Iraqi journal of civil engineering (IJCE)
P-ISSN: 1992-7428 ; E-ISSN: 2706-686X

Vol. 17 , No. 2 (2023) , pp. 82~ 90
DOI: 10.37650/ijce.2023.170208

Iraqi Journal of Civil Engineering

Journal homepage: https://ijce.uoanbar.edu.iq/

Optimizing The Number and Diameter of Piles to Enhance Foundation Resistance

Rasool Kadhim Mohammed Almaged[1*], Kadhim Jawad Abdulkadhim Alabbas[1]

[1]*Civil Engineering Department, University of Thi-Qar, Thi-Qar, Iraq*

PAPER INFO

Paper history
Received: 22/09/ 2023
Revised: 25/12/2023
Accepted: 30/12/2023

Keywords:
Experimental study
Geotechnical engineering
Nonlinear behavior
Piled rafts
Piles bearing

ABSTRACT

Studies in geotechnical engineering have studied the nonlinear behavior of soils. An experimental study was carried out on models of piled rafts, and four piles with a diameter of 25 mm and a length of (300, 400, and 500) mm were taken, with a raft of (180x180) mm, and compared with the piled-raft system of 180 × 180 raft and nine piles of 19 mm and 500 mm in diameter and length, respectively. They were tested for raft resistance, number of piles, length, and diameter while maintaining the spacing between piles. Test results showed the raft performance improved by 76% when adding piles. The increase in the (L/D) ratio for variable (L) length leads to an increase in pile share of 87% for the groups (2×2). Also, pile share was increased by 10% with a decrease in the diameter of piles and an increase in the number of piles in the group. Therefore, the increment in each pile's skin friction results in an increase in the bearing capacity of each pile.

1. Introduction:

Because the raft and piles work together to carry the applied loads from the structure to the deep soil, piling rafts are an economical foundation option in many cases. The piles are often employed as settlement "controllers" since they allow the differential deflections in the raft to be managed (Small & Poulos, 2007).

Foundations are designed to safely and economically transfer the load of a building to the soil, ensuring the structure's dependability and ease of maintenance (Sinha & Hanna, 2017). According to Basile (2015) and Poulos (2001), in recent years, many structures (especially high-rise buildings) have been built using mixed-piled raft foundation systems. Piled raft projects must consider numerous elements, including pile stiffness calculation, pile arrangement, raft thickness, type of reinforcement, and calculations appropriate to estimating raft displacement.

* *Corresponding author.* Tel.:+9647811051988; fax: +0-000-000-0000.
E-mail address: r.mohammed@utq.edu.iq

Mandolini et al. (2013) suggest making use of the "piled raft concept," which requires thinking about piles that "cooperate" with rafts rather than being viewed as an "alternative" to rafts in the traditional sense. Consequently, piled rafts are considered to be a type of foundation that contains several interfaces due to the interconnected nature of the piles that lie beneath the raft. Butterfield & Banerjee (1971) discovered that the pile cap has the potential to influence the load-settlement behavior and the load-distribution mechanism between the piles and the cap.

2. Methodology:

In this paper, poorly graded sandy soil is used. Steel models were used as rafts, aluminum tubes as piles, and a piled raft model was formed. All tests were conducted inside the laboratory.

2.1 Case Study

In the laboratory, experimental modelling has become one of the most effective tools for analyzing engineering issues. The experimental model study was performed with the size of the raft (180 x 180 x 20) mm, the dimensions of the pile (length, L = 300, 400, 500 mm), the number of piles (4), the pile diameter, Dp = 25 mm, and a second model for comparison. The dimensions of the pile are the length (L = 500 mm) and the pile diameter (Dp=19 mm). But the number is nine.

3. Test Setup:

A laboratory test model was prepared in the laboratory to simulate reality, as shown in Figure (1), which consists of a soil tank with dimensions of 1000x1000x800 mm. This tank was placed in an iron structure to resist the applied forces. This structure contains a hydraulic jack with a capacity of 50 tons installed at the end of a load cell with a capacity of 10 tons. The cell was connected to a load indicator to measure the load on the raft. Accurate stress gauges with dimensions of 7.4 x 4.1 mm were also used, and they were attached to the piles and connected to a stress indicator to measure the strains in the piles. Use (LVDT) 50 mm and connect it to the settlement indicator to measure the settlement at the centerline of the raft model. A digital indicator, 0.01 mm / 0.0005" (0 ~ 25.4 mm / 1"), was used to enhance the accuracy.

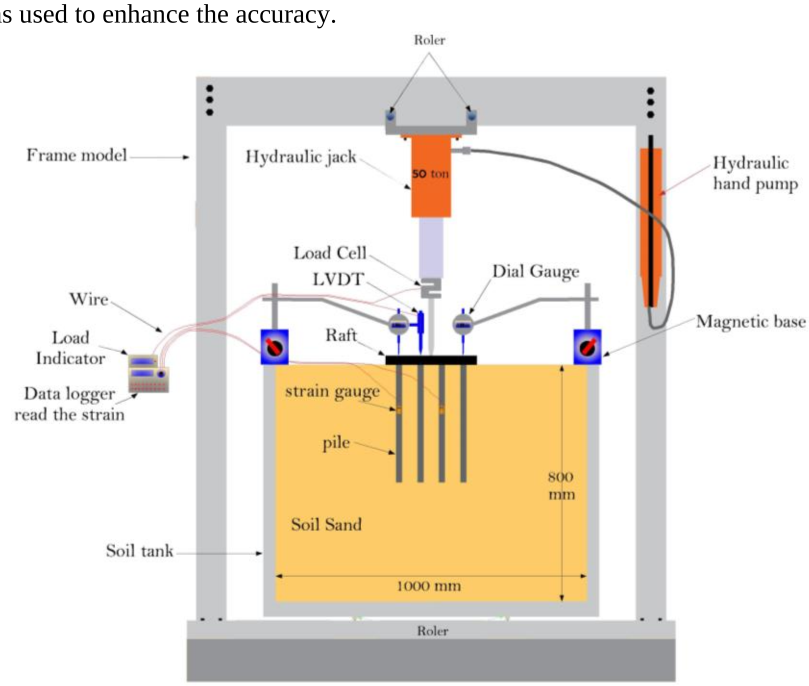


Fig. 1 Setup of the laboratory model.

4. Material:

4.1 Soil properties

The experiment employed sandy soil from the southern Iraqi province of Thi Qar. The maximum and minimum bounds for soil dry unit weights were determined using ASTM (D4253, 2000). The specific gravity test was carried out using ASTM (D-18, 2006) standards; the grain size distribution depicted in Figure (2) was analyzed using ASTM (D422, 2007) standards; and the internal friction angle was determined using ASTM (D3080, 2011) standards. Table (1) provides a full description of the physical characteristics of the soil sample.

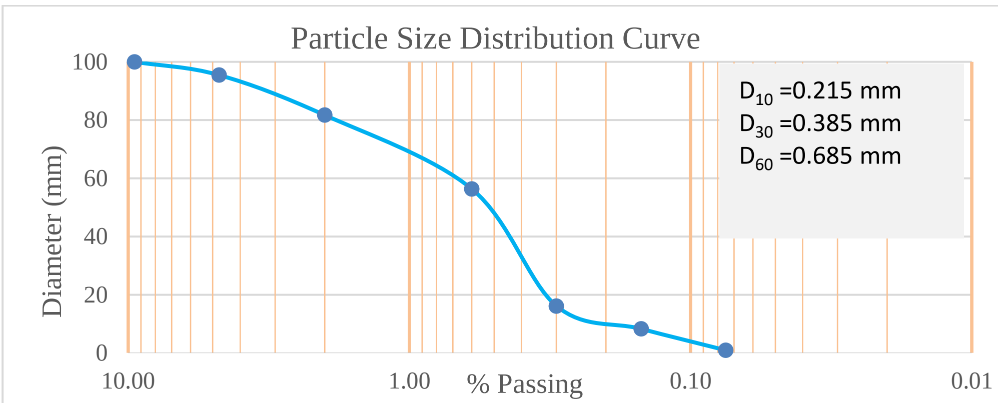


Fig. 2 Sand's grain size distribution.

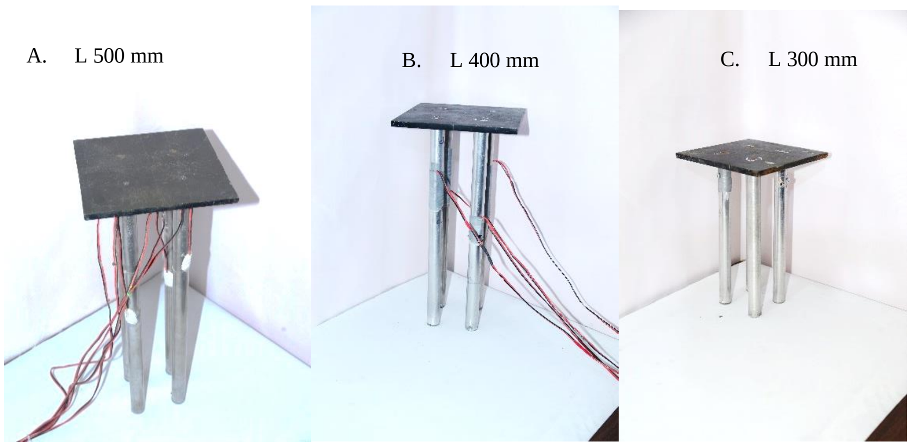
Table 1 – Physical characteristics of the sand under test.

Property	**Value**
Analysis of grain size	
Classification (USCS)*	SP
D_{10}	0.215 mm
D_{30}	0.385 mm
D_{60}	0.685 mm
C_c	1.01
C_u	3.19
G_s	2.564
Weights of dry units	
γd (max)	18.96 kN/m^3
γd (min)	15.41 kN/m^3
γd (test)	17.67 kN/m^3
Dr	70.73 %
Void ratio	
e_{max}	0.664
e_{min}	0.352
e_{test}	0.444
ϕ	39°

* USCS refers to Unified Soil Classification System

4.2 Piled Raft

The pile models in this study were constructed using aluminum hollow profiles with thicknesses of (1.10 and 1.30)mm and circular diameters of 19 and 25 mm. When L is the length of the pile and d is the outer width of the pile, the embedding ratio (depth to width) is equal to 12, 16, 20, 26. All tests maintain the distance between piles at 3xD, where s is the distance between piles. A flat surface steel with a thickness of 20 mm was also used to model the raft used in the test, as shown in Figure (3), representing the models used in this study. The size of the raft is (180 x 180 x 20) mm. Pile group (3 x 3) D 19 mm, (2 x 2) D 25 mm



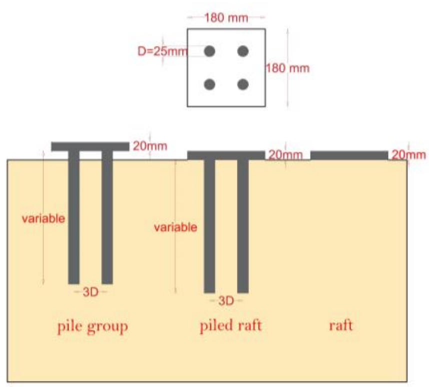
1. Raft (180x180mm), Diameter pile 25mm

2. Raft (180x180mm), Diameter pile 19mm

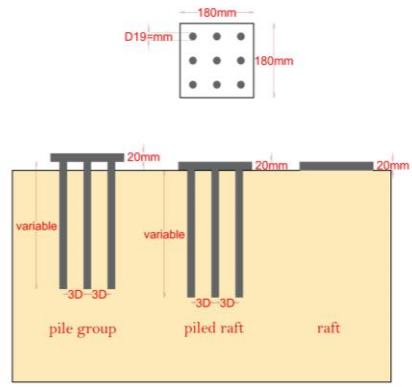
Fig. 3 represents the models used in this study.

4.2.1 Configurations of Pile Groups

In this investigation, pile group shapes that are symmetrical were chosen. The pile group prototypes employ two distinct pile arrangements. Groups (A) comprise piles (2x2) of diameter 25 mm and group (B) (3x3) of diameter 19 mm, as shown in the schematic diagram for the pile groups in Figure (4)



A.(2x2 Group) D=25mm



B. (3x3 Group) D=19mm

Fig. 4 Pile group arrangements used in the experimental tests.

5. Density proofing methods:

Using an electric vibrator for 15 seconds with a wooden plate to keep the sand particles from breaking was the ideal approach to determine the required density after a number of experiments to identify the best way to maintain the density and attain the relative density of 70 percent, as shown in Figure (5)**.** Yetimoglu et al. (1994) employed a similar technique.

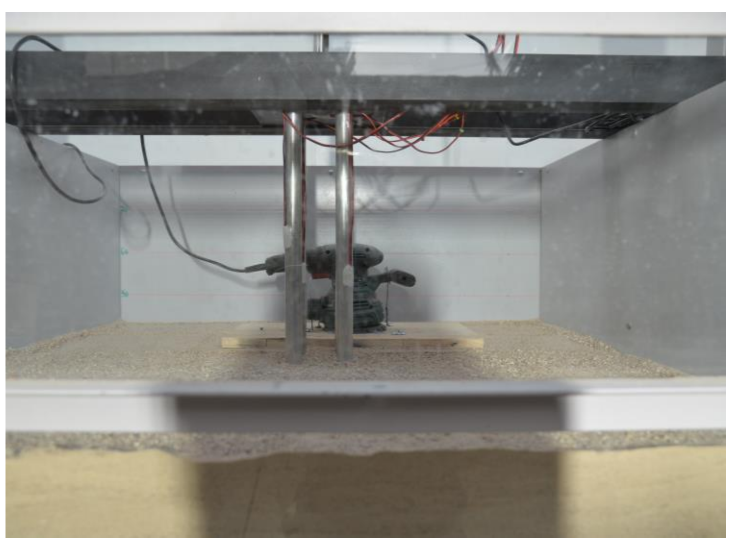


Fig. 5 Vibrating used in the technique.

6. Vertical load Application:

A mechanical jack was used to apply a vertical load. The test was continued, recording a continuous settlement of the piled raft under variable load incremental at 10 kN/min. The value of the applied load was read using a load cell, while the central settlement of the raft was measured using an LVDT of (LIN: ±0.1%) resolution, and the value of strain in piles was read using the PLX-DAQ_R2 PC by strain indicator. The above steps were repeated for each test. Figure (6) shows the piled-raft model ready to be tested.

Fig. 6 Piled raft model ready to be tested.

7. Results and Discussion:

After the practical experiment, the load-bearing capacity of the piles for the applied load and the settlement amount achieved in each group were known. Each pile has a specific cross-sectional area; the width of the columns (D) and the length (L) are different; the thickness of the raft is constant; and the spacing between the piles (3xD) is constant. The settlement at the midpoint against the vertical pressure applied at the center is plotted in the figures below.

Figures (7) and (8) show the behavior of the raft, the piles, and the piled raft when the modulation ratio (L/D) is (20, 26), respectively. Figure (9) also shows the behavior of changing the length of the piles at the embedding ratios 12, 16, and 20. As for the comparison between changing the diameter of the piles and their number with a constant length, its behavior was found, as illustrated in Figure (10).

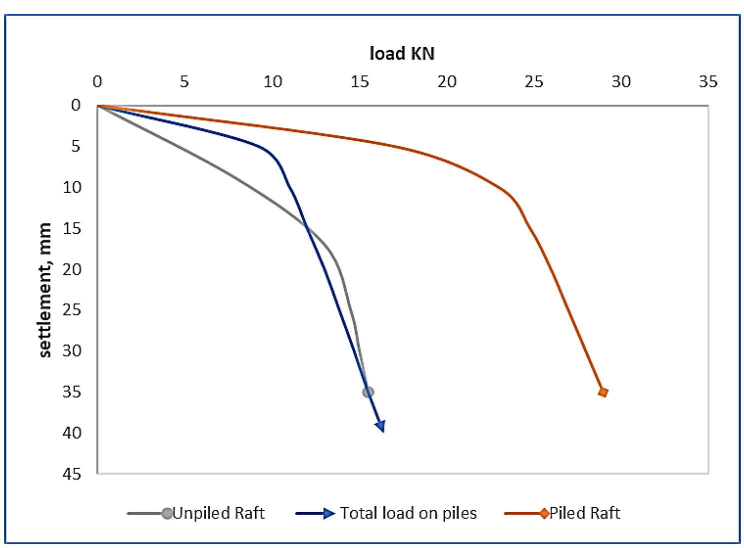


Fig. 7 Load – settlement curve for (2×2) unpiled raft, total on piles, piled raft (L=500, D=25) mm

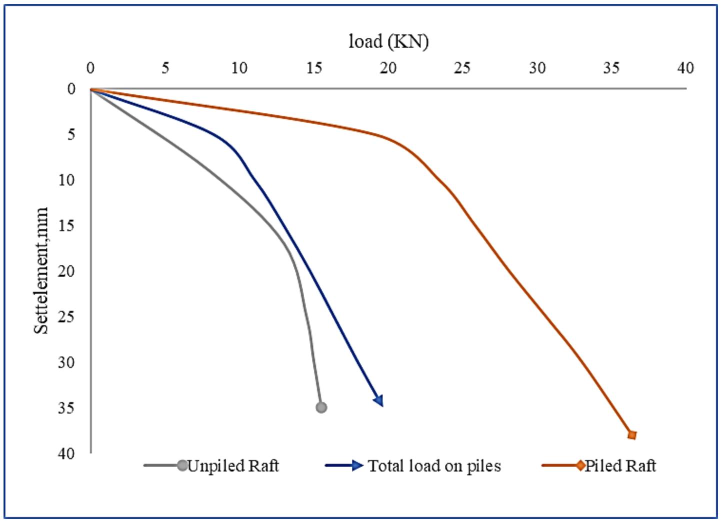


Fig. 8 Load – settlement curve for (3×3) unpiled raft, total on piles, piled raft (L=500, D=19) mm

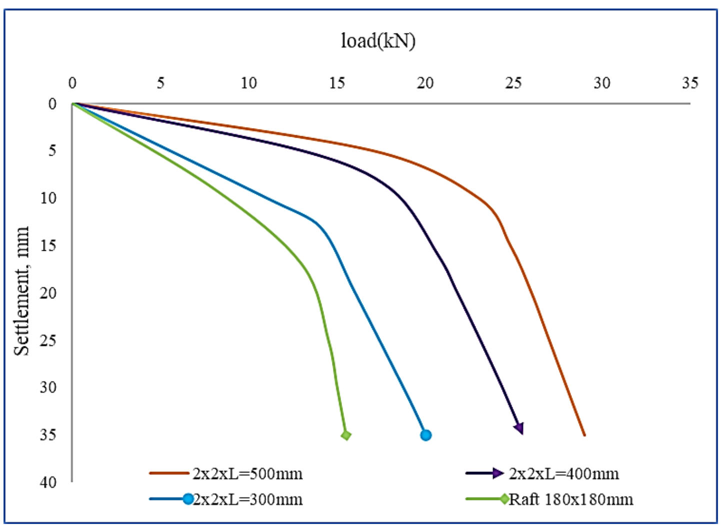


Fig. 9 Load – settlement curve for (2×2) raft, piled raft (L=500,400,300, D=25) mm

After studying the previous Figures (7) and (8), which represent the behavior of the raft and the behavior of the piles (2x2) with an embedding ratio (L/D) = 20. It was found that the piles reduced settlement by approximately 70%. When using the piled raft, the bearing capacity increases and decreases settlement. But when changing the diameter of the piles with the length constant, with the group (3x3) with the constant dimensions of the raft, and at the inclusion ratio (L/D) = 26, the settlement decrease ratio is 74%. But the bearing capacity increased by 10%. This shows that the smaller the diameter of the pile, the greater the penetration of the piles into the soil; thus, the Settlement increases, and the resistance in the piled raft decreases.

Figure (9), which represents the behavior of the piles with the raft, shows that when the length of the pile's changes, as the length of the piles grows and settlement falls, the bearing capacity rises.

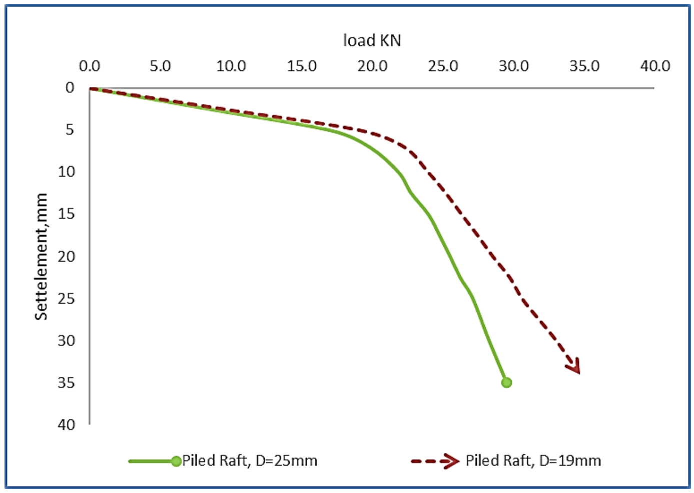


Fig. 10 Load-settlement curve for (3×3) with D=19mm, (2×2) with D=25mm, piled raft (raft 180×180) mm.

According to these figures (10), reducing the diameter of the piles while increasing the number of piles in the group improves the load-carrying capacity and reduces settlement by 74%.

8. Bearing capacity Ratio:

Piles are one of the ways to improve the soil, as they increase its resistance and reduce settlement. As shown in Figure (11), which shows the ratio of the bearing capacity to the length of the piles used

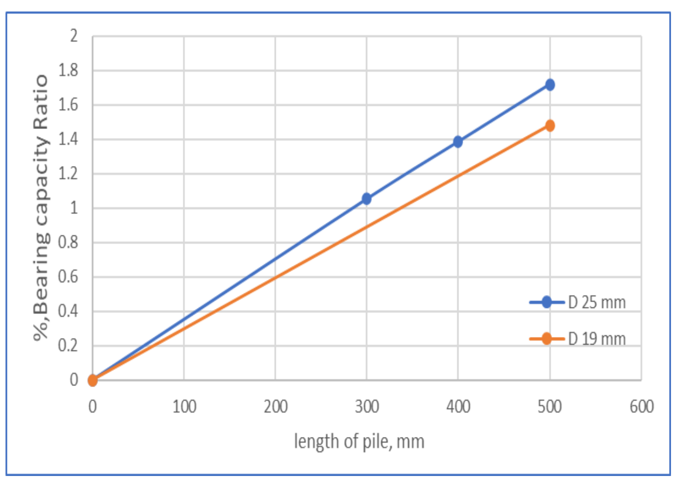


Fig. 11 Ratio of the load capacity to the length of the piles used

After studying Figure (11), it was found that when the piles' length and diameter increased, the foundation's ratio bearing capacity percentage increased.

9. Conclusions:

The primary findings of this study are derived from the experiments conducted as follow:

1- For the (2×2) group, the maximum difference in experimental settlement at the centre of the raft is 7.2 mm, as pile lengths increase from 300 to 500 mm.

2- The piled raft model's load-carrying capability rose by almost 87% when pile lengths went from 300 mm to 500 mm. This is because pile skin friction increases and the soil becomes stiffer in depth.
3- As the number of piles increased and their diameter fell in the group, the pile raft model's carrying capacity increased by around 10% and settlement was reduced by 74%.

References:

ASTM Committee D-18 on Soil and Rock. (2006). Standard test methods for minimum index density and unit weight of soils and calculation of relative density. *ASTM International*.

ASTM Committee D-18 on Soil and Rock. (2006). Standard test methods for specific gravity of soil solids by water pycnometer. *ASTM International*.

ASTM, D3080 /D3080M (2011). Standard test method for direct shear test of soils under consolidated drained conditions. *ASTM International*: *West Conshohocken, PA, USA.*

ASTM, D422-63 (2007). Standard test method for particle-size analysis of soils. *ASTM International*: *West Conshohocken, PA, USA.*

ASTM, D4253 (2000). Standard Test Methods for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table. *ASTM International*.

Basile, F. (2015). Non-linear analysis of vertically loaded piled rafts. *Computers and Geotechnics*, *63*, 73-82.

Butterfield, R., & Banerjee, P. K. (1971). The problem of pile group–pile cap interaction. *Geotechnique*, *21*(2), 135-142.

Mandolini, A., Di Laora, R., & Mascarucci, Y. (2013). Rational design of piled raft. *Procedia Engineering*, *57*, 45-52.

Poulos, H. G. (2001). Methods of analysis of piled raft foundations. *A Report Prepared on Behalf of Technical Committee TC18 of Piled Foundations*.

Sinha, A., & Hanna, A. M. (2017). 3D numerical model for piled raft foundation. *International Journal of Geomechanics*, *17*(2), 04016055.

Small, J. C., & Poulos, H. G. (2007). Nonlinear Analysis of Piled Raft Foundations. 40902(September 2017), 1–9. https://doi.org/10.1061/40902(221)14

Yetimoglu, T., Wu, J. T., & Saglamer, A. (1994). Bearing capacity of rectangular footings on geogrid-reinforced sand. *Journal of Geotechnical Engineering*, *120*(12), 2083-2099.