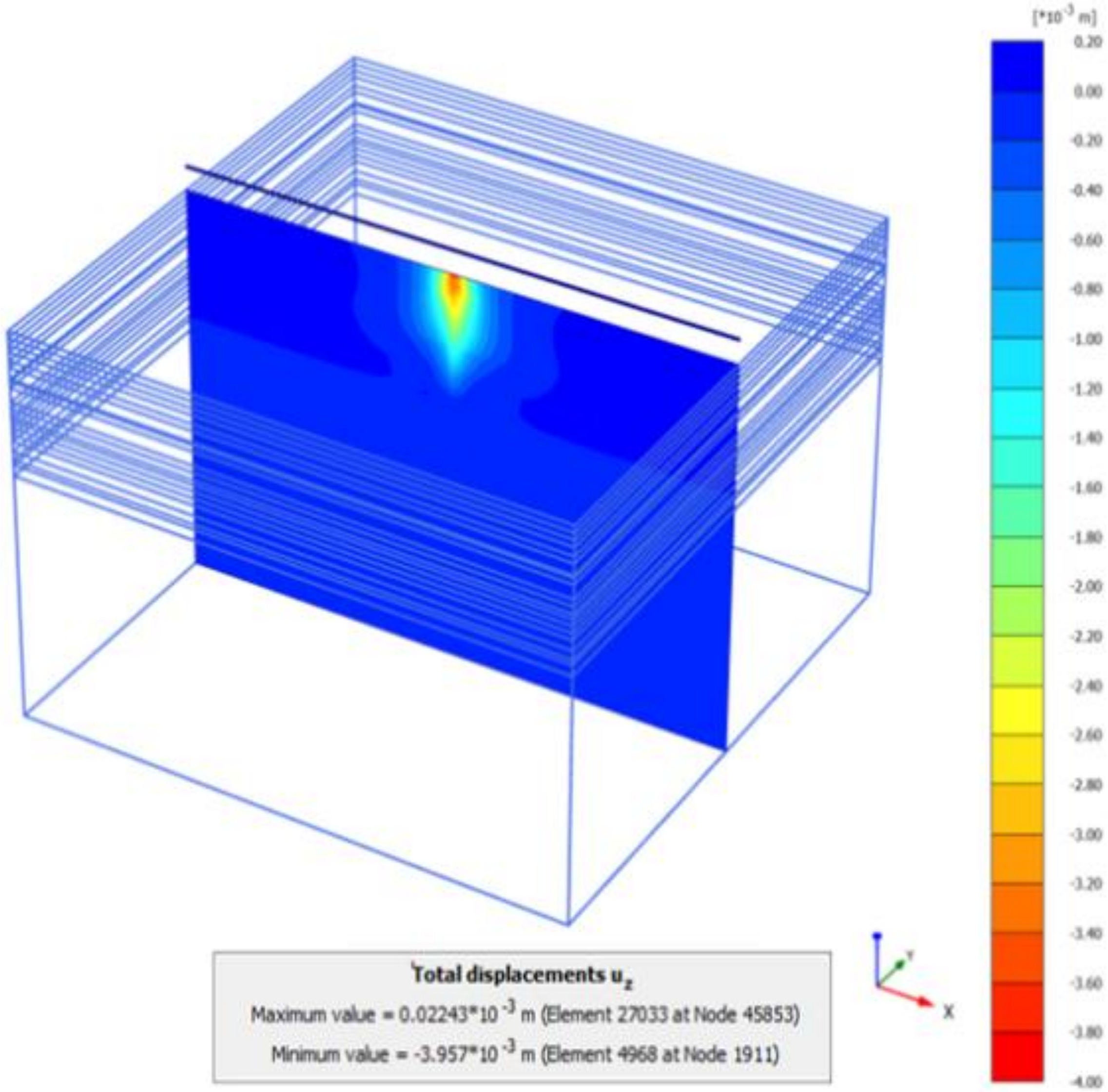


Figure 5.5. Settlement contours of soil (cross section) for maximum test load

5.2.2.1. Comparison of field test and 3D analysis

Table 5.4. Comparison of vertical settlement data corresponding to maximum test load of 3,222 kN

Methods	Vertical Settlement (mm)
Field Test	4.40
PLAXIS 3D Analysis	3.96

5.3. Load- Settlement Behaviour of FEA and Static Pile Load Test

5.3.1. Megech Dam Intake Pile Works

Piles are loaded up to 200% of the working load. The stage wise loading is applied by load increments of 375, 750, 1125, 1500, 1875, 2250, 2625, 3000, 3375, 3750, 4150, 4500, 4875, 5250, 5625, 6000, 6375, 6750, 7125 and 7500 kN at the pile head and the observed settlement for the corresponding loads was ploted.

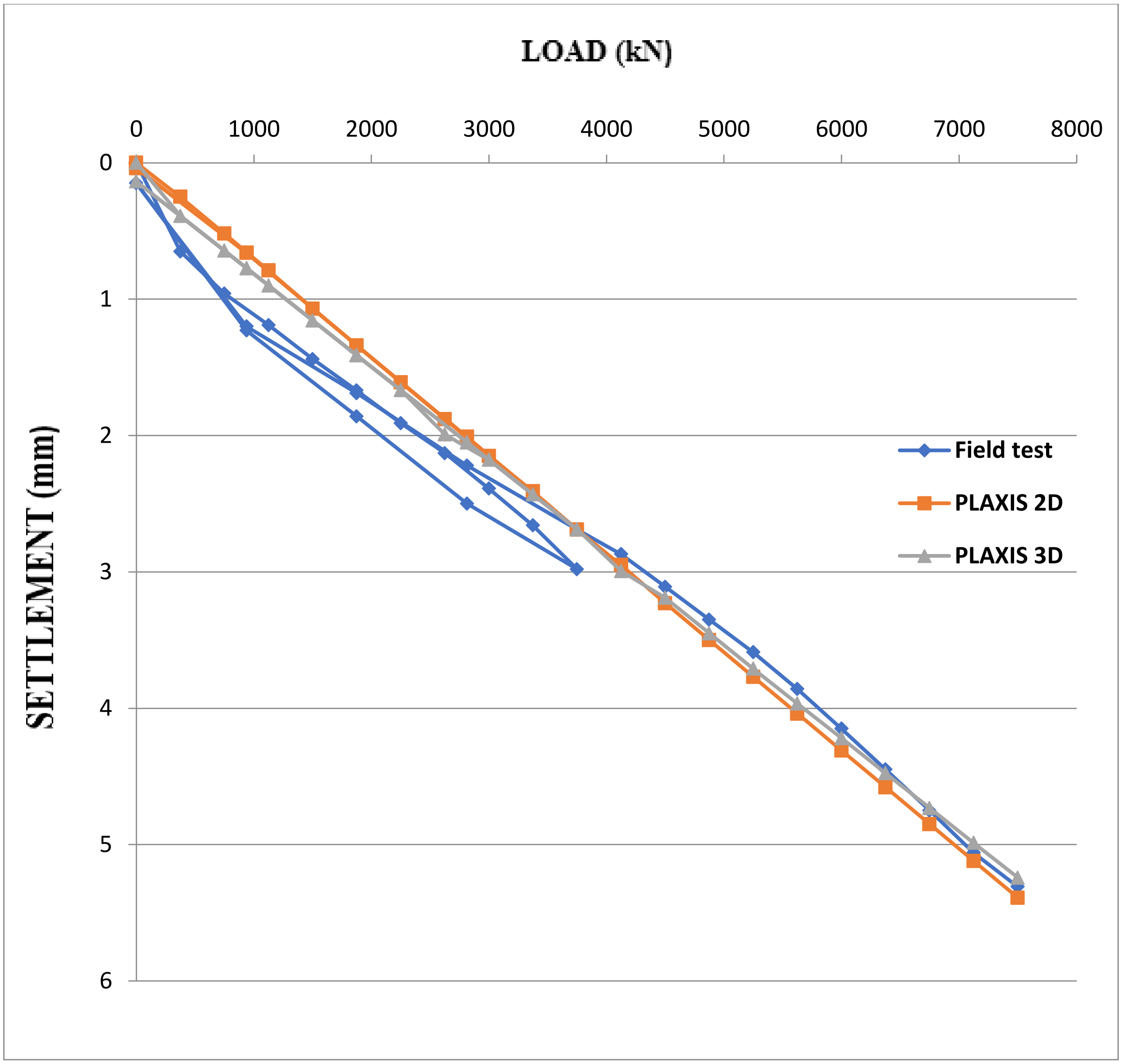


Figure 5.6. Comparison of load-settlement plots obtained from FEM analysis and field test result for single pile analysis (Megech Dam Intake Pile Work)

5.3.2. Amhara Credit and Saving Institute (ACSI)

Piles are loaded up to 200% of the working load. The stage wise loading is applied by load increments of 403, 806, 1209, 2014, 2417, 2820, and 3222 kN at the pile head and the observed settlement for the corresponding loads was ploted.

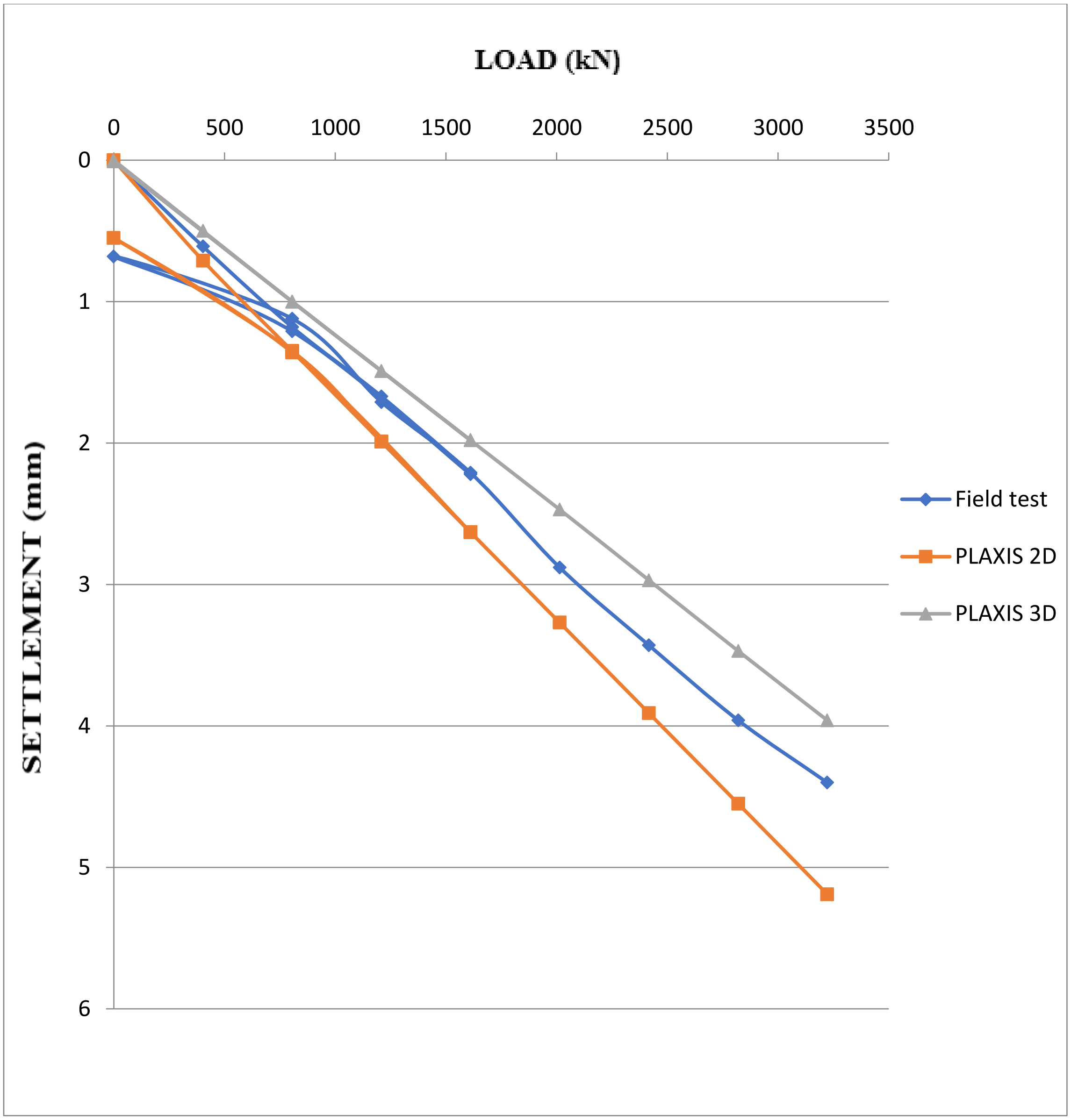


Figure 5.7. Comparison of load-settlement plots obtained from FEM analysis and field test result for single pile analysis (Amhara Credit and Saving Institute (ACSI)

5.4. Comparison of 2D, 3D and Field Test

5.4.1. Megech Dam Intake Pile Works

Table 5.5. Comparison of vertical settlement 2D, 3D and field test

Methods	Vertical settlement (mm)
Field test	5.31
PLAXIS 3D analysis	5.24
PLAXIS 2D analysis	5.39

5.4.2. Amhara Credit and Saving Institute (ACSI)

Table 5.6. Comparison of vertical settlement 2D, 3D and field test

Methods	Vertical settlement (mm)
Field test	4.40
PLAXIS 3D analysis	3.96
PLAXIS 2D analysis	5.19

From the above load settlement plot (Figure 5.6 and 5.7), it is shown that the curve obtained using PLAXIS simulations analysis result is close to field test results. 100% of the working load on Megech Dam Intake Pile project PLAXIS 2D analysis gives 2.69 mm at 3,750 kN and 5.39 mm at 7,500 kN (200% of the working load) . In the case of 3D analysis at 3,750 kN and 7,500 kN, the vertical displacement was 2.69 mm and 5.24 mm respectively. But the field test measured downward movement based on the pile load test report was 2.98 mm at 3,750 kN and 5.31 mm at 7,500 kN.

The result obtained from PLAXIS 2D analysis for Amhara Credit and Saving Institute (ACSI) project 100% of the working load gives 2.63 mm at 1,611 kN and 5.19 mm at 3,222 mm (200% of the working load). And the 3D analysis gives at 1,611 kN and 3,222 kN, the movement was 1.98 mm and 3.96 mm respectively. The measured movement on field test report was 2.22 mm at 1,611 kN 4.40 mm at 2,417 kN.

The result of the axisymmetric and three – dimensional models are close to field test results. It is very clear that the above correlation techniques and FEM analysis models i.e., Linear Elastic & Mohr- Coulomb models are the best models to predict realistic load- settlement behaviour of single pile. But it is necessary to perform more analyses of static pile load test to give general recommendation.

Chapter Six

Conclusions and Recommendations

6.1. Conclusions

It has been shown that it is possible to simulate load-settlement behavior of field pile load test in layered soils. This has been implemented using the PLAXIS 2D and PLAXIS 3D software packages. Some of the broad conclusions drawn from the results are:

- Numerical simulations in both PLAXIS 2D and PLAXIS 3D is an efficient way to evaluate the load-settlement behavior of pile load test and gives the best convergence to test results.
- The models incorporated in FEM which are Mohr-Coulomb for soils and linear elastic for pile perfectly validated/simulated the pile load test results.
- Understanding and selection of the appropriate material model and input parameters for FEM are extremely important and will badly affect the results if not given proper consideration.
- It is concluded that the distance between the symmetry axis and the vertical outer boundary, should be equal or higher than 2L and the distance between the surface and the rigid layer, should be equal or higher than 2.5L. It is observed that pile settlement results have been affected when analyses performed with closer limits.
- Mesh convergence study was performed and a very fine mesh has better accuracy.
- The results observed with embedded pile models in PLAXIS 3D are comparably better as of axisymmetric models.

6.2. Recommendations (For further research)

- Load - settlement behavior under the effect of lateral load for single pile with different length and diameter can be examined using FEM.
- Settlement behavior of axially loaded group piles for layered soil can be also studied using FEM.

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