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EXTENDED ABSTRACT

Experimental Investigation of Load- Displacement Behavior of Enlarged Base Piles under Oblique Tension Loadings in Sandy Soil

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1. Introduction

One of the most used deep foundations is piles. The piles are tall members that are used to transfer the foundation loads from the weak layers of the soil to the ground at a deeper and stronger layer. In some structures, the piles may be exposed to uplift forces, including those subjected to extreme overturning moments, such as power towers or docks. During numerical modeling in relation to vertical pile under axial load, it was observed that the axial load-bearing capacity of the pile was reduced at the presence of lateral loading (Abdel-Rahman and Achmus, 2006). For the pile under load, the ultimate vertical load ratio (P_u) to the lateral loading (P_L) was greater than 1, with a maximum resistance to load times, when the load angle was 30 degrees. The ratio P_u/P_L was between 0.18 and 0.72, and for the angle of 60 degrees, P_u/P_L less than 0.18 ratio, the ratio value is maximized at 90 degrees (Chattopadhyay and Pise, 1986). Baki et al. (2013) reported that the optimal load bearing of the piles under tensile loading is achieved in rough piles in anchored sand. By changing the angle of application of the tensile loading from zero to 60 degrees relative to the vertical, the pile frictional resistance only turns to the side resistance with the lateral side of the earth, and both components contribute to the final capacity. The study of piles behavior under oblique tension loadings showed that tensile loads are depending on the buried length ratio (L/d), the ratio of the enlarged base diameter to the pile diameter (B/d), the loading angle (α) and the relative density of the soil around the pile (D_r). The ultimate resistance of pile increases with increasing the ratios of (L/d), (B/d) and soil density. The analysis of the results showed that the critical angle (α_{cr}) which the pile reaches its maximum tensile strength depends on the ratio (L/d), (B/d) and soil density (Mandal et al., 2002). The tensile load capacity of the buried enlarged base pile in the sand was studied using physical modeling tests. Analysis of the results showed that the uplift tensile capacity of pile increases significantly with increasing the ratio of buried length to pile diameter more than two and also, increasing the relative density of the sand. The results also showed that the increase in the pile diameter leads to the tensile load of the pile (Nazir et al., 2015). A series of laboratory studies and numerical analysis of finite element were performed to evaluate the efficiency of enlarged base piles with increasing cross-section at different levels of the pile length in order to improve its uplift capacity. The results of the study showed that with increasing the cross-section of the pile at different levels, the tensile capacity of piles increased, and the amount of sand deformation around the pile decreased (Moayedi and Mosallanezhad, 2017).

In this paper, the tensile performance of circular piles on sand beds was investigated by small-scale laboratory experiments under oblique forces. Various parameters of simple and enlarged base pile models were evaluated, including the length of the pile (L), the diameter of the pile (d), the diameter of the enlarged base pile (B) and the loading angle (α).

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2. Methodology

Fig. (1-a) shows the loading apparatus, which was made at Bu-Ali Sina University. The 60*60*60cm soil chamber is located on the bottom of the frame. In Fig. (1-b) horizontal and vertical displacement gauges have been shown, and in Fig. (1-c) the enlarged base model piles are shown. The model piles are kept completely vertical with wires, until the end of sand raining in the soil chamber. After pouring the soil around the pile, the soil surface is completely flattened with a steel ruler. In the next step, the pile is placed on the surface of the soil at the desired location. Two LVDTs are provided with the help of magnetic clips in the desired locations, and their tips are tangent to the surface of the pile cap. After adjusting the device's hydraulic pressure and loading speed (displacement rate), running the software for recording data on the computer, introducing the calibration file into the software, and zeroing the number and electronic displacement, by turning on the electric motor, the test begins and the corresponding values of the force transfers will be saved by computer. The type of soil used is a dry fine silica sand. This sand is a poorly degraded sand and classified according to the unified classification system as SP ($C_{u=}$ 1.44 and C_c=1.16).

(a) (b) (c)

Fig. 1. Photoghraphs of: a) Modeling apparatus, b) Horizontal and vertical LVDTs, c) Enlarged base pile model

3. Results and discussion

In order to study the tensile behavior of different types of simple and enlarged base piles exposed to different loading, physical model experiments were carried out and load-displacement responses were presented for various parameters. The typical results of load-displacement response (horizontal and axial displacement) of pile models are presented in Figure 2 in terms of different parameters. To determine the final load of pile models, the maximum load method and the constant slope were used. The tensile load values verses displacement of pile models of 40-2 and 40-2-5 (pile length=40 cm, pile diameter=2 cm, and enlarged base pile diameter=5 cm) are shown in Figure 2 for different angles of oblique loading. The ultimate load of the pile for different loading angles (α =0˚, vertical loading, 30˚, 60˚, and 90˚, lateral loading) are 211, 191, 201, and 166 N, respectively for 40-2 model and 393, 211, 232, and 176 N for 40-2-5 model.

Comparison of the tensile strength results shows that for all loading angles, with increasing diameter of the pile at its end (base), tensile load values were significantly increased and the amount of displacement needed for resistance mobilization was slightly increased.

3.1. Effect of the ratio of length to diameter of piles

The results analysis showed that for all loading angles, the ultimate load increases with an increase in L/d ratio and leads to the improvement of tensile strength up to 19 times for a change of 4 times of L/d values, depending on different parameters. For the oblique angles of loading, the use of larger-length piles has more efficiency than the vertical loading.

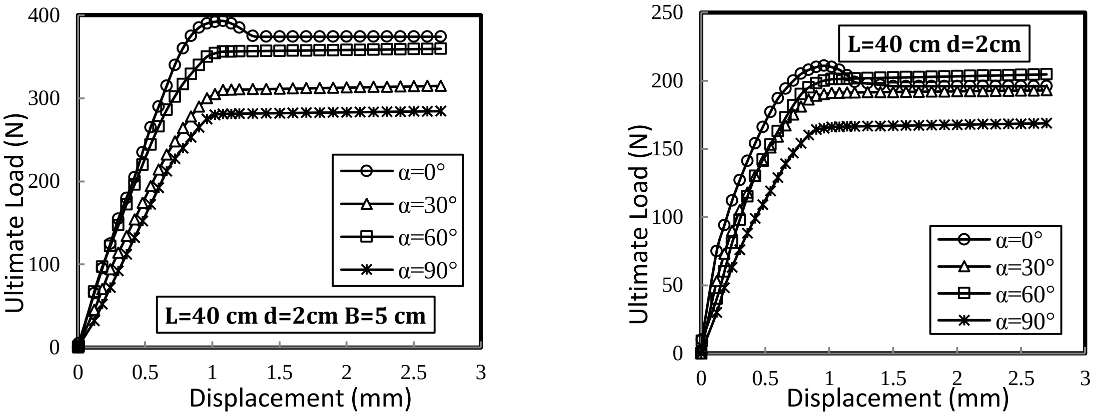

Fig. 2. Load- axial displacement diagram of the piles (d=2 cm, B=5 cm, and L=40 cm)

3.2. Effect of the ratio of enlarged base diameter to pile diameter

Based on the analysis of test results, it was observed that the tensile capacity increases with increasing diameter of the end of a simple pile (enlarged base of the pile), for all loading angles. The maximum improvement was obtained in the uplift case (loading with a zero angle). Also, the comparison of the results showed that for the same values of *B/d* ratio, with the increasing in the diameter pile from 1 to 2 times, the improvement values of tensile capacity decreased.

4. Conclusions

From this experimental study, the following important conclusions are obtained:

1. In all experimental studies, the ultimate loading of piles was due to soil failure, and rupture of the pile material is not occurred. The lateral failure of the soil around the pile is faster than its axial failure, and the most load-bearing capacity of the pile is generally derived from axial bearing capacity, plus a small amount of mobilized side resistance of the soil around the pile.
2. The displacement corresponding to the pile failure was about 5% -6% of pile diameter for simple and enlarged base piles.
3. With increasing tensile loading angle from zero to 90 degrees, tensile load values were reduced; for pile models, the minimum load was obtained for lateral loading (α=90°) and the maximum load was observed in the vertical position (α=0°).
4. For both conventional and enlarged base piles with a length to diameter ratio of 20, the angle at which the maximum bearing capacity of the pile under oblique loading is 60˚.
5. The comparison of the physical modeling results of pile models with those of theoretical relationships for validating the results of the research showed that the tensile capacities obtained from the experimental models and theoretical relationships have a relatively good and acceptable correlation, which indicates the accuracy of the modeling and its results.

5. References

Abdel-Rahman K, Achmus M, "Numerical Modelling of the Combined Axial and Lateral Loading of Vertical Piles", Institute of Soil Mechanics, Foundation Engineering and Waterpower Engineering, University of Hannover, Germany, 2006.

Baki B, Ahmet D, Mustafa, L, Bahadır O, Talha S, "An Investigation of Uplift Behavior of Vertical Piles Embedded in Reinforced Sand under Inclined Loads", 2nd International Balkans Conference on Challenges of Civil Engineering, BCCCE, 23-25 May, Epoka University, Tirana, Albania, 2013.

Chattopadhyay BC, Pise PJ, "Uplift Capacity of Piles in Sand, Journal of Geotechnical Engineering", 1986,112, 9, 888-903.

Mandal AK, Patra NR, Pise PJ, "Behaviour of Enlarged Base Piles in Sand under Oblique Pullout Loads", Indian Geotechnical Journal, 2002, 32 (4), 382-394.

Moayedi H, Mosallanezhad M, "Uplift resistance of belled and multi-belled piles in loose sand", Measurement, 2017, 109, 346-353.

Nazir R, Moayedi H, Pratikso A, Mosallanezhad M, "The uplift load capacity of an enlarged base pier embedded in dry sand", Arab J Geosci., 2015, 8, 7285-7296.