Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 54(11) (2023) 895-898
DOI: 10.22060/ceej.2022.21312.7685

Experimental investigation of flexible pile behavior under lateral cyclic and post cyclic loading in sandy soil

R. Owji, Gh. Habibagahi, M. Veiskarami *

School of Engineering, Shiraz University, Shiraz, Iran

ABSTRACT: Lateral behavior of piles is one of the most challenging design issues. While previous studies have mainly focused on rigid piles, a little attention has been paid to flexible ones. In this study, the behavior of flexible piles under lateral cyclic loading is investigated by experimental tests. For this purpose, a device was designed and commissioned for cyclic loading tests which can generate different types of sinusoidal loads. Measurement was made on the load and displacements during the cyclic loading with a loadcell and Linear Variable Differential Transducer (LVDT). The role of key parameters in cyclic loading including such as the frequency, loading interval, number of cycles, cyclic loading direction and also soil density were investigated. Moreover, post-cyclic loading tests were performed to evaluate piles lateral bearing capacity. Experimental observations showed that under one-way and two-way loadings, the stiffness gradually increases during 100 cycles of loading while under one-way without a complete unloading process, the stiffness starts to decrease and then remains constant. Increasing the frequency from 0.1Hz to 0.2Hz has shown a significant effect in increasing the lateral cyclic resistance. Under one-way loading, the residual force at the pile head increases with increasing the cyclic loading interval.

Review History:

Received: Apr. 19, 2022
Revised: Jul. 06, 2022
Accepted: Jul. 26, 2022
Available Online: Aug. 09, 2022

Keywords:

Pile
Cyclic loading
Lateral bearing capacity
Post cyclic
Frequency

1- Introduction.

Piles supporting tall buildings, bridges, and wind turbines are often subjected to lateral cyclic loads including wind, wave, and earthquake [1]. Lateral cyclic loads cause to increase of pile head displacements, stiffness reduction of soil, and increase of pore water pressure [2]. The design methods for piles are valid and reliable when they are investigated in the field or in a laboratory. Considering the limitations of test facilities and high costs for large-scale tests, conducting tests on small-scale piles are necessary. API p-y curves are conventional method for designing piles under lateral loading in which cyclic behavior of pile predicts by multiplying the static p-y curve by a correction factor of 0.9 [3]. Arshad and O'Kelly [4] examined the effects of amplitude, frequency, and shape of loading on the response of rigid pile. Comparisons between the symmetric and asymmetric two-way loading showed that asymmetric two-way loading leads to higher pile head rotation. Imam et al., [5] found that the behavior of piles under lateral cyclic loading is significantly influenced by the elastic modulus and section geometry of the pile. The most variations in soil stiffness were observed during the first 30 cycles and after 100 cycles of loading, no increases occurred in lateral force. Review of previous studies shows that the effects of cyclic loading direction on pile response are not fully understood. Therefore, this study aims to evaluate the lateral behavior of flexible pile under cyclic and post-cyclic loading with different loading direction and frequencies.

2- Materials and methods

The soil used in this study was dry silica sand which is classified as a poorly graded sand (SP). The uniformity coefficient (C_u) and coefficient of gradation (C_c) are 1.67 and 1.2, respectively. Shear strength parameters were determined using the direct shear test, where an inter-particle friction angle and cohesion were 35 degrees and zero, respectively.

In this research, circular steel pile with an outer diameter of 25mm and thickness of 0.6mm were used for loading tests. Moreover, the embedded length of pile was considered 550 mm. Soil box with the size of 900×600×300 mm^3 (height×length×width) was sufficiently large to decrease any boundary effects. The distance between the model pile and wall box should be larger than 10D to avoid side effects [6]. Moreover, a thickness of 5mm was considered as a wall thickness to minimize lateral deflection of soil box during lateral loading tests on the model pile. In order to perform cyclic loading tests with different amplitudes and frequencies, a new displacement-controlled loading device was designed and constructed. This loading system is capable of applying cyclic, post-cyclic, and monotonic loading. A hinged connection was inserted between loading shaft

*Corresponding author's email: mveiskarami@shirazu.ac.ir

Fig. 1. Experimental set-up for lateral cyclic loading test

and pile head, allow the pile head to rotate freely. Lateral displacement at pile head was measured using linear variable differential transformer (LVDT) and loadcell with capacity of 1.5 kN was employed to measure lateral force (Figure 1). Dry sand was compacted at layers with thickness of 50mm until the required density was achieved. Properties of cyclic loading including loading direction, frequency, amplitude, and number of cycles were considered in the test program.

3- Results and discussion

In this study, the lateral stiffness of the pile-soil system was described by a cyclic secant stiffness. Figure 2 shows influence of cyclic loading directions on lateral response of pile embedded in sand with relative density of 40%. For two-way cyclic loading, stiffness decreased during 10 first cycles and then gradually increased. One-way loading has a considerable effect on lateral capacity and after 10 cycles of loading, lateral force reaches to 90 N. Under two-way loading, the densification of sand particles around the pile leads to an increase of about 25% in the lateral capacity. Residual force induced by cyclic loading can be observed in post-cyclic loading results. These results confirm that the ultimate lateral capacity of the pile under two-way loading is higher compared to one-way loading.

4- Conclusions

In this study, lateral behavior of pile under cyclic and post-cyclic loading was investigated by constructing a new loading device. Factors affecting the cyclic loading including frequency, amplitude, and loading direction were comprehensively examined. The results show that under two-way loading, cyclic secant stiffness increases during 100 cycles of loading while under one-way without complete unloading, stiffness remains constant with an increase of cycles. Increase in frequency from 0.1 to 0.2 Hz has a considerable effect on lateral bearing capacity. Moreover, under frequency of 0.05 Hz, residual force induced by cyclic

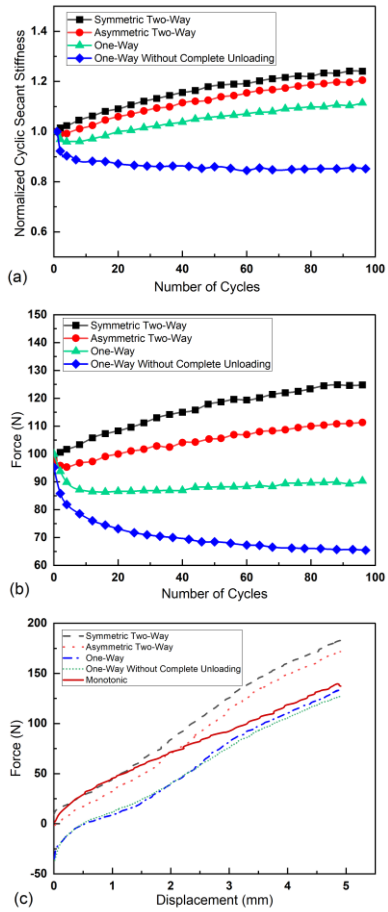

Fig. 2. Influence of cyclic loading on lateral response of pile: a) variation of stiffness, b) variation of pile head force, c) post-cyclic loading

loading leads to reduce of lateral capacity. Under one-way loading, an increase in loading amplitude causes to increase in ultimate lateral capacity and residual force.

References

[1] S. Basack, Design recommendations for pile subjected to cyclic load, Marine Georesources & Geotechnology, 33(4) (2015) 356-360.

[2] A. Puech, J. Garnier, Design of piles under cyclic loading: SOLCYP recommendations, John Wiley & Sons, 2017.

[3] R. Api, Recommended practice for planning, designing and constructing fixed offshore platforms-working stress design, API RP A, 2 (2000).

[4] M. Arshad, B.C. O'Kelly, Development of a rig to study model pile behaviour under repeating lateral loads, International Journal of Physical Modelling in Geotechnics, 14(3) (2014) 54-66.

[5] A. Faresghoshooni, S. Imam, A. Mahmoodi, Model Testing on the Effects of Section Geometry and Stiffness on the Cyclic Lateral Behavior of Piles in Loose Sand, International Journal of Civil Engineering, 19(5) (2021) 563-581.

[6] M. Khari, K.A. Kassim, A. Adnan, An experimental study on pile spacing effects under lateral loading in sand, The Scientific World Journal, 2013 (2013).

HOW TO CITE THIS ARTICLE

R. Owji, Gh. Habibagahi, M. Veiskarami, Experimental investigation of flexible pile behavior under lateral cyclic and post cyclic loading in sandy soil, Amirkabir J. Civil Eng., 54(11) (2023) 895-898.

DOI: 10.22060/ceej.2022.21312.7685