Finite Element Analysis on Pile-Soil Interaction under Wave Cyclic Load

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Abstract

A 2D finite element model to establish for study dynamic response of soil around pile under wave load. Using simplified calculation method for wave forces acting and Selection of master-slave contact simulation of pile - soil contact - separation effect of Contact area in the process of the whole power. Results show form the finite element analysis,Soil deformation biggest in the contact area of soil and pile under wave cyclic load, The soil deformation gradually smaller with the increase of soil depth. To obtain a dynamic response formula of soil with the increase of soil depth under wave cyclic load by the finite element simulation. The formula provides reference for the design of the wharf pile foundation under wave cyclic load.

Keywords

Dynamic Response; Cyclic Load; Finite Element Simulation.

1. Introduction

The dynamic response of a pile foundation under wave load dock is always the key of ocean engineering facilities design and construction technical issues Mostafaye [1] used the power p - y curve and t - z curve to simulate the pile soil interaction, the finite element method to calculate the dynamic response of a pile group under wave loading. Tianjin university shu-wang yan combined with soft clay strength degradation law and finite element method, analyzes the wave under circulating load semi-circular breakwater foundation stability and foundation reinforcement scheme is effective. Liu Run using three dimensional finite element analysis method, considering the deformation of pile body geometry nonlinear characteristic, has carried on the stability of the free standing to practical engineering simulation. Linear and nonlinear algorithm is studied in the differences of the results, and the inclination of pile, free standing length and the function of the pile top horizontal load condition, this paper compares and analyzes summarizes the regularity. The research results show that the calculated results of linear elastic algorithm be dangerous, inclination of pile, free standing length and the size of the horizontal load on the stability of the free standing all have great influence. Zhou jian, Gong Xiaonan [8] on normal consolidated saturated soft clay in Hangzhou stress control in the cyclic triaxial test, from the perspective of strain softening of soil under the cyclic load is studied. By studying different cyclic stress ratio under different frequency, overconsolidation ratio, different axial periodic strain softening of softening of soil are analyzed, at the same time established a reasonable mathematical model of the soil reflect the strain softening and the parameters were determined.

Based on the finite element method (fem), the first wave cycle for a long time to simplify the dynamic load calculation, pile foundation and soil around the Mohr - Coulomb failure criteria of ideal elastic-plastic model, selection of pile - soil master-slave contact way to simulate the dynamic process of contact interface area - separation effect, and then according to the simulation of this model, study on dynamic response characteristics of pile soil under wave load.

2. Establishment of the model

2.1 The selection of model parameters.

Using the large-scale finite element analysis software ABAQUS to the dynamic response of a pile foundation under wave load was simulated. Finite element model as shown in figure 3-6, large diameter concrete pipe pile structure of 48 m high. The grave was deeply 35 m, pile diameter of 1 m, Take 2 x 1011 elastic modulus, Poisson's ratio of 0.3, density of 7800 kg/m^3.The foundation soil model parameters as shown in table 1.

Table 1 the model parameters of foundation soil

Soil	H/m	c/kPa	φ/(°)	E/MPa	ν
sludge	0−2	10.5	16	20	0.35
mucky clay	2−5	9.1	16.1	5	0.4
silty clay	5−15	9.1	21.0	10	0.35
silty-fine sand	15−26	5.4	35.8	15	0.31
fine sand	26−40	4.2	32.1	18	0.37

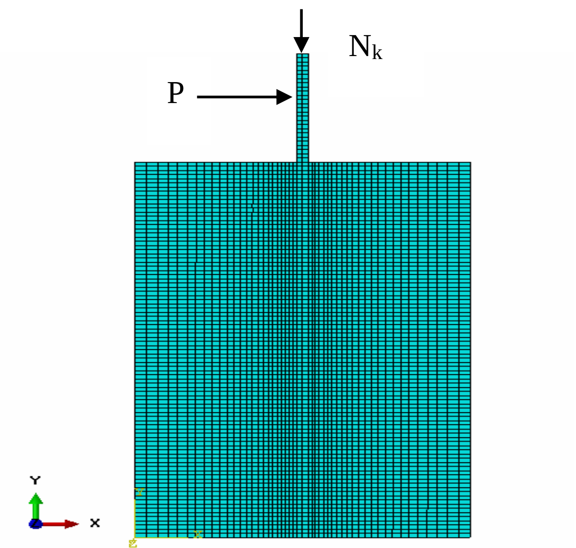


Fig. 1 Dynamic coupling analysis in 2D elastic-plasticmodel

2.2 The selection of model parameters

Under the action of wave load and cyclic loading, Friction between the outside wall of piles and soil of interaction of soil and pile bottom and the bottom of pile foundation of the overall stability and bearing effect plays a vital role, In order to be able to reflect the interaction between pile and soft soil system in the whole process of dynamic motion on the interface area open closure effect, Need to be established in the region of the pipe pile in contact with the soil master-slave contact area, considering the elastic modulus of pile structure is more than the elastic modulus of soil mass, Specify pipe pile interface is mainly on the interface structure, soil on the contact surface from the contact surface.

2.3 The simplified calculation of wave forces

The effect of wave load form mostly to impact load is described, The waves reach the diving area (water depth shallow),The wavelength decreases, and amplitude increases. When the depth of the water continues to fall, the waves will occur gradually broken. The waves in the process of broken release large amounts of energy. So, when crushing waves building will produce a great impact, which in turn affect building structure safety. The seaport hydrology specification JTJ 213-213[40] the calculation method of wave force is calculated. The bottom surface of the wave forces acting on the cylinder height above the z by inertial force component PI and velocity component of the PD of two parts:

$$P = P_D + P_I \tag{1}$$

$$P_D = \frac{1}{2}\frac{\gamma}{g} C_D D u|u| \tag{2}$$

$$P_I = \frac{\gamma}{g} C_M A \frac{\partial u}{\partial t} \tag{3}$$

$$\frac{\partial u}{\partial t} = -\frac{2\pi^2 H}{T^2}\frac{ch\frac{2\pi z}{L}}{sh\frac{2\pi d}{L}}\sin\ \omega t \tag{4}$$

$$u = \frac{\pi H}{T}\frac{ch\frac{2\pi z}{L}}{sh\frac{2\pi d}{L}}\cos\omega t \tag{5}$$

P_I - wave force of inertia force component（kn/m）;

P_D-- The speed of the wave forces acting on the component（kn/m）;

D--The diameter of the body (m);

A-- Cylinder area（m2）;

C_D-- Speed force coefficient, the circular section 1.2;

C_M-- Inertia force coefficient, for circular cross section 2.0;

u , Cu/Ct—Water points respectively the level of the orbital motion velocity (m/s) and the horizontal acceleration（m/s2）;

T--time（s）;

Due to the formula (1) - (5) is considered the wave force along the depth change, Also consider the periodic wave force,In ABAQUS software simulation, therefore, need to certain simplification of wave force, the depth of 9.33 m average wave action area is divided into 9 section contour area, In order to consider the change of the wave force along the depth, and then by calculating available input function of the wave forces acting on each layer, the first layer of wave force changing with time curve is shown in figure 2,P wave forces along the depth of the change of z as shown in figure 3, H for arbitrary phase wave in the height above the surface.

Table 2 The wave force function with different depth of pile

layer	Diameter(m)	The wave force input function
1	0-1	P=19.515cos ωt -665.26sin ωt
2	1-2	P=27.074cos ωt -783.58sin ωt
3	2-3	P=47.809cos ωt -1041.27sin ωt
4	3-4	P=97.127cos ωt -1484.15sin ωt
5	4-5	P=211.676cos ωt -2191sin ωt
6	5-6	P=476.57cos ωt -3287.5sin ωt
7	6-7	P=1088.6cos ωt -4968.7sin ωt
8	7-8	P=2502.7cos ωt -7533.7sin ωt
9	8-9	P=5769.4cos ωt -114387sin ωt

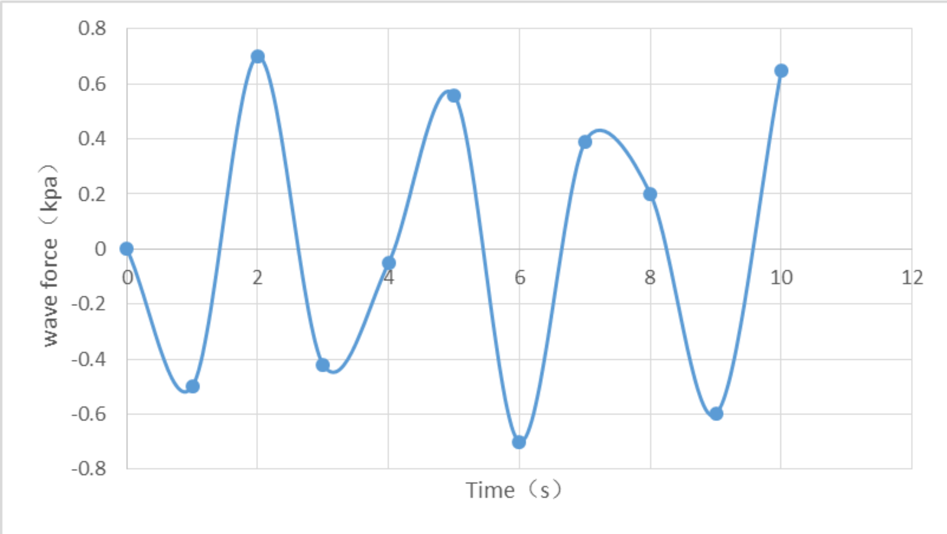
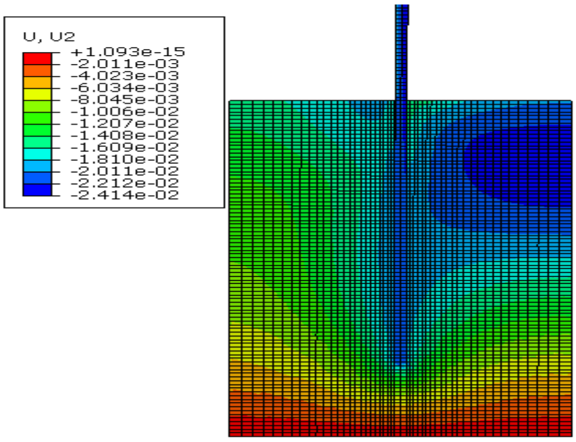


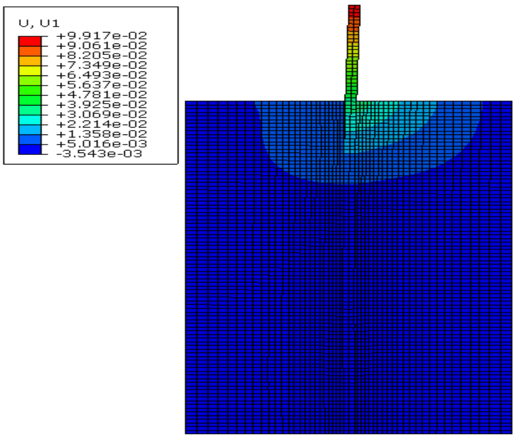
Fig. 2 The change curve of wave force

3. Results

As mentioned above using Abaqus finite element model is established, and according to the final simplified results of wave force in 1.3 exert wave loads on the finite element model, the finite element run images and the analysis results are as follows:



(a) Horizontal direction



(b) Vertical direction

Fig. 3 Pile foundation deformation figure under wave cyclic load

It can be seen in figure 3, pile foundation under the effect of gravity stress, the vertical displacement of the largest (U2) is 0.35 mm, and around in the pile, the pile driving process is similar to that of a practical, the result is good. As a result of the action of wave load is in the horizontal direction, so the soil horizontal displacement value (U1) should be the biggest, and wave loads of pile soil contact point displacement, the largest up to 47.8 mm, with the decrease of depth gradually increase its displacement. Pile foundation under wave load along the depth of foundation soil stress change rule as shown in figure 4. Can be seen in figure 3, pile foundation under the effect of gravity stress, the vertical displacement of the largest (U2) is 0.35 mm, and around in the pile, the similar to the actual process of pile driving, the result is good. As a result of the action of wave load is in the horizontal direction, so the soil horizontal displacement value (U1) should be the biggest, and displacement of the pile soil contact point under wave load, the largest up to 47.8 mm, With the decrease of depth gradually increase its displacement. Pile foundation under wave load along the depth of foundation soil stress change rule as shown in figure 4.

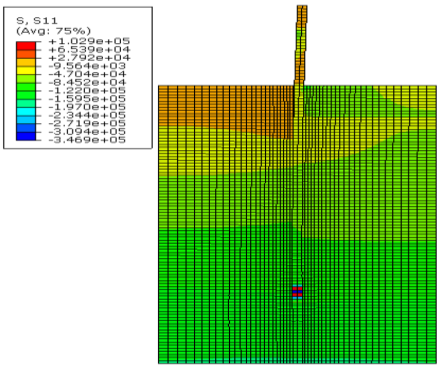


Fig. 4 The soil stress diagram under wave cyclic load

From figure 4, the wave loads, a horizontal stress component sigma x (i.e., S11) as the change of depth is not obvious, appears at the bottom of the pile stress, this is due to model change in stress of the pile and expanded. According to the foundation soil foundation soil stress diagram can be extracted under wave load and no load cases additional stress change curve of soil along the depth direction. As shown in figure 5:

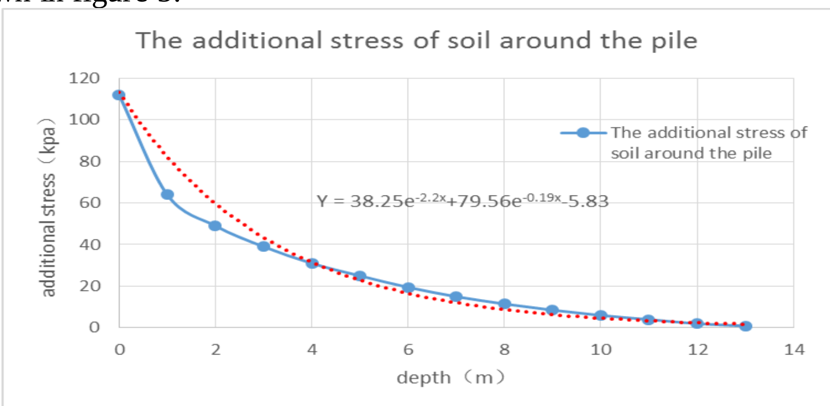


Fig. 5 The stress change curve Soil along the depth direction of soil

As can be seen from the curve, the influence of wave load foundation soil depth of about 13 m, using the quadratic exponential function under the action of the wave load of dynamic response of soil around pile to carry on the fitting, can get the equation of stress changing with depth:

$$P = 38.25e-2.2x+79.56e-0.19x-5.83 \tag{6}$$

By this equation can be calculated under wave load at any depth of pile soil's dynamic stress response.

4. Conclusion

For dynamic response of soil around pile under wave load, the simplified method, the selection of wave forces acting on the pile - soil master-slave contact way to simulate the dynamic process of contact interface area - separation effect, the following conclusion is obtained by simulation based on the finite element simulation analysis:

(1) Choose the master-slave contact model can well simulate the dynamic process of pile soil contact interface area - separation effect.

(2) Pile soil contact surface wave loads, deformation of soil is the largest, with the increase of soil depth, soil deformation decrease gradually.

(3) Wave load effect of foundation soil depth of about 13 m, more than the depth can be ignored its influence, the dynamic response of soil pile foundation under wave load formula.

Acknowledgements

This paper is funded supported by Tianjin Research Program of Application Foundation and Advanced Technology (13JCQNJC07800,15JCQNJC07900),The Science and technology plan projects of Tianjin port, the views expressed are authors alone.

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