LTU Journal of Advanced Computing & Engineering (LTU-JACE)

ISSN: 3102-0801 (Print)
Volume 1. Issue 1

LTU-JACE 2026 VOL.1 (1):

PLAXIS 3D Simulation and Field Validation of Static Load Behaviour for Bored Pile Foundations: A Comparative Study on Technical Accuracy and Efficiency

Aashish Deo[1], Manish Ayer[2], Niraj KC[3]*, Narayan Ghimire[2]

[1] Mandan Bhandari College of Engineering, Pokhara University, Urlabari, Nepal

[2] Institute of Engineering and Information Technology, Lumbini Technological University, Banke, Nepal

[3] Institute of Engineering and Information Technology, Lumbini Technological University, Banke, Nepal

*Corresponding Email: dean.niraj@ltu.edu.np

Received: 7 December 2025 / Accepted: 1 February 2026 / Published: 1 March 2026

Abstract

This study investigates the static axial load behaviour of bored cast-in-situ pile foundations through three-dimensional numerical simulation using site-specific geotechnical data obtained from the Kamal Khola Bridge under the SASEC Highway Enhancement Project, Nepal. Although static load testing (SLT) provides reliable pile performance assessment, it is often time-consuming and costly; therefore, this research evaluates the applicability of finite element modelling using PLAXIS 3D as an efficient and economical alternative. Detailed subsurface characterization, including borehole logs, standard penetration test (SPT) data, and engineering soil parameters at the pier location, was incorporated into the numerical model. The soil was simulated using the Mohr–Coulomb constitutive model, while the pile was modelled as a linear elastic material. A mesh sensitivity analysis was conducted using very fine, fine, medium, coarse, and very coarse mesh configurations to examine their influence on prediction accuracy. The numerical results were validated against field SLT data comprising load–settlement responses, initial and final settlements, and elastic rebound measurements. The comparison demonstrated strong agreement between simulated and measured responses, with percentage differences in allowable load ranging from 9.7% to 11.8% and settlement variations between 2.2% and 13% across different mesh refinements. Additionally, a comparative assessment of testing time and cost revealed that numerical simulation reduced overall duration and expenditure by approximately 58.33% and 66.67%, respectively, compared to field

SLT. The findings confirm that PLAXIS 3D can reliably replicate field pile load behaviour and serve as a practical verification tool, enabling economical, time-efficient, and safe foundation design practices under Nepalese soil conditions.

Keywords: *Static Load Test, Numerical Simulation, PLAXIS 3D, Pile Foundation, Kamal Khola Bridge, Mesh Refinement, Load-Settlement Behaviour, Allowable Load.*

1. Introduction

Pile foundations are essential in bridge engineering for safely transferring large axial loads to deeper, competent soil or rock strata, particularly in compressible or geotechnically complex ground conditions. The static load test (SLT) is widely recognized as the most reliable method for determining pile load-bearing capacity and load–settlement behavior; however, its application is often limited by high cost, long testing duration, and logistical complexity, especially in developing countries such as Nepal (Siemaszko, 2024). Consequently, pile design frequently relies on empirical methods that may result in unsafe under design or uneconomical overdesign.

Recent advances in Finite Element Method (FEM)–based numerical modeling provide a practical alternative by enabling realistic simulation of soil–pile interaction under static loading conditions. When calibrated with site-specific geotechnical data, numerical simulations can accurately predict load–settlement response and allowable load, offering a cost- and time-efficient substitute for extensive field testing (Teshager, 2019). In this study, PLAXIS 3D was used to simulate the static load behavior of a bored cast-in-situ pile at the Kamal Khola Bridge, Nepal, and the results were validated against field static load test data to assess the reliability and practical applicability of numerical simulation for pile foundation verification.

Static Load Tests (SLTs) remain the benchmark method for evaluating pile load-bearing capacity and load–settlement behaviour, as they directly capture soil–pile interaction under in-service loading conditions (Siemaszko, 2024). Field-based studies continue to confirm the reliability of SLTs for capacity estimation in various soil conditions. For instance, (Verumandy et al., 2024) demonstrated that SLTs provide dependable estimates of ultimate bearing capacity for screw piles in soft soils, although uncertainties related to groundwater fluctuations were identified, highlighting the need for complementary analytical or numerical approaches.

Due to the high cost, long testing duration, and logistical challenges associated with SLTs, Finite Element Method (FEM)–based numerical modelling has gained widespread acceptance as an effective alternative or supplementary tool. FEM allows realistic simulation of soil stratigraphy, constitutive behaviour, and soil–pile interaction beyond the simplifying assumptions of traditional analytical methods

(Teshager, 2019). Among FEM-based software, PLAXIS 3D has been extensively used for simulating pile load tests and predicting settlement and load transfer behaviour.

Several studies have validated the capability of PLAXIS-based simulations through comparison with field test data. (Krasiński and Wiszniewski, 2017) investigated large-diameter bored piles and reported close agreement between numerical predictions and static load test results, although discrepancies were attributed to simplified soil parameters and uncertainties in material stiffness. (Gong et al., 2018) demonstrated that finite element simulations accurately predicted ultimate bearing capacity and consolidation settlement of PHC pile foundations, particularly when advanced soil models were employed.

Research has also emphasized the importance of soil constitutive modelling and interface representation. (Gowthaman and Nasvi, 2018) showed that combined nonlinear–linear modelling approaches, incorporating nonlinear soil behaviour near the pile shaft, significantly improve settlement predictions compared to fully linear or fully nonlinear analyses. Similarly, (Teshager, 2019) highlighted that mesh refinement and proper soil–pile interface calibration are critical factors governing numerical accuracy.

Studies focusing on Nepalese conditions remain limited. (Gupta and Dahal, 2023) applied PLAXIS 3D to model axially loaded piles in sandy soils in Nepal and reported that simulation accuracy strongly depends on appropriate soil modulus correlations derived from local SPT data. Their findings underline the need for site-specific calibration and further validation of FEM approaches under Nepalese geotechnical conditions.

Overall, the literature confirms that PLAXIS-based FEM simulations can reliably replicate pile load–settlement behaviour when calibrated with accurate geotechnical data. However, careful selection of soil models, mesh density, and interface parameters is essential. These findings support the use of numerical simulation as a credible and efficient alternative to full-scale static load testing, particularly in resource-constrained and geotechnically complex environments.

2. Methodology

The approach comprised site investigation, data acquisition, material characterization, numerical modeling, specification of boundary and meshing conditions, load application, and model validation. Field and laboratory investigation data were integrated with three-dimensional finite element simulations performed using PLAXIS 3D to enable a comparative evaluation of simulated pile behavior and field static load test (SLT) results for a bored cast-in-situ pile foundation.

2.1 Study Area

The study was conducted at the Kamal Khola Bridge along the Kakarbhitta–Laukahi section of the East–West Highway (NH-01), constructed under the SASEC Highway Enhancement Project. The bridge site lies within the Terai plains, an alluvial depositional environment characterized by fine- to coarse-grained sands interbedded with gravel and silt layers. The groundwater table was observed at approximately 0.3 m below ground level. The bridge substructure employs bored cast-in-situ piles, selected for their load-carrying efficiency and suitability for granular soils.

2.2 Soil Investigation Summary

Confirmatory drilling was conducted at the pier location up to 27 m deep. Field tests included Standard Penetration Test (SPT) and Dynamic Cone Penetration Test (DCPT) at 1.5 m intervals. Laboratory tests included grain size analysis, specific gravity, moisture content, and shear strength parameters through direct shear tests.

2.3 Model Geometry and Boundary Conditions

A 3D soil domain of 40m * 40m * 30m was developed using PLAXIS 3D to minimize boundary effects. The pile was centrally positioned within the model.

Boundary conditions were defined as follows:

a. Bottom boundary: Fully fixed in all directions

b. Lateral boundaries: Fixed horizontally but allowed vertical movement to simulate realistic ground conditions

2.4 Soil Profile Summary

a. Top layers: loose to medium dense sand with gravel

b. Deeper layers: medium dense to dense sandy gravel and silty sand

c. Groundwater table: 0.3 m below surface for pier

The results revealed a layered soil profile comprising loose to medium-dense sand near the surface and dense sandy gravel and silty sand at depth. These findings informed the selection of soil parameters for numerical modeling.

Table 1: Stratigraphy and Soil Layers

	Geotechnical		Pile Depth											
Layer No.	Top Depth (m)	Bottom Depth (m)	Top Depth(m)	Bottom Depth (m)	Soil Type	N	γ (kN/m³)	γ_sat (kN/m³)	E50 (kPa)	ν	φ' (deg)	psi	c' (kPa)	R_{inter}
1	0	1.5	Effective length of pile starts from 3.26 m below drilling level		Sand	13	17.1	19.1	13172	0.3	29	-	0	0.98
2	1.5	3			Sand```	14	17.1	19.1	14186	0.3	29	-	0	0.98
3	3.2	3.26			Sand	17	17.1	19.1	17225	0.3	30	0	0	0.98
4	3.26	4.5	0	1.24	Sand	17	17.1	19.1	17225	0.3	30	0	0	0.98
5	4.5	6	1.24	2.74	Sand	18	19.5	21.5	18239	0.3	31	1	0	0.98
6	6	7.5	2.74	4.24	Sand	17	19.5	21.5	17225	0.3	31	1	0	0.98
7	7.5	9	4.24	5.74	Sand	32	19.5	21.5	32424	0.3	33	3	0	0.98
8	9	10.5	5.74	7.24	sand	32	18.5	20.5	32424	0.3	33	3	0	0.98
9	10.5	12	7.24	8.74	Silty Sand	22	17.4	19.4	11146	0.32	32	2	0	0.98
10	12	13.5	8.74	10.24	Silty Sand	19	17.4	19.4	9626	0.32	31	1	0	0.98
11	13.5	15	10.24	11.74	Silty Sand	21	17.4	19.4	10639	0.32	31	1	0	0.98
12	15	16.5	11.74	13.24	Sand	29	19.2	21.2	29384	0.3	33	3	0	0.98
13	16.5	18	13.24	14.74	Sand	50	18.3	20.3	50663	0.3	36	6	0	0.98
14	18	19.5	14.74	16.24	Sand	35	18.3	20.3	35464	0.3	34	4	0	0.98
15	19.5	21	16.24	17.74	Sand	30	18.3	20.3	30398	0.3	33	3	0	0.98
16	21	22.5	17.74	19.24	Sand	32	19.3	21.3	32424	0.3	34	4	0	0.98
17	22.5	24	19.24	20.74	Sand	29	19.3	21.3	29384	0.3	33	3	0	0.98
18	24	25.5	20.74	22.24	Sand	30	19.3	21.3	30398	0.3	34	4	0	0.98
19	25.5	27	22.24	23.74	Sand	50	20.1	22.1	50663	0.3	37	7	0	0.98
20	27	28.56	23.74	25.24	Sand	27	20.1	22.1	27358	0.3	34	4	0	0.98
21	28.56	33.26	25.2	30	Sand	27	20.1	22.1	27358	0.3	34	4	0	0.98

2.5 Data Used in Simulation

The different layers of pile parameter and soil parameter are listed in Table 2 and Table 3.

Table 2 Pile parameter

S. N	Property	Pier Pile
1	Pile Type	Bored Cast-in-Situ
2	Diameter (m)	1
3	Length (m)	25
4	Material	Concrete (M35)
5	Ep (kPa)	30000000
6	ν_p	0.2
7	Rinter	0.98
8	Material Modeled	Linear Elastic
9	Drainage type	Non-porous
10	Unit Weight (KN/m^3)	24

Table 1 : Key parameters adopted for numerical modelling

SN	Parameters	Symbol	Range Used	Sources/Basis	Importance
1	Friction Angle	ϕ	30°–38°	From corrected SPT-N and lab shear tests	Controls shear resistance in granular soil
2	Dilation Angle	ψ	0°–8°	Eq. (1)	soil tends to expand (dilate) or contract
3	Cohesion	c	0–5	Lab data and assumptions for fine content	Used in Mohr-Coulomb strength model
4	Unit Weight	γ	17–21 kN/m^3	Lab tests	Used to calculate self-weight of soil mass

5	Elastic Modulus	E	10–45 MPa	Empirical correlation with N-value (Eq. (2))	Defines stiffness and deformation behavior
6	Poisson's Ratio	ν	0.3 for sandy soil, 0.32 for silty sand, and 0.2 for concrete	Literature	Describes volumetric strain response
7	Pile Diameter	D	1.0 m	Design specification	Width of bored cast-in-situ pile
8	Pile Length	L	25 m for pier	Design specification	Depth based on bearing strata
9	Concrete Modulus	Ep	30 GPa	Concrete standard	Defines the pile's elastic stiffness
10	Interface Reduction	R_{inter}	0.98	Typical value for concrete-soil	Reduces strength at soil-structure interface

2.6 Material Modeling

2.6.1 Soil Model

The Mohr–Coulomb elastic–perfectly plastic model was adopted due to its suitability for granular soils and widespread use in geotechnical analysis. The model parameters included: elastic modulus (E), Poisson's ratio (ν), cohesion (c), friction angle (φ) & dilatancy angle (ψ).

2.6.2 Pile Model

The pile was modeled as a linear elastic material with diameter= 1.0 m, length= 25 m, Elastic modulus= 30 GPa, Poisson's ratio = 0.2 and unit weight = 24 kN/m³

2.6.3 Soil–Pile Interface

An interface reduction factor (Rinter = 0.98) was used to represent realistic soil–pile interaction behavior.

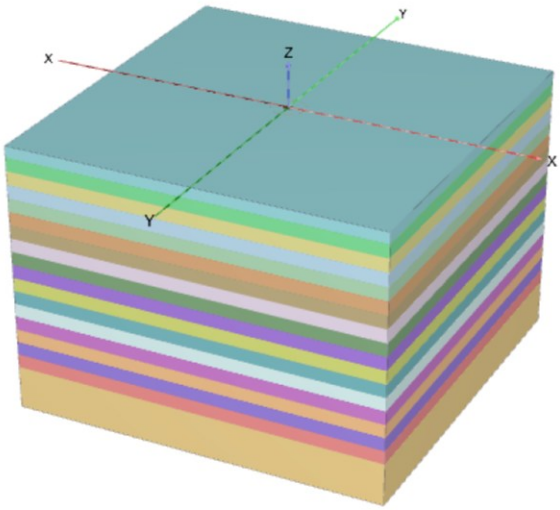

Figure 1: Soil Stratigraphy

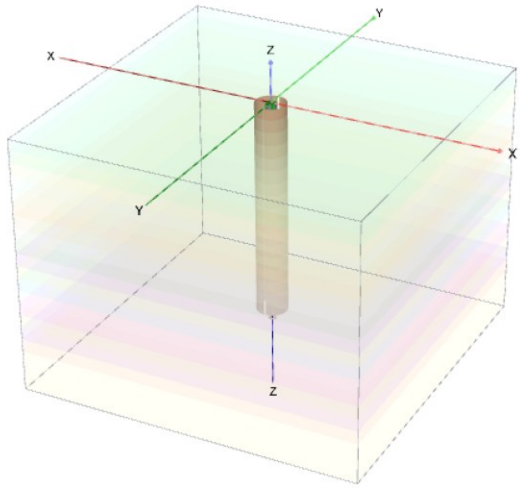

Figure 2: Soil-Pile Configuration

2.7 Simulation of Static Load Test and allowable load

2.7.1 Simulation of Static Load Test

2.7.1.1 Loading Procedure

The static load was applied incrementally following IRC 78:2014 and ASTM D1143 standards.

a. Initial load: 25% of design load

b. Subsequent increments: 25% of design load per stage

c. Maximum applied load: 2937 kN

d. Loading stages: 0 KN, 391.6 KN,783 KN, 1174KN, 1566KN,1958 KN, 2349 KN, 2741 KN, 2937 KN

e. Holding period: Each load stage was held constant until the simulated settlement reached equilibrium

2.7.1.2 Unloading Procedure

Load was released in similar decrements from 2937KN to 2741 KN, 2349 KN, 1958KN, 1566KN, 1174KN, 783KN, 392KN, and 0 KN until zero, to capture elastic rebound behavior.

2.7.1.3 Conversion of Point load to Surface load

Since PLAXIS uses surface loading, the point loads were converted to equivalent pressure values (kN/m²) based on pile head area as follows:

Table 4: Applied load stages and equivalent surface loading

Stage	Diameter (m)	Area (m^2)	Load(P) (KN)	Surface Loading (KN/m^2)
Loading Stage	1	0.785	0	0.00
	1	0.785	391.6	498.85
	1	0.785	783.2	997.71
	1	0.785	1174.8	1496.56
	1	0.785	1566.4	1995.41
	1	0.785	1958	2494.27
	1	0.785	2349.6	2993.12
	1	0.785	2741.2	3491.97
	1	0.785	2937	3741.40
Unloading Stage	1	0.785	2741.2	3491.97
	1	0.785	2349.6	2993.12
	1	0.785	1958	2494.27
	1	0.785	1566.4	1995.41
	1	0.785	1174.8	1496.56
	1	0.785	783.2	997.71
	1	0.785	391.6	498.85
	1	0.785	0	0.00

2.7.1.4 Model type 1

Load-displacement curves were generated from PLAXIS results. Deformation values(u_z) for each equivalent loading and unloading case.

2.7.2 Simulation for Allowable load

A secondary model configuration (Model type 2) was developed to estimate the allowable load using prescribed displacement method. Displacement increments of 0 mm, 6 mm, 12 mm, 25 mm, 50 mm, 75 mm, 100 mm, 125 mm were applied at the pile head. The corresponding load response was analyzed to determine the load corresponding to allowable settlement limits as per IS2911 (Part 1,2010) using the following criteria:

a. Total settlement =12 mm

b. Total Settlement = 10% of pile diameter

c. Net settlement criterion was not applicable as net settlement was < 6 mm

2.8 Mesh Refinement Study

Finite element meshing was performed using five density levels: very fine, fine, medium, coarse, and very coarse.

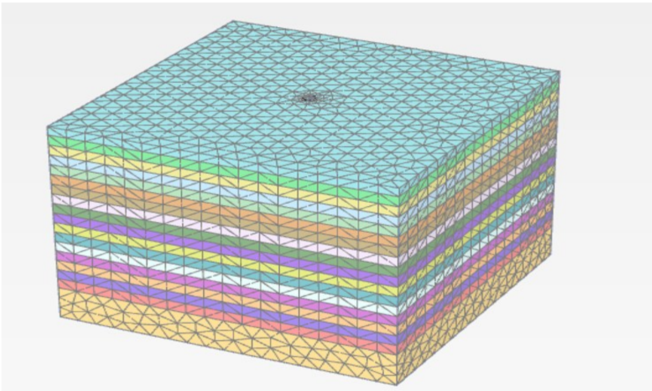

Figure 3: Mesh Statistics of Finite Element Model in PLAXIS 3D.

Table 5: Mesh Statistics of finite element model in PLAXIS 3D

S. N	Statistics	Very Fine	Fine	Medium	Coarse	Very Coarse
1	Number of soil elements	92756	49677	28742	24722	24546
2	Number of nodes	132753	72696	43209	37446	37089
3	Average element size(m)	1.736	2.092	2.468	2.554	2.549
4	Maximum element Size(m)	3.468	4.947	6.330	7.288	7.452
5	Minimum element size(m)	0.2697	0.1625	0.2703	0.2487	0.2487

2.9 Time and Cost Comparison Framework

Practical implementation in engineering projects also requires consideration of economic and temporal efficiency. Therefore, to extend the scope of evaluation beyond technical parameters, the present study introduces a Time and Cost Comparison Framework, which systematically assesses the differences in testing duration and total expenditure between the field SLT and the PLAXIS 3D simulation. This framework enables a holistic comparison by integrating both performance and practicality, thereby providing a realistic basis for recommending simulation-based verification in geotechnical design. The comparative assessment utilizes actual project records and simulation logs as summarized in Table 6

Table 6: Data sources for economic and time comparison

S. N	Parameter	Field SLT Data Source	Simulation Data Source
1	Duration	Field test log	PLAXIS 3D analysis log and computational record
2	Cost	Site testing expenditure, labor and equipment records	Software license cost and engineer time estimate
3	Manpower	On-site technical and mechanical team	One design engineer
4	Equipment	Reaction frame, Kentledge, hydraulic jack, dial gauges	Licensed PLAXIS 3D software, standard workstation

The quantitative comparison is based on two governing relations

a. Time Saving Percentage

$$\text{Time Saving}(\%) = \frac{T_{field} - T_{simulation}}{T_{field}} \quad \text{Eq. 1}$$

b. Cost Saving Percentage

$$\text{Cost Saving}(\%) = \frac{C_{field} - C_{simulation}}{C_{field}} \quad \text{Eq. 2}$$

Where:

T_{field} = Total duration of field static load test (days)

$T_{simulation}$ = Duration of PLAXIS 3D analysis (days)

C_{field} = Total cost of field static load test (NPR)

$C_{simulation}$ = Total cost of simulation (NPR)

These relations express the proportional reduction in testing time and cost that can be achieved through simulation compared to the traditional field test

3. Results and Discussion

3.1 Load–Settlement Behavior

The numerical load–settlement response closely matched the field static load test results. Settlement increased gradually with applied load, indicating elastic behavior within working load limits.

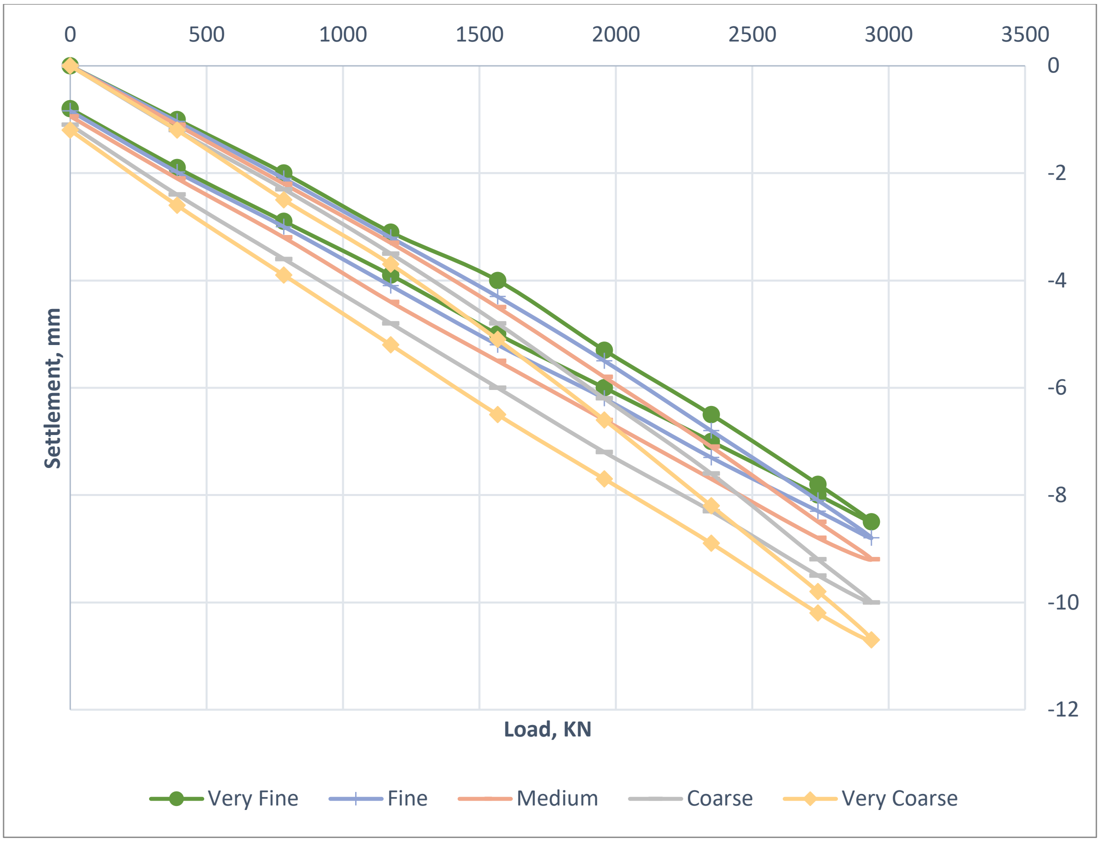

Figure 4: Load vs Settlement Curve for primary model(Loading and Unloading cases)

The simulated load-settlement curves (Figure 4) generated from the PLAXIS simulations exhibit a characteristic non-linear trend, which is characteristic of pile foundations under axial loading. The response can be divided into three phases:

a. Initial Elastic Phase:

At lower load levels (up to ~30% of design load), the settlement increased linearly with applied load. This stage represents the elastic deformation of the soil-pile system.

b. Transition Phase:

Beyond 30–70% of the design load, a deviation from linearity was observed. The slope of the curve gradually decreased, indicating the onset of plastic deformation within the soil mass and partial mobilization of shaft resistance.

c. Plastic Phase:

Beyond 70 % of the ultimate load, the settlement increased disproportionately relatively to load increments. This nonlinear behavior corresponds to the mobilization of the ultimate bearing capacity and the formation of plastic zones around the pile shaft and base.

The overall shape and trend of the simulated load–settlement curve closely resemble those observed in the field static load test, thereby confirming that the finite element model successfully captured the progressive mobilization of pile resistance under static axial loading. The model realistically represented both the elastic and plastic response of the pile–soil interaction system, validating the suitability of the Mohr–Coulomb soil model for drained conditions prevalent at the Kamal Khola Bridge site.

The clear distinction between the elastic, transition, and plastic phases further demonstrates the capability of the numerical model to replicate the actual behaviour of pile foundations under incremental loading.

3.2 Comparison of Simulated and Field Load-Settlement Curves

A graphical comparison between simulated and field load-settlement curves indicates:

a. The average simulated net settlement is 0.97mm, which was 5.74% difference from the field net settlement(0.92mm).

b. Up to the design load, the simulated and field curves exhibited almost identical trends, demonstrating that the PLAXIS model accurately represented elastic soil–pile behaviour.

c. At higher loads, simulation predicted slightly higher settlements than observed in the field. This discrepancy is attributed to:

   Simplification of soil constitutive behavior using the Mohr-Coulomb model, which does not fully capture strain-dependent stiffness degradation (stiffness reduction at small strains).

   Idealized pile-soil interface (Rinter=0.98) assumptions in the numerical model that neglects minor slippage and shear transfer variations observed in real conditions.

Despite these simplifications, deviations remained within acceptable geotechnical tolerance limits (<10%), validating the reliability of the FEM approach in simulating pile performance under Nepalese soil conditions.

3.3 Allowable Load Determination

The allowable load capacity of the pile was determined from the simulated load–displacement responses using the prescribed displacement method in accordance with IS 2911 (Part 1, Section 1, 2010). This approach defines the allowable load as the load corresponding to the smaller of two criteria: (i) a total settlement of 12 mm, or (ii) a total settlement equal to 10% of the pile diameter (100 mm in this study). The simulated load–settlement curves for various mesh densities were analysed to evaluate the influence of mesh refinement on the computed allowable load.

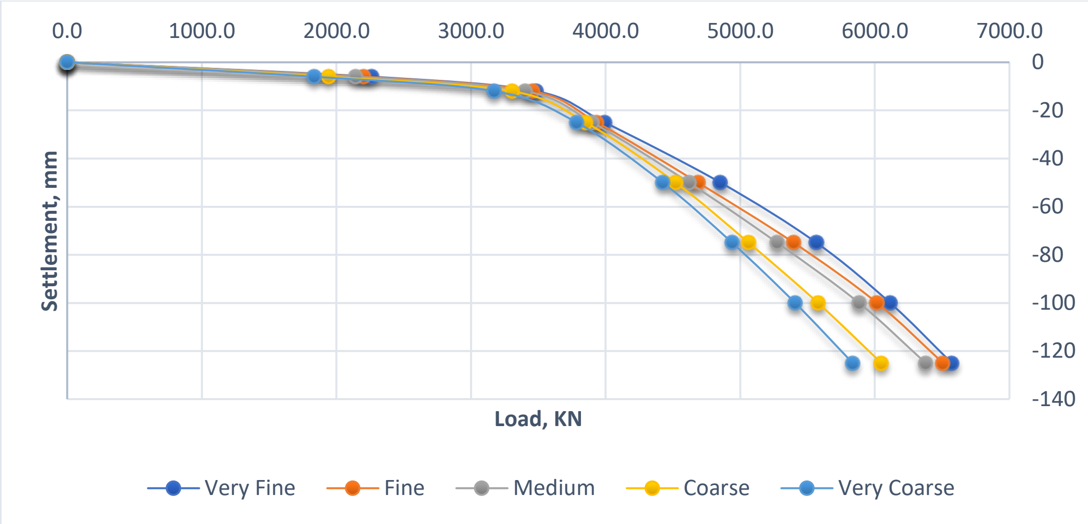

Figure 5: Load vs Settlement Curve for determining allowable load

3.4 Validation with Field Data

The net settlement in field was 0.92mm where as we obtained 0.8mm, 0.84mm, 0.94mm, 1.1mmand 1.2mm for different mesh from very fine to very coarse. The allowable load in field was 2572KN whereas we obtained 2322KN, 2305.3KN, 2268KN, 2202.7KN and 2114.7KN for different meshes from very fine to very coarse. The comparison between simulated and field results revealed: Settlement deviation: 2.2%–13%. and allowable load deviation: 9.7%–11.8%. These results confirm the reliability of PLAXIS 3D for predicting pile performance.

3.5 Time and Cost Comparison

A comparative assessment of time and cost was carried out between the conventional static load test and numerical analysis. The results indicate that numerical modeling significantly reduces both testing duration and overall cost. Overall, numerical simulation resulted in approximately 58.33% reduction in time and 66.67% reduction in cost, highlighting its practical advantage for design-stage evaluation.

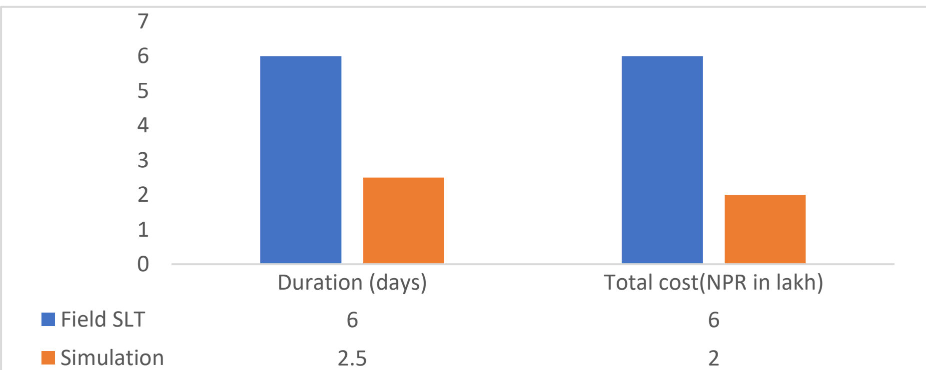

Figure 6: Comparison of time and cost between field and simulated SLT

The numerical analysis demonstrated that the simulated pile behavior closely matched field performance, confirming the validity of the finite element approach for static load prediction. Mesh refinement significantly influenced both accuracy and computational demand, with the medium mesh proving optimal. Deviations between simulated and field data were within the range of 2.2–13% for settlement and 9.7–11.8% for allowable load — well within acceptable geotechnical tolerances. Meanwhile, the economic and temporal analysis established that simulation consumes only 66.67% of the total cost and 58.33% of total time with much less manpower compared to field testing.

4. Conclusion

This study evaluated the static axial load behaviour of a bored cast-in-situ pile foundation using three-dimensional finite element modelling in PLAXIS 3D and validated the numerical results against field static load test data from the Kamal Khola Bridge project in Nepal. Site-specific geotechnical parameters obtained from detailed field and laboratory investigations were incorporated into the numerical model to realistically simulate pile–soil interaction under axial loading conditions.

The numerical simulations demonstrated good agreement with field static load test results in terms of load–settlement response, pile head displacement, and elastic rebound behaviour. The percentage difference between numerically predicted and measured allowable load capacities ranged from approximately 9.7% to 11.8%, while settlement variations were observed within a range of 2.2% to 13% depending on mesh refinement. These results confirmed that PLAXIS 3D can reliably replicate field pile behaviour when appropriate soil parameters, constitutive models, and boundary conditions are adopted.

In addition to technical validation, a comparative assessment of testing duration and cost revealed that numerical simulation reduced overall time and cost by approximately 58.33% and 66.67%, respectively, compared to conventional field static load testing.

Overall, the findings demonstrated that three-dimensional numerical simulation using PLAXIS 3D provides a reliable, economical, and time-efficient alternative for evaluating pile foundation performance. The study supports the integration of FEM-based numerical modelling as a practical verification tool in bridge foundation design under Nepalese geotechnical conditions and similar alluvial environments, while reducing dependence on extensive full-scale field testing.

References

Here is the detailed reference list for the sources cited within the manuscript, including their respective DOI links as provided in your documentation:

Detailed Reference List

i. Gong, S., Cai, G., Liu, S., & Puppala, A. J. (2018). Numerical Simulation of Bearing Capacity and Consolidation Characteristics of PHC Pile Foundation. In L. Li, B. Cetin, & X. Yang (Eds.), *Proceedings of GeoShanghai 2018 International Conference: Ground Improvement and Geosynthetics* (pp. 178–185). Springer Singapore. https://doi.org/10.1007/978-981-13-0122-3_20

ii. Gowthaman, S., & Nasvi, M. C. M. (2018). Three—Dimensional Numerical Simulation and Validation of Load-settlement Behaviour of a Pile Group under Compressive Loading. *Engineer: Journal of the Institution of Engineers, Sri Lanka*, *51*(1), 9. https://doi.org/10.4038/engineer.v51i1.7283

iii. Gupta, S. K., & Dahal, B. K. (2023). Finite Element Analysis on Load-Settlement Behavior of Axially Loaded Pile on Sand. *Journal of Engineering Technology and Planning*, *4*(1), 72–81. https://doi.org/10.3126/joetp.v4i1.58443

iv. Krasiński, A., & Wiszniewski, M. (2017). Static Load Test on Instrumented Pile – Field Data and Numerical Simulations. *Studia Geotechnica et Mechanica*, *39*(3), 17–25. https://doi.org/10.1515/sgem-2017-0026

v. Siemaszko, P. (2024). Pile–Soil Interaction during Static Load Test. *Studia Geotechnica et Mechanica*, *46*(3), 164–175. https://doi.org/10.2478/sgem-2024-0010

vi. Teshager, D. K. (2019). *Numerical Simulation Of Static Pile Load Test On Stratified Soil Deposits*. *7*(11).

vii. Verumandy, K., Arulrajah, A., Mirzababaei, M., & Rajeev, P. (2024). Static Load Testing of Instrumented Screw Piles in Soft Soil Deposits. *International Journal of Geosynthetics and Ground Engineering*, *10*(1), 10. https://doi.org/10.1007/s40891-023-00519-x