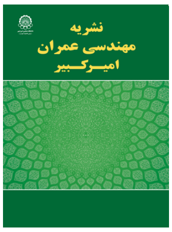

Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 53(7) (2021) 605-608
DOI: 10.22060/ceej.2020.17487.6580

Parametric Study of Kinematic Interaction in Pile-Cohesive Soil under Dynamic Loads

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ABSTRACT: Pile foundations are widely used to ensure the stability of structures subjected to seismic excitation. Numerous structures and foundations in soil-pile-structure systems have been destroyed during the occurrence of earthquakes. Because of the complexities involved in soil-pile interaction problems and the lack of precise methods, it is necessary to use numerical methods for analyzing soil-pile interaction problems. Several factors are affecting the dynamic response of a pile in the soil-pile system. These factors can be divided into three main categories: geometrical factors, material properties, and load characteristics. Studying the effects and importance of these factors in the response of the pile will help geotechnical engineers to optimize their design. In this research, three-dimensional modeling has been developed using the FLAC3D computer program, and the effects of various soil and pile properties on the dynamic behavior of a single pile in clayey soils are evaluated. One of the most important subjects in the numerical modeling of soil-pile system dynamic response is the constitutive model considered for the soil. This strongly affects the accuracy of results. In this study, a softening model has been used for the behavior of the soil under dynamic loads. Sinusoidal harmonic loading has been applied to the model base as the acceleration time history, and the variations of bending moments, shear forces, and displacements along the pile are obtained for all analyses carried out in this study. The results showed that the kinematic interaction coefficient depends on the loading characteristics and in the high frequencies head pile response was lower than the free field.

Review History:

Received: Dec. 08, 2019
Revised: Feb. 02, 2020
Accepted: May. 13, 2020
Available Online: May. 28, 2020

Keywords:

Dynamic response
Single pile
Clayey soil
Soil-pile interaction
Numerical analysis

1. INTRODUCTION

In recent years, many studies have been carried out on the dynamic response of piles and affecting parameters on it; despite extensive research on this topic, predicting the behavior of piles during an earthquake is still a contentious issue in the field of geotechnical engineering.

Appropriate assessment of the seismic behavior of deep foundations requires paying attention to the effects of the kinematic interaction of the soil-foundation system. Three-dimensional numerical modeling is one of the most powerful tools for nonlinear analysis of the dynamic interaction of the soil-pile system.

A review of the previous studies reveals that they have some limitations. The most important limitations of these studies are the two-dimensional modeling, the focus on superstructure response, the assumption of linear behavior for soil, and the use of simple Winkler-based models for soil-pile interaction. The main purpose of this study is the investigation of the dynamic response of a single pile embedded in cohesive soil under dynamic loading. To this end, the behavior of a single pile under dynamic loading in the framework of fully nonlinear three-dimensional numerical analyses has been evaluated.

2. METHODOLOGY

In the present study, to ensure the accuracy of numerical modeling, the soil-pile system studied by Maheshwari *et al.* (2004) has been simulated using FLAC3D software and the obtained results were compared with those given by the referred study according to "Fig. 1".

To select the appropriate dimensions for the model in dynamic analysis, cubic models with dimensions of 12, 16, 20, and 24 meters have been developed and subjected to dynamic loading from the bottom of the model. Based on the results of this sensitivity analysis, 20 meters were selected as dimensions of the models in the X, Y, and Z directions. The concrete single piles were simulated using flexural elements and were placed in the center of the model.

The soil has a softening behavior in the range of medium and large strains. So, the nonlinear constitutive model was used to obtain more accuracy in the modeling of the soil-pile system dynamic behavior. Also, Rayleigh damping was used for modeling soil energy dissipation during cycles of load application. A schematic view of the created model is shown in "Fig. 2".

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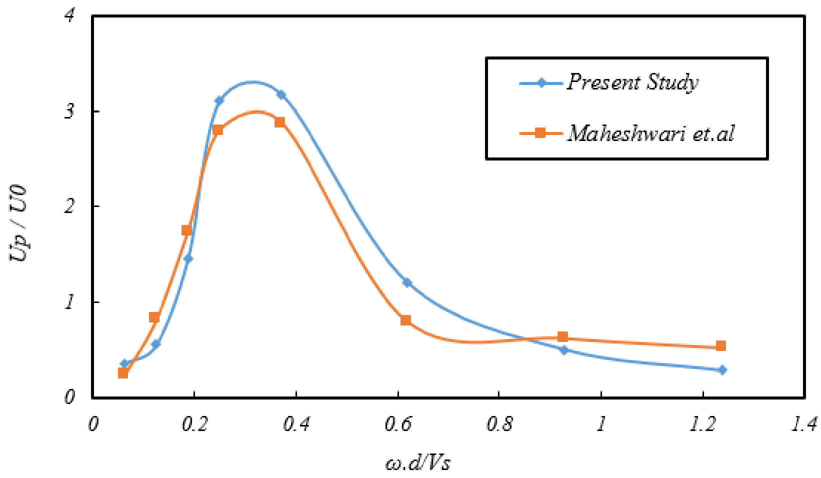

Fig. 1. Response of pile head in dynamic loading

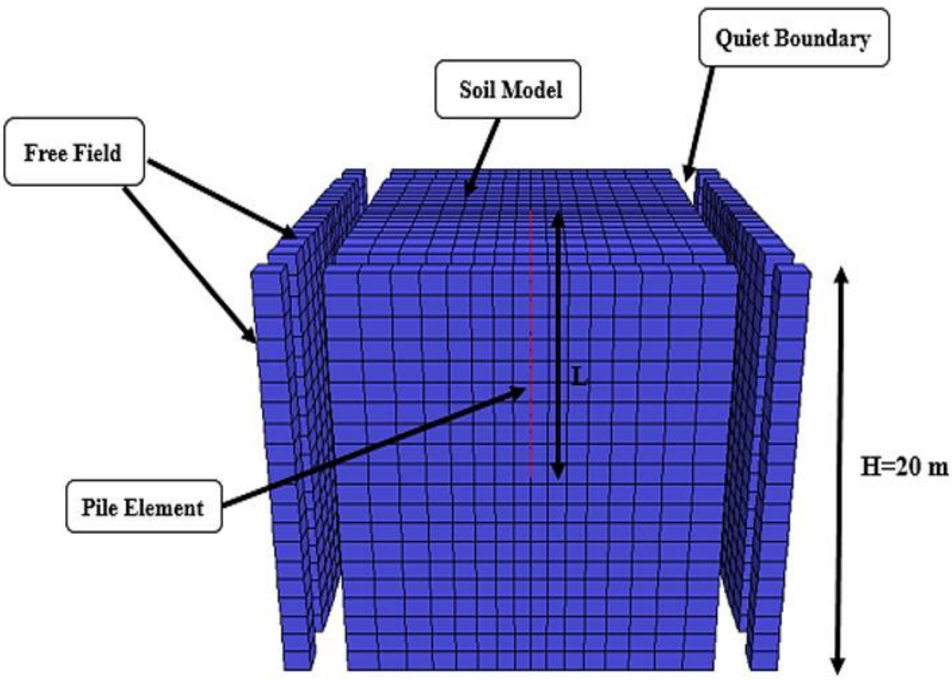

Fig. 2. Schematic view of the created model

3. RESULTS AND DISCUSSION

To investigate the effect of various parameters like loading frequency and amplitude, diameter and length of the pile, and soil stiffness, on the dynamic response of the single pile in clayey soil, a set of dynamic analyses have been conducted in the time domain. In each analysis, the maximum bending moments and displacements induced along with the pile by dynamic loading have been studied.

The contour diagram of the shear strain rates at the end of dynamic loading, according to "Fig. 3", illustrates that the highest rate of shear strain occurred at the bottom of the model, and the end of the pile. The soil in those areas had the highest displacement values.

The distribution of bending moments along the pile indicates that that the maximum bending moments occur at the top and in the middle of the single piles. Bending moments at the tip of the pile reached approximately zero. Also, based on the parametric study, it can be concluded that increasing stiffness of the soil causes an increase in bending moment and a decrease in pile head displacements induced due to dynamic loading. The results showed that pile head displacement increases as the dynamic loading time increases.

Another study conducted in this study is to evaluate the responses pile in the time domain. As can be seen in "Fig. 4", the results show that pile head displacement increases as the dynamic loading time increases.

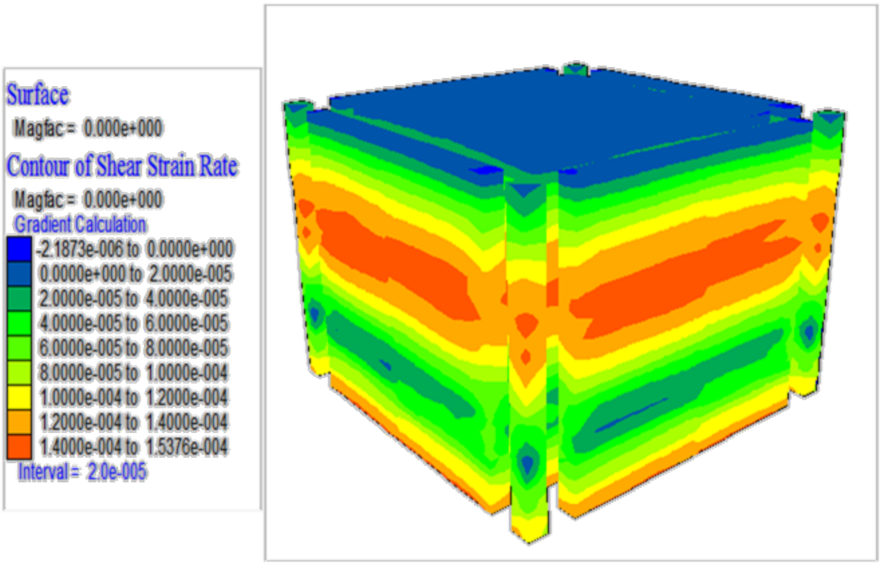

Fig. 3. Contour of shear strain rate after dynamic loading

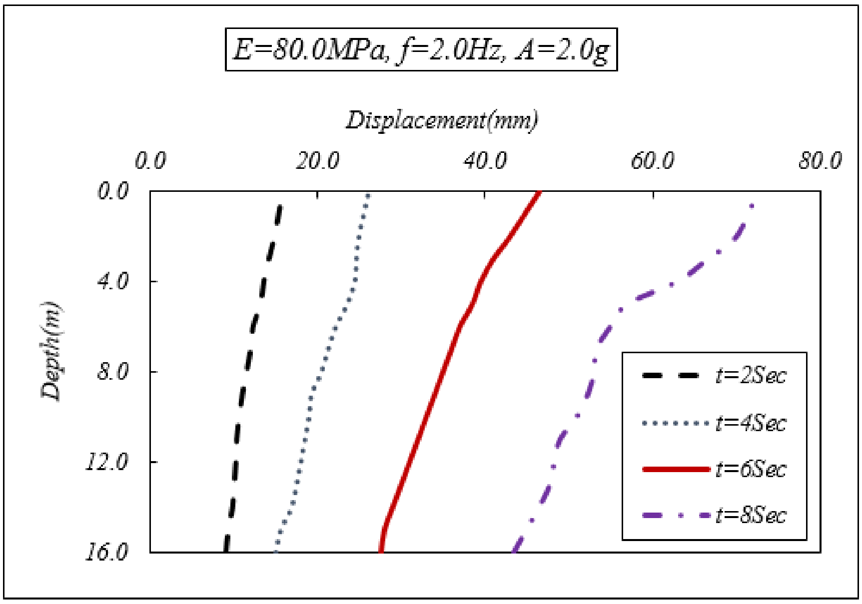

Fig. 4. Displacement along the pile in dynamic loading for 1m diameter pile

4. CONCLUSION

In the present study, the dynamic behavior of single piles embedded in the cohesive soil was studied in the time domain. The models were subjected to sinusoidal harmonic loading and the response of the pile and affecting parameters on it were investigated. Based on the analyses conducted in this study, the following results have been concluded:

1. As the diameter of the pile increased, bending moments and displacements induced along with the pile by dynamic loading, increased significantly and decreased, respectively.

2. Increasing the stiffness of the cohesive soil layer caused an increase in the bending moment and a decrease in displacements induced in the pile.

3. Increasing the length of the pile caused an increase in displacements induced along with the pile. It should be noted that in many practical cases, increasing the length of the pile to achieve a layer with sufficient strength is inevitable.

4. The value of the kinematic interaction coefficient depends on the loading characteristics. Increasing the diameter of the pile has also reduced the value of the kinematic interaction coefficient, and for all diameters, this coefficient was less than 1.0. This means that equating foundation displacement with free field motion is conservative.

5. At high frequencies, it was perceived that the response of the pile head response is less than the free field response. In other words, the free field had more permanent displacements

than the pile head.

6. Under dynamic loading, the highest shear strains were induced at the bottom of the model and the end of the pile.

7. Pile length was the most affecting parameter among the studied factors on pile bending moments. Therefore, it is necessary to pay more attention to select the pile length in the geotechnical design of piles.

REFERENCES

[1] Anandarajah, J. Zhang, Simplified finite element modeling of nonlinear dynamic pile-soil interaction, Retrieved February, 10 (2000) 2005.

[2] Y. Cai, P. Gould, C. Desai, Nonlinear analysis of 3D seismic interaction of soil–pile–structure systems and application, Engineering Structures, 22(2) (2000) 191-199.

[3] B.K. Maheshwari, K.Z. Truman, M.H.E. Naggar, P.L. Gould, Three-dimensional finite element nonlinear dynamic analysis of pile groups for lateral transient and seismic excitations, Canadian Geotechnical Journal, 41(1) (2004) 118-133.

[4] F. Dezi, S. Carbonari, G. Leoni, Kinematic bending moments in pile foundations, Soil Dynamics and Earthquake Engineering, 30(3) (2010) 119-132.

[5] S. Sica, G. Mylonakis, A.L. Simonelli, Transient kinematic pile bending in two-layer soil, Soil Dynamics and Earthquake Engineering, 31(7) (2011) 891-905.

[6] C. Tsai, D. Park, C. W. Chen, Selection of the optimal frequencies of viscous damping formulation in nonlinear time-domain site response analysis, Soil Dynamics and Earthquake Engineering, 67 (2014) 353-358.

HOW TO CITE THIS ARTICLE

M.M. Ahmadi, M.J. Mashinchian, S. Hadei, Parametric Study of Kinematic Interaction in Pile-Cohesive Soil under Dynamic Loads , Amirkabir J. Civil Eng., 53(7) (2021) 605-608.

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