Geotechnical Engineering Journal of SEAGS & AGSSEA

https://ph01.tci-thaijo.org/index.php/seags_agssea_journal

Experimental and Theoretical Evaluation of Pile Bearing Capacity Utilizing the All-Pile Program

Makki K. Mohsen[1], Maha H. Abood[2], Saad F. A. Al-Wakel[3]
[1] Civil Engineering Dep University of Technology, Al-Sina"a Street, Iraq
E-mail: 40139@uotechnology.edu.iq
[2] Civil Engineering Dep, University of Technology, Al-Sina"a Street, Iraq
E-mail:maha.h.abood@uotechnology.edu.iq
[3] Civil Engineering Dep, University of Technology, Al-Sina"a Street, Iraq
E-mail:40108@uotechnology.edu.iq

ABSTRACT: The number and distribution of piles are considered to be significantly influenced by the estimation of pile bearing capacity, which is depending on the results of an on-site loading test. Based on the soil properties determined through laboratory and field experiments, the load-settlement relationship for different piles was calculated using the All-Pile program in this investigation. Additionally, it was employed to assess the bearing capacity of the piles by comparing theoretical and practical outcomes according to a variety of criteria. According to the outcomes of field tests and an analysis of the load subsidence relationship derived from soil investigations, it was determined that the program is capable of estimating the bearing capacity of piles for various types and values, accordingly determining the bearing capacity of the piles. Considering the research findings that the study presents, the theoretical method (All pile program) results of bearing capacity are about 15% higher than practical bearing capacity of Pile Load Test result and the theoretical results could be used to predict the practical ultimate bearing capacity according to the relation between the theoretical and practical results observed in the present study. When the piles lengthen from 25 to 45 meters, the ultimate bearing capacity of the practical results increases by roughly 35%, while for theocratic results increase about 21%.

KEYWORDS: Pile Bearing Capacity, Settlement, and All-Pile Program

1. INTRODUCTION

The deep foundation type, known as pile foundations, is a solution that can be used when heavy structural loads and inadequate ground conditions render shallow foundations incapable of supporting sufficient loads. Because the load transfer mechanisms of pile foundations are complex, understanding them is important. (Sharo et al., 2022; Vural et al., 2023)

The length, cross-section, and shape of the pile, how the soil is arranged and its short- and long-term properties, and the method of pile installation all affect the pile's ability to support a given load. (Wrana, 2015; Muszyński & Wyjadłowski, 2019).

The most effective component of deep foundations used in many different kinds of heavily loaded structures, including tall buildings, offshore ports, wind power mills, and storage silos, is bored piles with large diameter. Most often, they are used to reduce settlement and support large loads. (Eid et al., 2019; Ezzat et al., 2019)

Although field pile load tests are very costly and time-consuming, it is advised by various international standards for geotechnical and foundation design to use in-situ loading tests to determine the large-diameter bored piles' capacity (DIN 4014 (1990) and ASHTOO LRFD (2005)).

The tested pile can safely support greater loads than the design load, per the results of an in-situ loading test. The settlement that transpired when the load reached 200% of the operational load was lower than the permitted settlement (Eid et al., 2018)

For pile design, some popular and recent techniques listed in BNBC 2015 are: α, which calculates the piles' short-term load capacity (total stress); β, which calculates the piles' long-term load capacity (effective stress) in cohesive and cohesionless soils; and direct measurements of residual load using the Standard Penetration Test (SPT). Most of the time, soil parameters from laboratory tests are used to estimate these component resistance forces. (Yasin et al., 2009).

With experimental and theoretical assistance from the All-Pile program, this study aimed to provide a comprehensive evaluation of pile bearing capacity. This evaluation will be based on the type, profile, properties, load, and group of the piles, as well as the soil properties and whether the load is vertical or lateral.

2. METHODOLOGY

2.1 Site Investigations

To ensure accuracy and optimize geomaterial data, it is imperative to execute a comprehensive site investigation plan. The site investigation plan ought to expressly incorporate uncertainties pertaining to the property and soil geology.
Standard penetration tests (SPT) and the drilling of eight (8) boreholes to a depth of 45 meters from the current ground level are part of the field investigation.

The 45-meter depth lies below the zone where comparatively incompressible materials were subjected to significant foundation pressure. The drilling procedure followed the standards established by ASTM D 1452 and D5783. According to the data in Table 1, the subsurface investigation at the site has predominantly uncovered sandy soil.

The testing program comprises essential assessments for the soil being investigated, including the following: Visual Classification (ASTMD-2488), Specific Gravity (ASTMD-854), Natural Moisture Content and Unit Weight (ASTMD-2216), Grain Size Distribution (ASTMD-422), Liquid and Plastic Limits (ASTMD-4318), and Shear Test [ASTM D-2166 Unconfined Compression Test, ASTM D-2850 Triaxial Compression Test, and ASTM D-3080 Direct Shear Test].
The following are assessed: Consolidation and Swelling Tests (ASTM D-2435-02), Chemical Analysis of Soil, Soil Sulfate Content (SO_3), and Total Soluble Salt Content (comprising chloride, organic

https://doi.org/10.14456/seagj.2026.9 Published on 25 June 2026

matter, and PH). Every test was performed in adherence to the most recent standards established by ASTM.

The soil's consistency was assessed at multiple depths throughout the drilling operation using the Standard Penetration Test (SPT). The test was conducted in accordance with ASTM D1586-99. The experiment entails quantifying the number of strikes required to deliver a 140-pound (63.5-kilogram) Standard Hammer, positioned at a 30-inch (76 cm) descent, to penetrate a 2-inch (50.8 mm) diameter Standard Split Spoon Sampler into the soil over a distance of 12 inches (30.5 cm).

Figure 1 illustrates the subsoil strata that were explored through the implementation of eight boreholes at a depth of 45 meters at the site of the project.

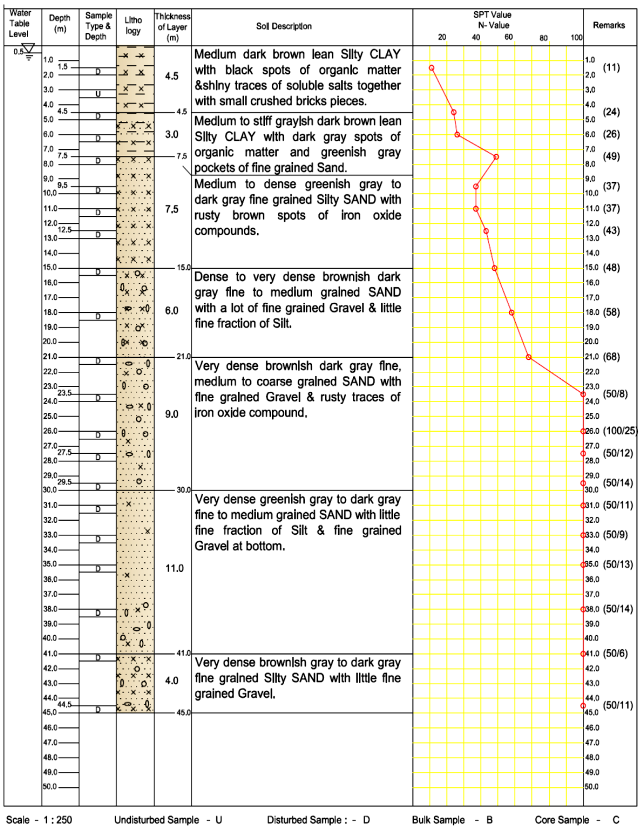


Figure 1 Soil profile of test done in field

2.2 PLATE LOAD TEST

Plate load testing is performed on rock, sediment fills, and soils. This type of testing is more appropriate for fine-grained and coarse-grained soils. Plate load tests, including BS1377-9: 1990, TS 5744: 1988, and ASTM D 1194-94, have been standardized internationally. Settlement and bearing capacity of the soil are crucial factors in geotechnical engineering foundation design. The plate loading test can quantify the subgrade modulus, elasticity modulus, ultimate bearing capacity, and foundation settlement (EVK, 2022).

The Kentledge method is a method for conducting plate load tests in which the entire compression load is applied as an inert weight. The Kentledge reaction was facilitated by means of a road roller.

The test burden was subsequently transmitted via a hydraulic jack and an additional Kentledge reaction assembly. The framework was capable of bearing the full load at a single point, from which a hydraulic ram or crane could incrementally shift the burden to the uppermost section of the pile. In general, the center of gravity of the reaction load was aligned with the axis of the contact area of the soil. The load transmitted by the jack was aligned with the plate's contact area. The settlement was measured using appropriately positioned dial gauges.

2.3 Bearing Capacity and Settlement

2.3.1 Pile Capacity Calculation Formula

Together with end bearing (Q_b), adhesion and skin friction (Q_s) make up the ultimate bearing capacity of a pile (Q_u), which is typically larger than the clay end bearing.

$$Q_u = Q_s + Q_b \tag{1}$$

$$Q_u = \alpha\, C_u A_s + N_c C_{ub} A_b \tag{2}$$

where:
C_u = the soil's shear strength next to the shaft
α = Shaft Adhesion Factor is assumed to be 2/3
A_s = pile shaft's surface area
N_c = the bearing capacity factor, which is 9
C_{ub} = the soil shear strength of as 2/3d below the base (d = base diameter)
A_b = area of the biled base

Additionally, a variety of Meyerhof (1965–1976) suggested methods were employed to determine the necessary lengths of driven and bored piles based on the findings of common penetration tests.

For Driven pile

$$Q_b = (4N)(L_b/B)A_b \tag{3}$$

$$Q_s = (0.1N)A_s = \Sigma f_s \tag{4}$$

For bored pile

$$Q_b = (1.4N)(L_b/B)A_b \tag{5}$$

$$Q_s = (0.067N)\, A_s = \Sigma f_s \tag{6}$$

$$Q_s = (0.5N)\, A_s = \Sigma f_s \text{ (in clay)} \tag{7}$$

where:
Q_b = bearing resistance of the pile (ton)
Q_s = skin friction of the pile (ton)
A_s = surface area of the pile = 0.275×4×D
L_b = part of pile length that penetrated in bearing layer
B = width or diameter of pile
N = average number of blows of standard penetration test

2.3.2 Settlement Calculation Formula

The method for calculating the settlement of single piles is the method proposed by (Poulos, 1989), a single pile's entire settlement is made up of

- Skin friction-based settlement as described in Eq. 8

$$w_{SE} = \frac{Q_{all}}{LE_s} I \tag{8}$$

where:
Q_{all} = allowable bearing capacity
L = pile length
E_s = soil modulus of elasticity
I = $0.5 + L/D$
D = depth of pile

- Settlement of the pile base represented by Eq. 9

$$w_b = \frac{Q_{base}}{R_b G_b}\frac{1-\nu}{4} \tag{9}$$

where:
ν = Poisson's ratio of soil,
R_b = radius at the base
G_b = shear modulus at the base

- Elastic shortening settlement of the single pile is presented by:

$$W_P = C \frac{Q_{allfriction}}{A_S E_S} \quad (10)$$

where:
C = reduction factor (C ≈ 0.5 for all piles, C ≈ 0.7 for soft soil)

The shortening settlement is calculated only when (E_p/E_s < 500), and then the total settlement of the pile will be calculated as:

$$W = W_S + W_P \quad (11)$$

2.4 ALL-PILE PROGRAM

Numerical analysis has become increasingly important in the design of pile foundations. Various techniques have been developed to predict how loads are transferred and how the pile settles along its length. However, these empirical methods may not be suitable for varying pile and soil conditions and are also costly and time-consuming, leading to higher construction costs. To overcome these challenges, numerical analysis using soil properties obtained from field soil tests can easily generate load-settlement curves and evaluate the performance of pile foundations (Mohshin et al., 2023).

The pile load capacity in the current study is analyzed using the All-Pile program. All-Pile can handle piles of any type, including auger-cast, driven, drilled, steel tubing, H-shaped, and tapered piles. (All-Pile manual, 2014)

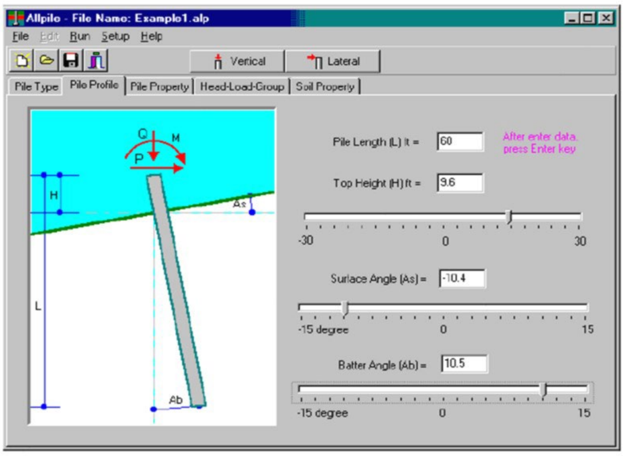


Figure 2 Pile Profile Input Page

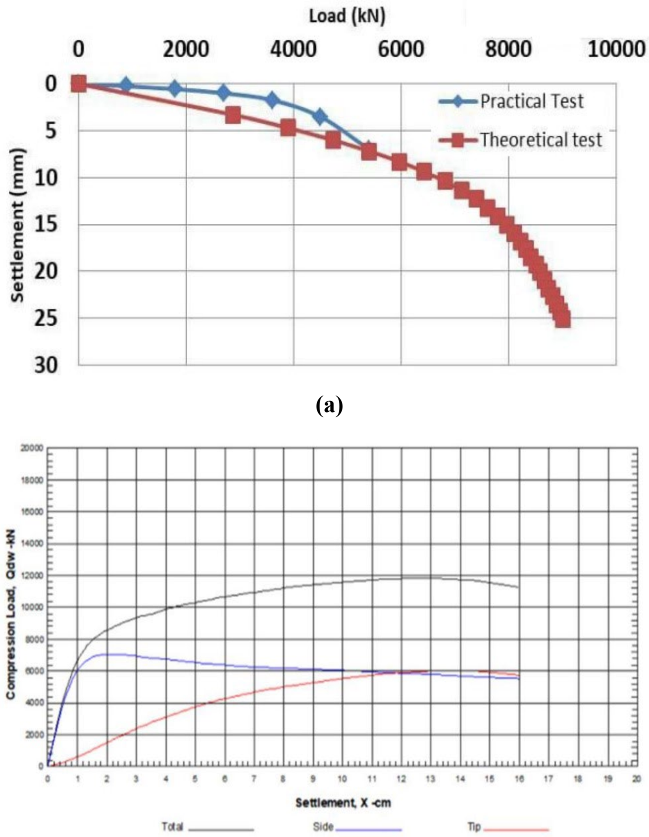
Figure 1 presents pile profile information, and the diagram on the left side reflects the information you input on the right side.

where:
P = horizontal load at top of pile
Q = vertical load at pile top. For a batter pile, Q is the axial load
M = moment load at top of pile
L = projected length of pile in vertical direction
H = top height above ground
A_s = surface angle, limited up to 30 degrees
A_b = batter angle of pile limited up to 30 degrees

3. RESULTS

To ascertain the bearing capacity of piles of each pile embedded length (25, 28, 30, 31, 43.5, and 45 meters), a set of seven field pile load tests was used. The ASTM D 1143-2007 specification is followed in conducting the pile load test for the piles under investigation. The working load is 3600 kN, and the test was conducted to 5400 kN, about 150% of the working load. The project's soil investigation states that the All-pile program was used to determine the piles' capacity to support a specified load.

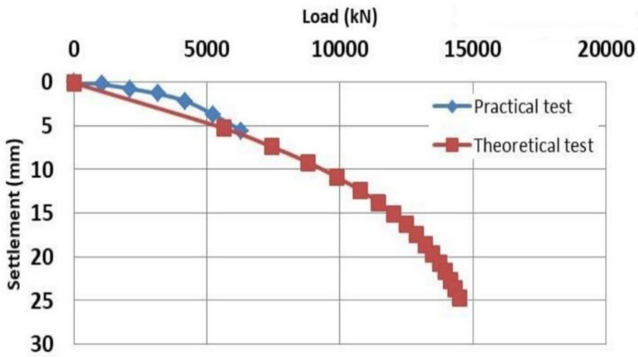
Figures 3 to 9 show the comparison between theoretical and practical load settlement curves for the concrete pile under study. The figures show that there is convergence between the two approaches and the results obtained from all pile program generally are greater than the load test.



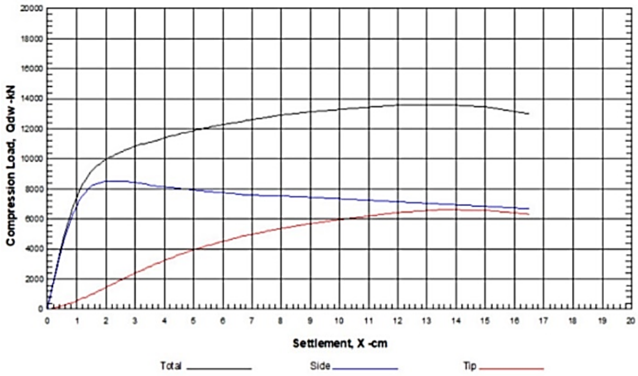
(a)

(b)

Figure 3 Load settlement curves for pile with diameter 1200mm and embedded length 25000 mm (a) theoretical and practical results (b) numerical analysis

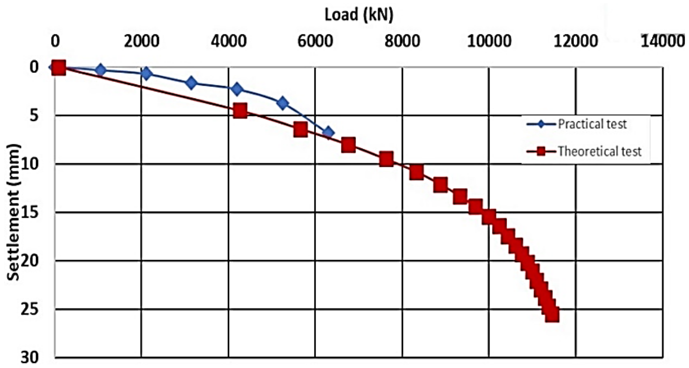


(a)

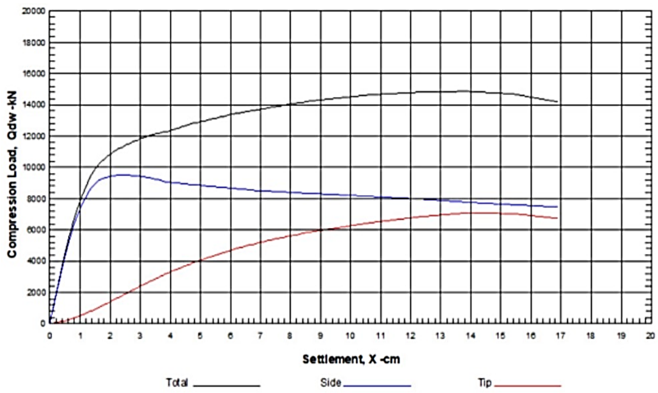


(b)

Figure 4 Load settlement curves for pile with diameter 1200mm and embedded length 28000 mm (a) theoretical and practical results (b) numerical results

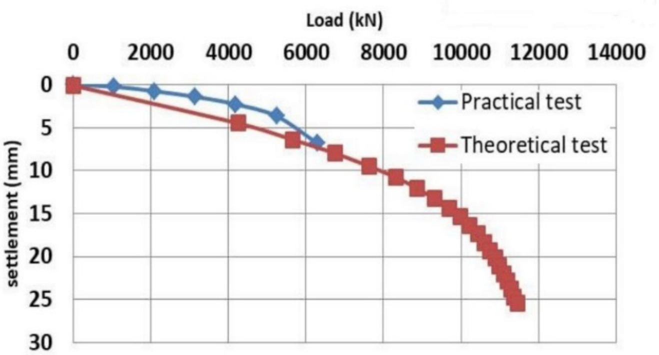


(a)

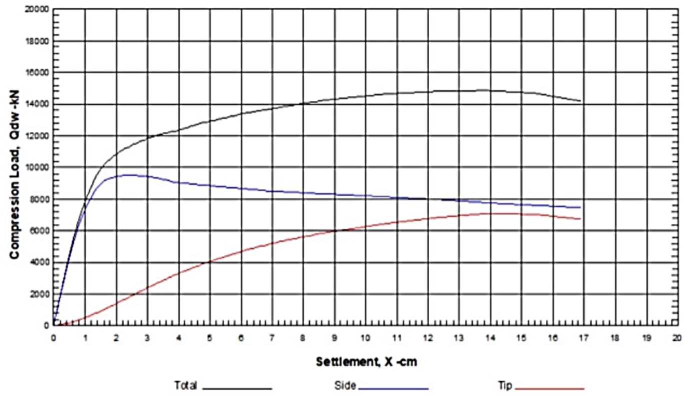


(b)

Figure 5 Load settlement curves for pile with diameter 1200mm and embedded length 30000 mm (a) theoretical and practical results (b) numerical results

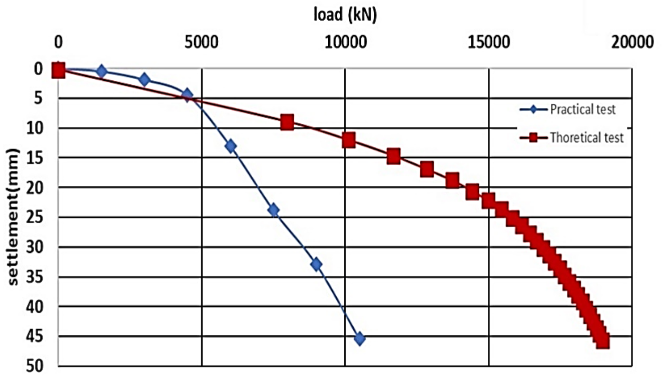


(a)

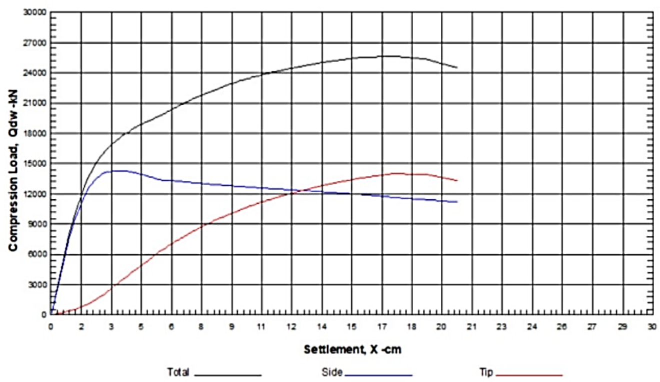


(b)

Figure 6 Load settlement curves for pile with diameter 1200mm and embedded length 31000 mm (a) theoretical and practical results(b) numerical results

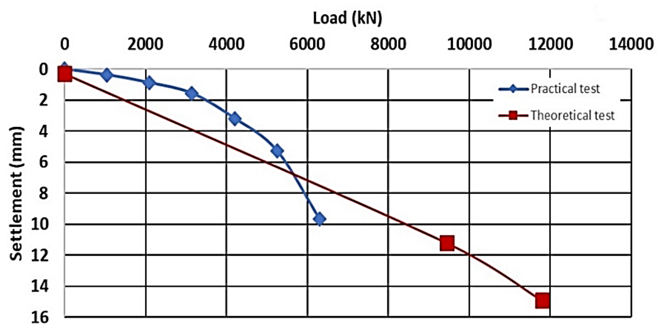


(a)

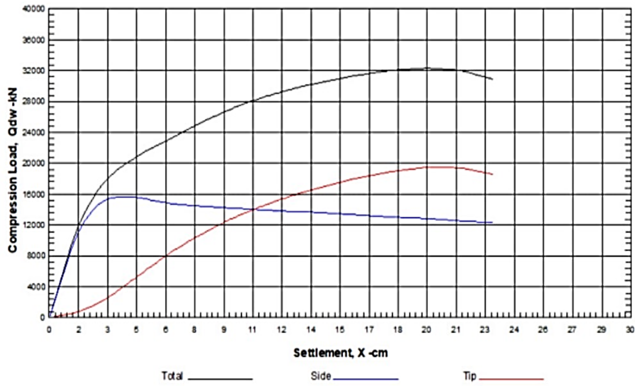


(b)

Figure 7 Load settlement curves for pile with diameter 1200mm and embedded length 40000 mm (a) theoretical and practical results(b) numerical results

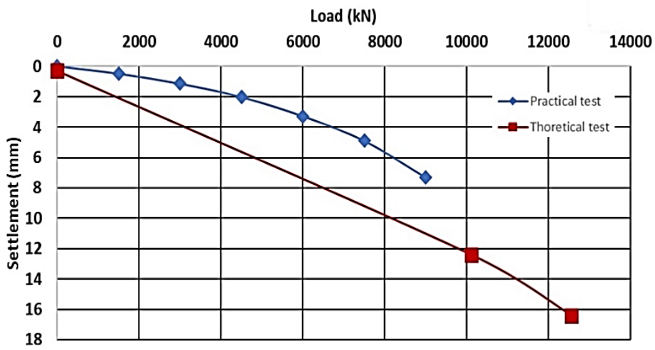


(a)

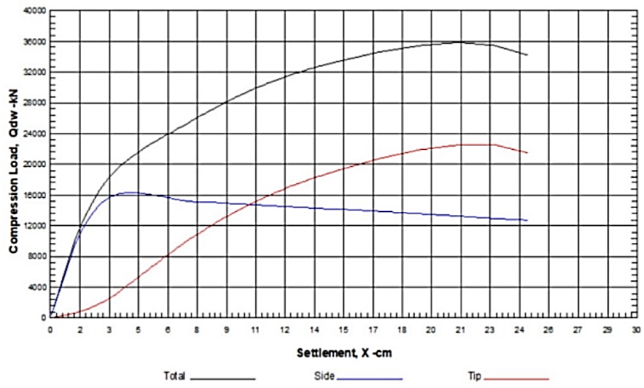


(b)

Figure 8 Load settlement curves for pile with diameter 1200mm and embedded length 43500 mm (a) theoretical and practical results(b) numerical results



(a)



(b)

Figure 9 Load settlement curves for pile with diameter 1200mm and embedded length 45000 mm (a) theoretical and practical results(b) numerical results

A correlation between the ultimate bearing capacity (Q_{ult}) obtained from theoretical results and Practical results for 1200 mm settlement is shown in Figure 10. The figure shows that the theoretical results are higher than the practical results because of the effect of natural soil circumstances in the practical test, according to the equation below:

$$(Q_{ult})_{Pract.} = 1.688(Q_{ult})_{Th} - 6990 \qquad (12)$$

where:

$(Q_{ult})_{Pract}$ practical ultimate bearing capacity

$(Q_{ult})_{Th:}$ theoretical ultimate bearing capacity

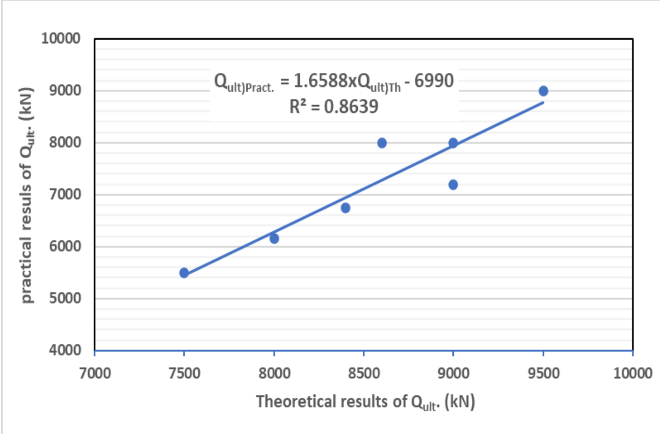


Figure 10 A correlation between the ultimate bearing capacity (Q_{ult}) of theoretical and Practical results.

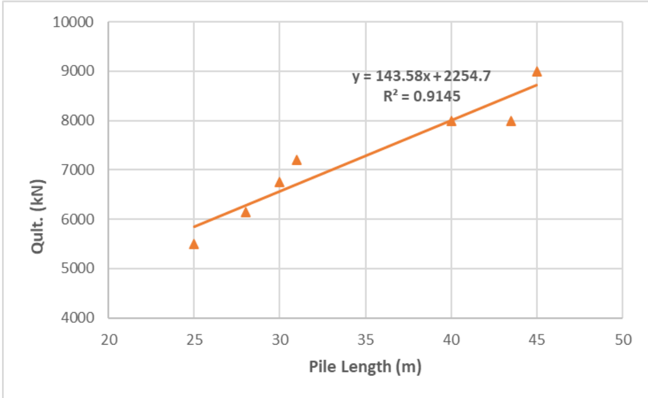


Figure 11 A correlation between pile length and the ultimate bearing capacity (Q_{ult}) of Practical results.

4. CONCLUSIONS

1. The load-settlement results from the analysis provided a platform for comparing the numerical results for the piles under study with the results of the theoretical method (Meyerhof's formula) and the Pile Load Test (failure criterion 10% of the pile tip diameter).
2. The ultimate bearing capacity of practical results increases by about 35% when the pile length increases from 25 m to 45 m, while it increases by about 21% for theoretical results.
3. The allowable compressive load capacity by the theoretical method (All pile method) results are about 15% higher than the allowable compressive load capacity of the Pile Load Test result because of the effect of natural soil circumstances in the practical tests.
4. Theoretical results $(Q_{ult})_{Th}$ could be used to predict the practical ultimate bearing capacity (Q_{ult})Pract using the equation $[(Q_{ult})_{Pract.} = 1.688(Q_{ult})_{Th} - 6990]$.

5. REFERENCES

All-Pile manual, version 7, 1 and 2, USA, (2014).

AASHTO LRFD. (2005). Bridge Design Specifications – SI units, 3rd ed., Washington, DC, AASHTO

ASTM, "Standard Classification of Soils for Engineering Purposes (Unified Soil Classification System)," ASTM Designation: D 2487-02, Annual Book of ASTM Standards, copyright American Society for Testing and Materials, Volume 04.08,

ASTM. (2007). "Standard Test Method for Piles Under Static Axial Compressive Load", ASTM D 1143-07.

ASTM D 1194-94 Standard Test Method for Bearing Capacity of Soil for Static Load and Spread Footings, USA.

British Standards Institution, "BS 1377, Part 9", British Standards Institution, London, 1990.

ÇEVİK, S. (2022). "Evaluation of Plate Load Test Results A CASE STUDY IN ANKARA/TURKEY". Teknik Mühendislik ve Müşavirlik A.Ş., İstanbul. J ESOGU Engin Arch Fac., 30(2), 253–259.

DIN 4014. (1990). German Association for Earthworks and Foundation Engineering, Deutsches Institute fur Normung,Berlin, Germany.

Eid, M., Hefny, A., Sorour, T., Zaghloul, Y. & Ezzat, M. (2018). "Full-Scale Well Instrumented Large Diameter Bored Pile Load Test in Multi Layered Soil: A Case Study of Damietta Port New Grain Silos Project". International Journal of Current Engineering and Technology, Vol.8, No.1

Ezzat, M., Zaghloul, Y., Sorour, T., Hefny, A., & Eid, M. (2019). "Numerical Simulation of Axially Loaded to Failure Large Diameter Bored Pile". World Academy of Science, Engineering and Technology, International Journal of Geotechnical and Geological Engineering Vol:13, No:5, 2019.

Ezzat, M., Eid, M., Hefny, A., Sorour, T., & Zaghloul, Y. (2019). "Numerical Analysis of Large Diameter Bored Pile Installed in Multi Layered Soil: A Case Study of Damietta Port New Grain Silos Project", International Journal of Current Engineering and Technology, vol 13, No 9. doi:10.3233/978-1-60750-031-5-1325

Meyerhof, G. G. (1976). "Bearing Capacity and Settlement of Pile Foundations". J. Geotech. Eng. Div. 102, 197–228. M D 1452 D5783

Mohshin, M., Abrar, M., Abiduzzaman, Rudra, S. N., & Riyadh, M. M. (2023). "Load-Displacement and Load Transfer Mechanisms of Pile Foundation Using AllPile Software". Proceedings of International Conference on Planning, Architecture and Civil Engineering, 12 - 14 October 2023, Rajshahi University of Engineering & Technology, Rajshahi, Bangladesh, pp. 610 – 615.

Muszyński, Z., & Wyjadłowski, M. (2019). "Assessment of the Shear Strength of Pile-to-Soil Interfaces Based on Pile Surface Topography Using Laser Scanning. Sensors". 19, 1012. https://doi.org/10.3390/s19051012

Sharo, A., Al-Shorman, B., Bani Baker, M., Nusier, O., & Alawneh, A. (2022). "New Approach for Predicting the Load-Displacement Curve of Axially Loaded Piles in Sand". Case Stud. Constr. Mater., Vol.17, e01674. ISSN 2214-5095, https://doi.org/10.1016/j.cscm.2022.e01674

Tian, W., & Galaa, A. (2021). "Plate Load Test on Rock with Soaking Under a Massive Raft Foundation, Innovative Infrastructure Solutions". 6:45. https://doi.org/10.1007/s41062-020-00434-4.

Vural, İ., Kabaca, H., Poyraz, S. (2023). "A Novel Approach Proposal for Estimation of Ultimate Pile Bearing Capacity Based on Pile Loading Test Data". Applied Sciences; 13(13):7993. https://doi.org/10.3390/app13137993

Yasin, S. J. M., Alam, M. J.; Islam, M. S., & Siddique, A. (2009). "Static Load Capacity of RCC Piles in Soft Clay – A Case Study". Proceedings of the 17th International Conference on Soil Mechanics and Geotechnical Engineering, M. Hamza et al. (Eds.), Egypt, pp. 1325 – 1328.