Pakistan Journal of Engineering and Technology, PakJET
ISSN (p): 2664-2042, ISSN (e): 2664-2050
Volume: 5, Number: 3, Pages: 1- 6, Year: 2022

Effect of Contact Pressure on the Lateral Capacity of Piles

Wali Ullah*, Kiramat Ali, Irfan Jamil, Muhammad Asad Fahim, Muhammad Zeeshan, and Aqeel Ur Rehman

Civil Engineering Department, University of Engineering and Technology Peshawar, Pakistan
Corresponding author: Wali Ullah (e-mail: wali7662@gmail.com).

Received: 15/05/2022, Revised: 30/08/2022, Accepted: 25/09/2022

Abstract- **This study aims to determine how to contact pressure affects pile capacity. First, a single pile model was subjected to a total of six tests, five conducted under varying surface loads and one conducted on a single pile raft. Plaxis- 3D was utilized in the second step of numerical modelling to imitate experimental activity. The galvanized iron pipe was used as a model pipe, and for confining pressure, a rectangular plate made of aluminum had a slot in the center for placing a pile. For numerical study in Plaxis 3-D pile was used as a model pile surrounding the soil to find the relative displacement between the piles and surrounding the soil. In the proposed research work, the axial and lateral capacity of the pile increases due to the contact pressure of the soil. As a result of the interaction between the pile and the raft, when the results were compared, the pile tightly connected to the raft took less axial force than the other pile that was not. Similar outcomes emerged from the trials when they were conducted in Plaxis 3-D.**

Index Terms-- **Contact pressure, piles, raft, strain gauge, confining pressure.**

I. INTRODUCTION

In the past, structures were constructed with the use of piles. Woods were being used at the time to make the soil more rigid. Various formulas for foundation lateral and vertical design are available due to numerous numerical and experimental research studies. We can place a raft under tall buildings when the soil's bearing ability is sufficient, but when the raft cannot support the entire weight, we can place piles underneath it, known as a pile raft foundation [1].

In harbour and quay constructions, where ships and wave action apply horizontal forces to offshore structures, all tall structures are vulnerable to wind and wave action. In those structures built in earthquake-prone areas, lateral forces are applied to piles. Additionally, because soft clay has a low shear strength and high compressibility, there could be significant deformation. The optimum type of foundation for these constructions in such circumstances is a pile foundation. To determine the bearing capacity of a pile, the vertical load should be examined first. Then, the lateral load's flexural behavior should be determined only small lateral loads may be accommodated by this design method, but in offshore and big structures, lateral loads are typically very substantial, accounting for up to 10–20% of the vertical load. Winkler foundation theory has been frequently applied to pile design when the lateral load pressure-displacement (P-Y) technique is used. The Finite Element Method can be used to analyze this issue thanks to the developing new tools (FEM).

A mixed pile raft foundation is the optimum option for all high-rise structures. The weight was once thought to be carried by either a raft or a pile, but it has now been determined that the load is spread by both, making the system more useful and efficient. The interaction of pile-pile, raft-pile, and soil-pile-raft is frequently disregarded in the design of pile raft foundations, which results in an uneconomical design. Disregarding various interaction elements will produce an unsafe design.[2] and [3] piles utilized in the foundation serve as "settlement reducers" and "stress reducers," and rafts can serve as differential settlement reducers and distribute the weight to all the piles.

The contact pressure between the piles will determine how the lateral weight is distributed. Due to the raft's lack of soil contact, it is impossible to quantify the effect of single heaps in pile groups. In this situation, the soil beneath the cap of pile groups supporting bridge piers is typically eroded by water.

A) SINGLE PILE UNDER LATERAL LOADING

Pile is subjected to lateral loads such as seismic loads, wind loads, debris loads, etc. piles usually resist the Skin friction load through the shaft of the pile and with the help of passive resistance through passive soils [4]. When a lateral load is applied to the pile, the lateral displacement "y" compresses the ground at the front of the pile like passive ground, reducing the ground stress at the rear of the pile [5]. It is shown in Fig.1. Displacement reduces in the length direction of the pile, then a point reached which no lateral load can be identified. When the lateral load is applied, the pile response depends on many factors like loading, installation

This work is licensed under a Creative Commons Attribution 4.0 International License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

techniques, pile head conditions, and geometrical and structural properties [6]. After the analytical investigation, we know that when a vertical load increases, the lateral displacement of piles also increases.

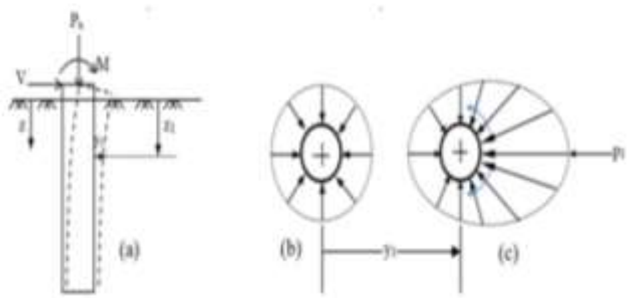


FIGURE 1. Single pile under lateral loading.

B) HORIZONTAL LOAD DISTRIBUTION

They considered the below components in lateral load, as shown in Fig2 [7]. 1) Piles resist load through skin resistance, and the soil in front of the piles shows passive resistance. 2)Load is also resisted by a pile cap embedded in the soil. 3)Due to skin friction, the load is also resisted.

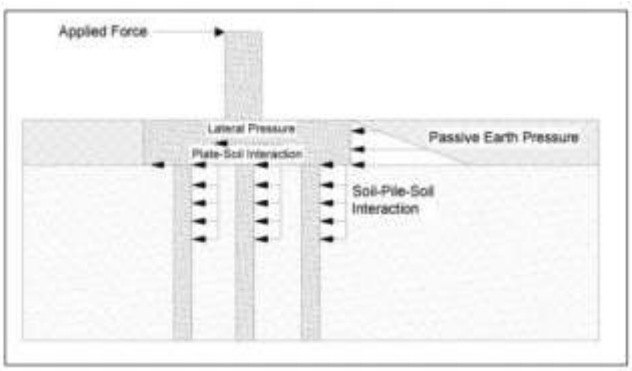


FIGURE 2. Horizontal Load Distribution (Russo, Viggiani and Mandolin, 2o11

II. METHODOLOGY

A) SIEVE ANALYSIS, MAXIMUM AND MINIMUM RELATIVE DENSITY TESTS

According to ASTM D422, the sand used in the model was sieved. Figure 3 shows the grain size distribution curve, after which the percent passes from each screen. The coefficient uniformity and coefficient of curvature are 3.2 and 0.551; respectively. The sand used was allowed to fall from a one-inch height with the help of a funnel to achieve the minimum relative density. The sand is vibrated to obtain the maximum density, as shown in Fig. 4. The minimum and maximum density is a very important indicator of the compactness condition of soil mass, which influences engineering features such as compressibility, permeability, and strength parameters.

B. DIRECT SHEAR TEST

A direct shear test represented in Fig. 5 was performed for the sand. ASTM D-3080 is used to find the friction angle of soil, cohesion, and interface friction angle. All the tests were performed on a uniform density of 60%, shown in Fig. 6. The direct shear test's typical result is shown in Fig. 7.

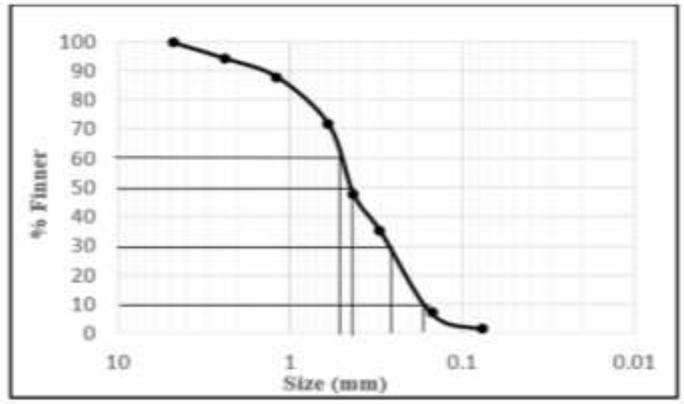


FIGURE 3. Gradation of the curve for Dry Sand.

FIGURE 4. Vibrating Table for Maximum dry density sand.

FIGURE 5. Direct Shear Test Equipment.

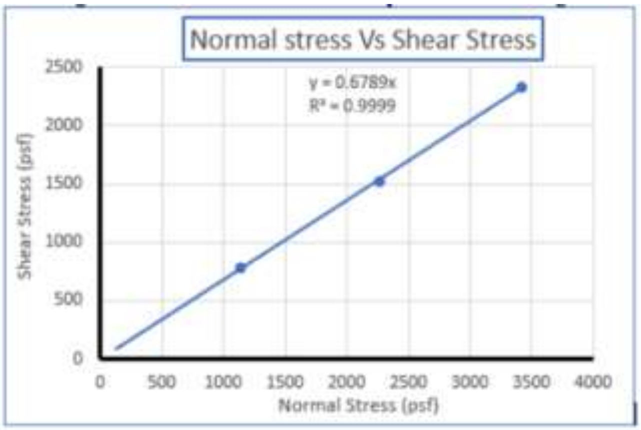


FIGURE 7 Direct Shear Test typical result.

C. TRIAXIAL TEST

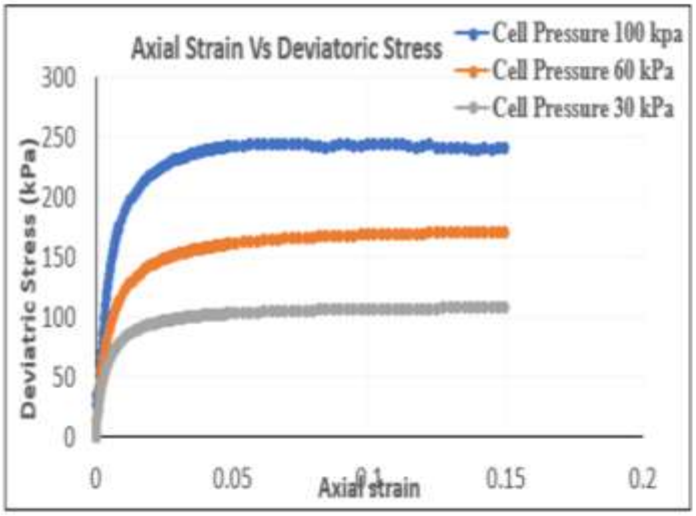
Triaxial tests are used to find the stiffness and shear strength parameters. A pile whose length is 1.5 feet is selected at a base with a low maximum confined pressure. Hence the test was carried out at very low pressure at 10KPa, 40KPa, and 100KPa. There are three different soil conditions on which we can perform the Triaxial test, i.e., unconsolidated undrained, consolidated drained, and consolidated undrained. A cylindrical sample is represented in Fig.8, whose height is 78mm and its diameter is 38mm, which confirms the length-to-diameter ratio is two, prepared through a compaction procedure in a sample. At three different cell pressures, the consolidated undrained test is conducted on sand samples whose cell pressure is 30kPa, 60kPa, and 90kPa, as shown in Fig. 9. The stress-strain curve for various cell types of pressure is represented in Fig. 10.

FIGURE 8. Triaxial Apparatus

D. MODEL CONTAINER

A large rectangular steel container is large in which we performed all the tests which satisfy the boundary conditions as shown in Fig. 11. The box used in the experimental work there a height is 1.524m, a width of 0.914m, and a length is 1.22m. The thickness of the steel box is 6mm with diagonal, lateral, and vertical, as shown in Fig. 12.

FIGURE 9. Soil Sample Prepared in the mold



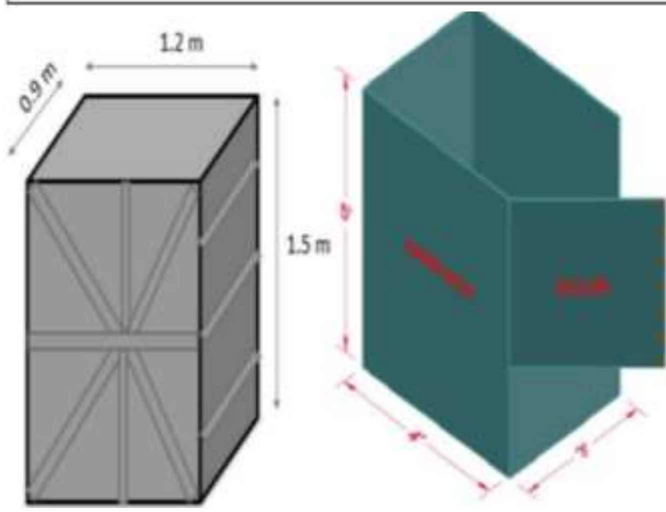


FIGURE 11. Model Container of Conducting an experimental test.

E. MOBILE PLUVIATOR

In order to achieve the uniform density in tests, so a special pluviator as shown in Fig. 13 was designed. in which sand is poured. We can use uniform densities ranging from 10% to 90% in a large area.

Following are the main components of a mobile pluviator.
1) Hopper
2) Shutters (the rate of discharge is controlled through perforated plates)
3) Sieve (soil uniformly whose sieve#4 is used)
4) An adjustable frame is three-dimensionally moveable.

FIGURE 13. Mobile Pluviator installed above the soil box.

F. MODEL PILE and RAFT

Pipe made up of galvanized iron whose length is 0.61m there external diameter is 19mm and thickness is 2mm used as model pile as shown in Fig. 14. The small load cell was attached at the pile tip made up of a nut and bolt system by installing 360-ohm strain gauges to measure the lateral and axial load. The raft made up of aluminum with a thickness is of 25.4mm (1inch), and 69pa is the value of the young modulus of elasticity, as shown in fig 18. The dimensions of the square raft are 305mm x 305mm, as represented in Fig. 15.

FIGURE 12. Test Container with Inclined and Vertical braces

FIGURE 14. Pipe made up of galvanized iron

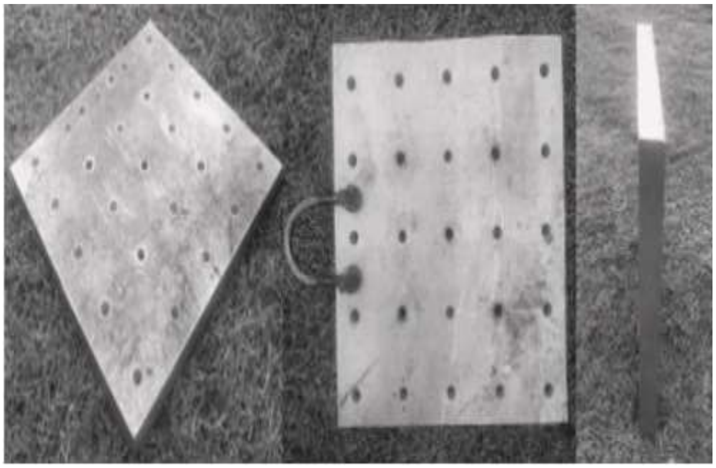


FIGURE15. 25.4mm thick aluminum

TABLE IV. MATERIAL PROPERTIES

	Friction angle	Cohesion(kpa)	E_{50REF} (mpa)	E_{oed} (Mpa)	E_{ur} (Mpa)	
Sand	34°	0	17	17	51	0.33
Interface	23°	0	17	17	51	0.3
GI Pile	--	--	200000			0.3

III. RESULTS AND DISCUSSION

A. LATERAL LOAD TESTS ON SINGLE PILE

The lateral load is applied to the pile under different surface loads, and the lateral displacement curve is recorded. For different loads, the contact pressure graph was drawn between lateral load vs lateral displacement, as represented in Fig. 19. It is clear from the graph that when we increase the contact pressure, the lateral pile capacity increases and, at high load, shows very stiff behavior. The pile, whose displacement is 2mm, and the lateral capacity increases from 175 to 499N when the vertical load increases from 0 to 5745Pascal.

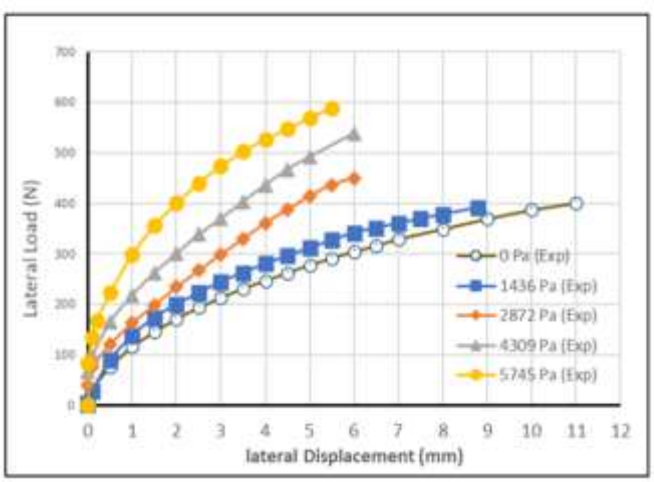


FIGURE 19. Lateral Load vs Lateral Displacement

B. LATERAL CAPACITY OF SINGLE PILE

When the surface load is applied at different contact pressure and a graph is drawn between the lateral loads and the lateral load-displacement which is shown in Fig. 20. It is clear from the curve that when contact pressure increases the lateral capacity of pile also increases almost linearly

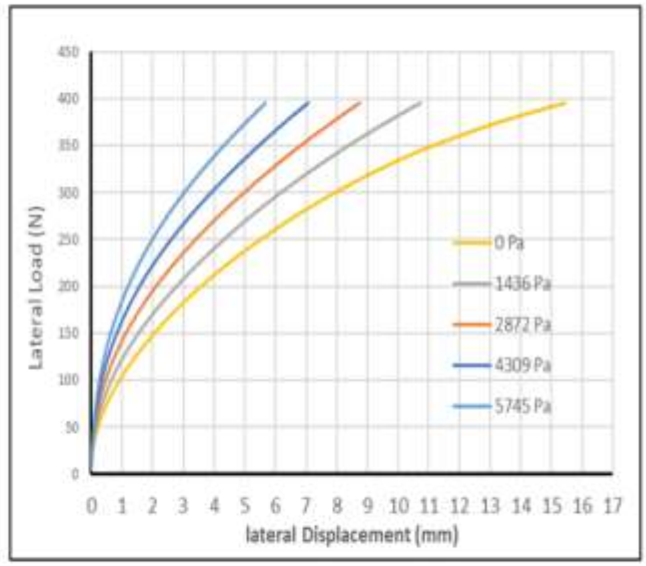


FIGURE 20. Lateral Displacement vs Lateral load curve.

C.WHEN PILES ARE RIGIDLY CONNECTED TO RAFT

A single pile raft test was conducted with the pile rigidly attached to the raft to account for the interaction between the raft and the pile. The single pile raft was subjected to 3500 N of incremental stress, and Fig. 21. Illustrates the resulting deformation and load transferred to the pile. The load taken by raft, calculated by deducting the load taken by pile from the total applied load, was divided to get the contact pressure.

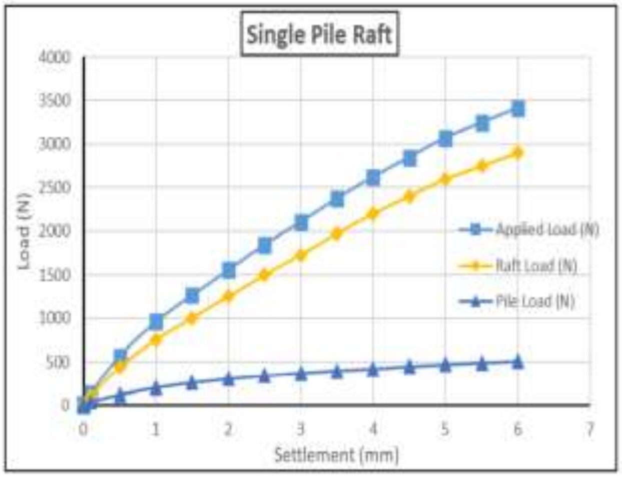


FIGURE 21. rigidly connection of pile

D. INTERACTION CURVE

The effect of raft rigid connection on the increase of pile bearing capacity with surface load was observed when the results of a single without contact to the raft was compared to the pile with rigid connection to raft. From Fig. 22, it is clear that with an increase in contact pressure from 1436Pa to 5745Pa the percentage difference between the two piles increases from 25% to 60%. Initially, no difference is expected at low contact pressure, but after 2872 Pa, the non-linear difference occurs, as shown in Fig. 22.

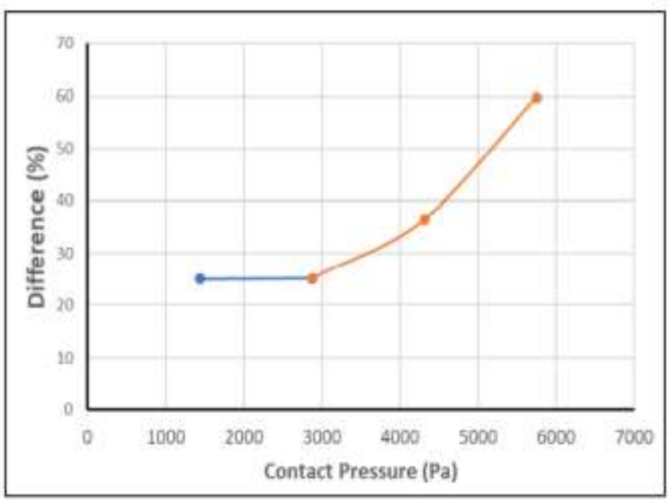


FIGURE 22. Interaction Curve

IV. CONCLUSIONS

When the vertical load goes from 0Pa to 5745Pa, the capacity of a single pile rises from 190 to 325pa (1,5mm), and the lateral capacity rises from 175N to 400N (2mm). The contact pressure between the soil and the raft also increases piles' lateral and axial capacity. The interaction factor rises from 25% to 60% when the vertical load increases from 1436 to 5745 Pascal. Piles with extra length will cause overlapping of pressure bulb and settlement.

FUNDING STATEMENT

The authors received no specific funding for this study.

CONFLICTS OF INTEREST

The authors declare they have no conflicts of interest to report regarding the present study.

REFERENCES

[1] Poulos, H.G., "Piled raft foundations," *Design and application Géotechnique*,vol.*51*, no. *2,* pp. 95-113**.** January 2001**.** DOI**:**10.1680/geot.2001.51.2.95.

[2] Luca de, G.Russo "Analysis and Performance of Piled Rafts Designed Using Innovative Criteria" *Journal of Geotechnical and Geoenvironmental Engineering* vol. 134, no 8, pp. 1118-1128, 2008. DOI: 10.1061/(ASCE)1090-0241(2008)134:8(1118)

[3] E B Altalhe "Pile Foundation Design" *Advance Geotechnical Engineering* July 2022.

[4] Huang, A., Hsueh, C., ONeill, M. W., Chern, S. and Chen**, "**'Effects of construction on laterally loaded pile groups**"** *Journal of Geotechnical and geoenvironmental Engineering* vol. 127, no. 5, pp. 385–397, 2001. DOI: 10.1061/(ASCE)1090-0241(2001)127:5(385)

[5] Jamil, I., & Ahmad, I, "Bending moments in raft of a piled raft system using Winkler analysis" *Geomechanics and Engineering,* vol. 18, no. 1, pp. 41-48, 2019. DOI**:** 10.12989/gae.2019.18.1.000

[6] Kitiyodom, P, T Matsumoto, and K Horikoshi "Analyses of vertical and horizontal load tests on piled raft models in dry sand," *Proceedings of the International Conference on Soil Mechanics and Geotechnical Engineering 2005, pp. 2005–2008.* DOI:10.3208/sandf.50.63

[7] Khari, M., Kassim, K. A., & Adnan, "An experimental study on pile spacing effects under lateral loading in sand". *The scientific world journal*, vol. 2013, 2013. DOI: 10.1155/2013/734292