

Numerical Simulation of Dynamic Deformation Characteristics of Composite Foundation

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Abstract. The influence of piles design parameters such as pile diameter, pile length and pile stiffness on dynamic deformation characteristics of gravel pile composite foundation and CFG pile composite foundation was analyzed. The calculation results show that the influence of pile diameter on dynamic deformation of gravel pile composite foundation is more significant, the influence of pile length on dynamic deformation of two types of composite foundation is very small, and the dynamic deformation of composite foundation decreases with the pile stiffness increasing.

Introduction

Composite foundation is one of the common foundation treatment methods. With the earthquake occurring frequently, in order to guarantee engineering safety, studying the dynamic characteristics of composite foundation is necessary. The dynamic characteristics of composite foundation are more complex than that of natural foundation, because the composite foundation contains reinforced body and soil, and they have greatly different mechanical properties.

At present, there are many domestic and foreign scholars to study the dynamic characteristics of composite foundation. Anti-liquefaction characteristics of gravel pile composite foundation were studied by experiment or numerical simulation [1-6]; dynamic characteristics of different bonding material pile composite foundation were studied [7-10] etc. But the dynamic deformation of composite foundation still needs to study deeply.

This paper will take the gravel pile composite foundation and CFG pile composite foundation as examples, combined with the actual geological data of oil depot, to study the dynamic deformation characteristics of composite foundation. When calculating, storage tank load is simplified to a uniform load which is 120kPa.

Calculation Parameters and Numerical Calculation Model

Calculation Parameters

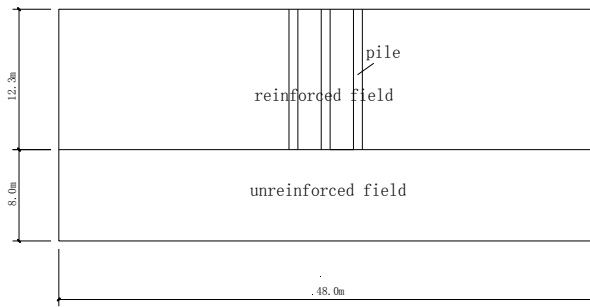
Composite foundation calculation parameters are shown in table 1. Without special instructions, the pile diameter is 0.6m, the pile length is 12m, the pile spacing is 1.8m, and the stiffness of CFG pile is 1600MPa during dynamic calculation.

Numerical Calculation Model

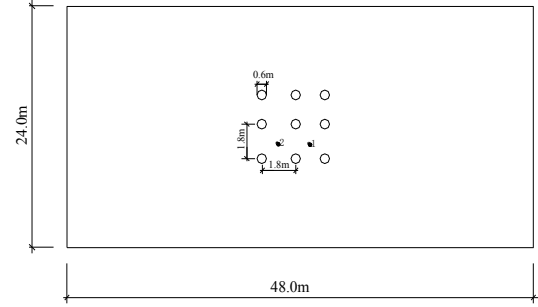
The layout scheme of composite foundation is shown in Fig. 1. Excess pore water pressure and displacement induced by static load are cleared during dynamic analysis. The bottom surface of calculation model is impermeable bedrock, and the top surface is permeable free surface. The free boundary is arranged around the model. CFG pile is considered to be linear elastic. The meshing of composite foundation is shown in Fig. 2.

Tab. 1 Calculation Parameters

| Soil type | Thickness [m] | Density [g/cm ³] | Modulus of Compressibility [MPa] | Poisson's ratio | Angle of Internal friction [°] | Cohesion [kPa] | Coefficient of permeability [cm/s] |
|-------------|---------------|------------------------------|----------------------------------|-----------------|--------------------------------|----------------|------------------------------------|
| Cushion | 0.3 | 1.91 | 12.0 | 0.30 | 28.0 | — | 3.2×10^{-2} |
| Clay | 2.0 | 1.87 | 3.0 | 0.35 | 7.5 | 13 | 9.0×10^{-7} |
| Silt | 10.0 | 1.99 | 2.5 | 0.35 | 13.5 | 40 | 4.6×10^{-6} |
| Coarse sand | 5.0 | 1.91 | 12.0 | 0.32 | 13.3 | 36 | 3.2×10^{-5} |
| Mudstone | 3.0 | 2.21 | 55.8 | 0.30 | — | — | — |
| CFG pile | 12.0 | 2.30 | 2250 | 0.25 | — | — | — |
| Gravel pile | 12.0 | 2.09 | 200 | 0.3 | 36.0 | — | 2.8×10^{-3} |

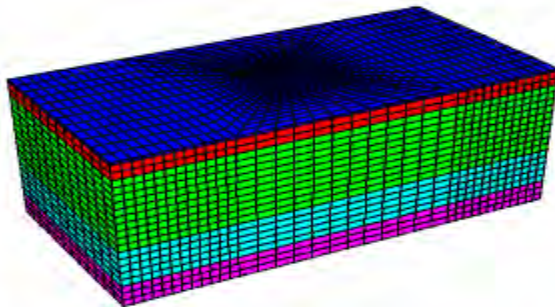


(a) The plan of composite foundation

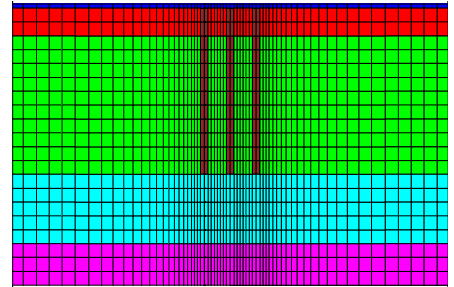


(b) The section plan of composite foundation

Fig. 1 The Layout Scheme of Composite Foundation



(a) The three-dimensional meshing graph



(b) The section plan of meshing

Fig. 2 Schematics of Meshing

Seismic Wave Input

EI CENTRO wave being used as the input seismic wave is shown in Fig. 3. The maximum acceleration is adjusted to 0.2g as the maximum acceleration when the fortification intensity is 8 degrees. Only the unidirectional vertical seismic shear wave is considered, without considering the two or three direction input.

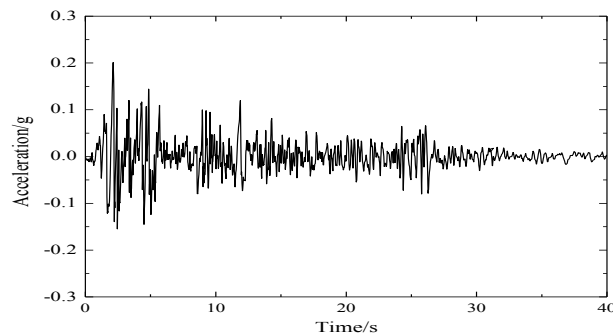


Fig. 3 Acceleration Time Curve of EI CENTRO Wave

Calculation Results and Analysis

Analysis of Foundation Dynamic Deformation Characteristics

The dynamic deformation curve of natural foundation under seismic is shown in Fig. 4. It can be seen that the dynamic deformation of foundation is mainly concentrated in the surface. With the increase of depth, the settlement of foundation decreases rapidly. It has become very small in the 2m depth.

Fig. 5 reflects the vertical dynamic deformation curve of different foundation at 1 point in Fig. 1. The results show that the dynamic deformation of composite foundation is obviously smaller than natural foundation, and under the same conditions, the reducing deformation effect of CFG pile composite foundation is relatively obvious.

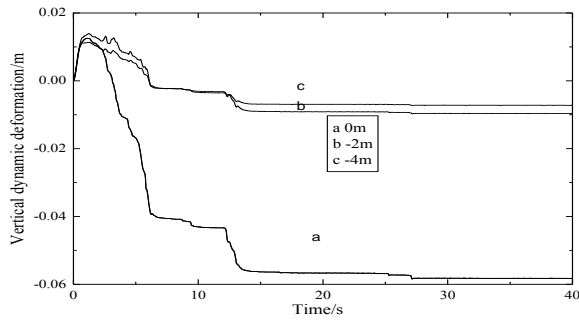


Fig. 4 Dynamic Deformation Curve of Natural Foundation during Earthquake

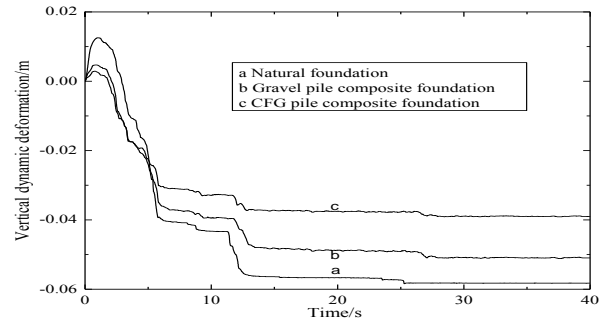
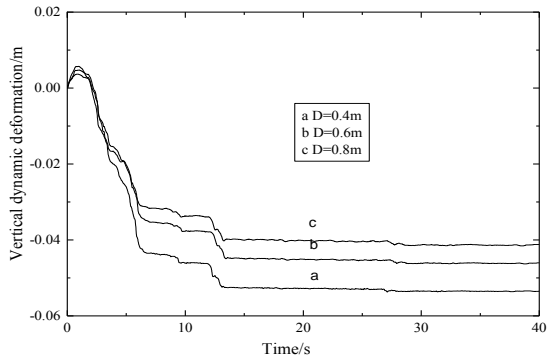
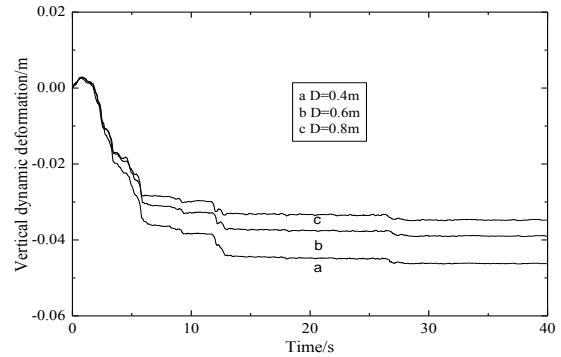


Fig. 5 Dynamic Deformation Time Curve of Different Foundation during Earthquake

The Influence of Pile Diameter on Foundation Dynamic Deformation



(a) Gravel pile composite foundation



(b) CFG pile composite foundation

Fig. 6 the Vertical Dynamic Deformation Curve in Different Pile Diameters

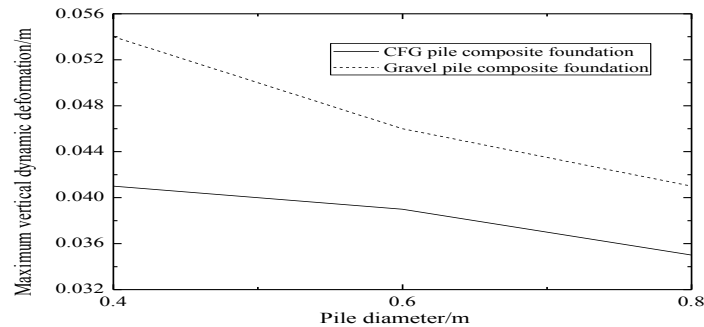


Fig. 7 the Influence Law of Pile Diameter on Foundation Dynamic Deformation

Keeping pile length and pile spacing unchanged, and adopting different pile diameter to calculate, the calculation curve is shown in Fig. 6. It shows that with the pile diameter or area replacement ratio

increasing, the vertical dynamic deformation of composite foundation decreases gradually. The maximum vertical dynamic deformation of CFG pile composite foundation when the pile diameter is 0.4m is approximately equal that of gravel pile composite foundation when it's pile diameter is 0.8m. The influence law of pile diameter on foundation dynamic deformation is also shown in Fig. 7.

The Influence of Pile Length on Foundation Dynamic Deformation

Keeping pile diameter and pile spacing unchanged, and adopting different pile length to calculate, the calculation curve is shown in Fig. 8. The curve reflects that the influence of gravel pile length on dynamic deformation of composite foundation is very small. With CFG pile length increasing, the dynamic deformation of composite foundation decreases.

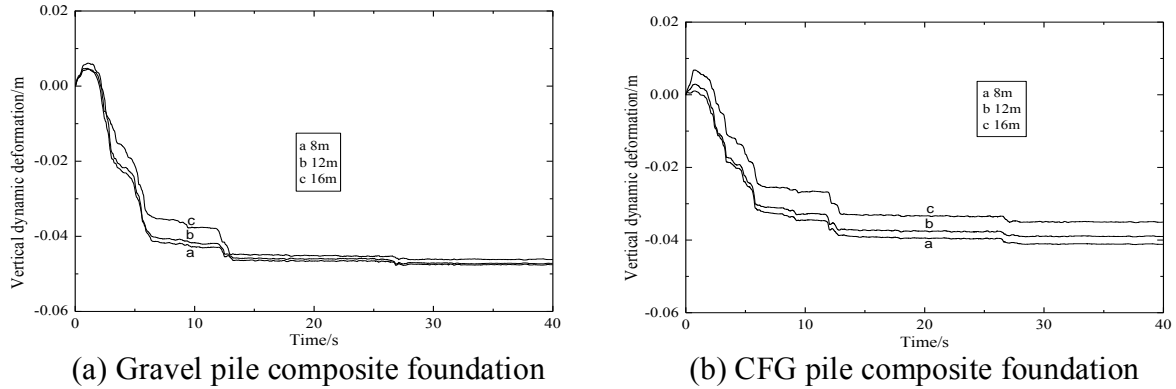


Fig. 8 the Vertical Dynamic Deformation Curve in Different Pile Length

The Influence of CFG Pile Stiffness on Foundation Dynamic Deformation

Fig. 9 reflects that the influence of CFG pile stiffness on foundation vertical dynamic deformation. With pile stiffness increasing, the dynamic deformation of composite foundation decreases. In practical engineering, the bonding material piles can be increased pile stiffness through changing pile body material ratio to reduce the dynamic deformation of composite foundation.

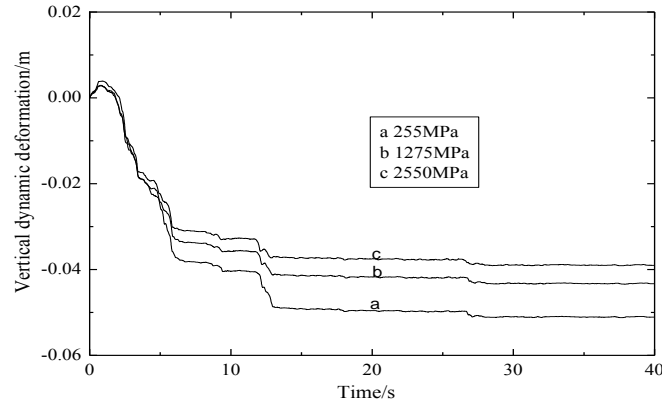


Fig. 9 the Vertical Dynamic Deformation Curve in Different CFG Pile Stiffness

Summary

- (1) The influence of pile diameter on dynamic deformation of discrete material pile composite foundation is bigger than that of binding body material pile composite foundation.
- (2) The influence of pile length on dynamic deformation of composite foundation is very small. In practical engineering, if only in order to reduce the dynamic deformation, it may be appropriate to reduce pile length to reduce engineering cost.
- (3) In practical engineering, it may improve pile stiffness to reduce dynamic deformation of composite foundation by changing the ratio of pile body material.

(4) Because there are many types of piles, only Gravel pile composite foundation and CFG pile composite foundation were analyzed in paper, the dynamic deformation characteristics of other types pile composite foundation should be researched too.

Acknowledgement

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