

Model tests on pervious concrete pile and impervious concrete pile composite foundation

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Abstract. Taking the advantages of high permeability and high strength, pervious concrete piles is suitable for improving ground bearing capacity and reduce the post-construction settlement, so pervious concrete pile composite foundation is a new foundation treatment. As pervious concrete piles were designed to accelerate soil consolidation and improve the ground bearing capacity, so model test of pervious concrete piles were conducted to evaluate the consolidation effect. Pervious concrete with porosity 20%, 25%, 30% and 35% was designed to compare the strength and permeability, and the porosity of 30% was selected, so the pile was made for the model test. Compared with impervious concrete pile composite foundation, as the pervious pile shortens the drainage path, pervious concrete pile composite foundation can shorten the consolidation time by about 30.3% and significantly reduce the peak value of excess pore pressure. With the increase of load and consolidation rate of soil around the pile, the stress ratio of pervious concrete pile increase first, then decrease and tend to be flat.

1 Introduction

In recent years, composite foundation methods have been widely used to enhance the bearing capacity of foundations and reduce the settlement and liquefaction potential of ground. PHC (pre-stressed high-strength concrete) piles were used in the connection project of Chongqi bridge on the north bank of Yangtze River estuary, as for the deep soft soil, they doesn't work that well. So pervious concrete piles method that combines the advantages of higher stiffness and speeding up the consolidation of soft soil foundation was put forward. Muhannad T^[1-2], Cui X. Z.^[3-5] and Mei G. X.^[6] has studied the advantages of acceleration of excess pore water pressure dissipation and consolidation, but this method is still in this infancy, so further research is still needed.

2 Testing

2.1 Pervious concrete properties

Table 1. Mixing procedure

Procedure	
Step 1	Mix aggregate and 50%-60% water
Step 2	Mix together for 3 minutes
Step 3	Add cement and the rest water
Step 4	Mix thoroughly for 30s

Pervious concrete pile is made of pervious concrete. In the test, aggregate (limestone), cement (P.O. 52.5) and water was mixed for the pervious concrete. The target porosity was set as 20%, 25%, 30% and 35%, the size of aggregate was set as 3-5mm and 4-6mm, and the following equation (1) was used to calculate the amount of mixtures. And the pervious concrete was prepared by the methods in Table 1.

$$\frac{m_g}{\rho_g} + \frac{m_c}{\rho_c} + \frac{m_w}{\rho_w} + P = 1 \quad (1)$$

where m_g , m_c , m_w is the amount of aggregate, cement and water per unit (kg/m^3); ρ_g , ρ_c , ρ_w is the density of aggregate, cement and water (kg/m^3); P is the designed porosity (%).

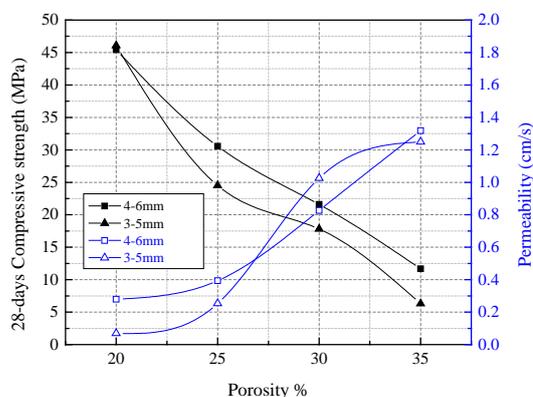


Fig. 1. Pervious concrete properties

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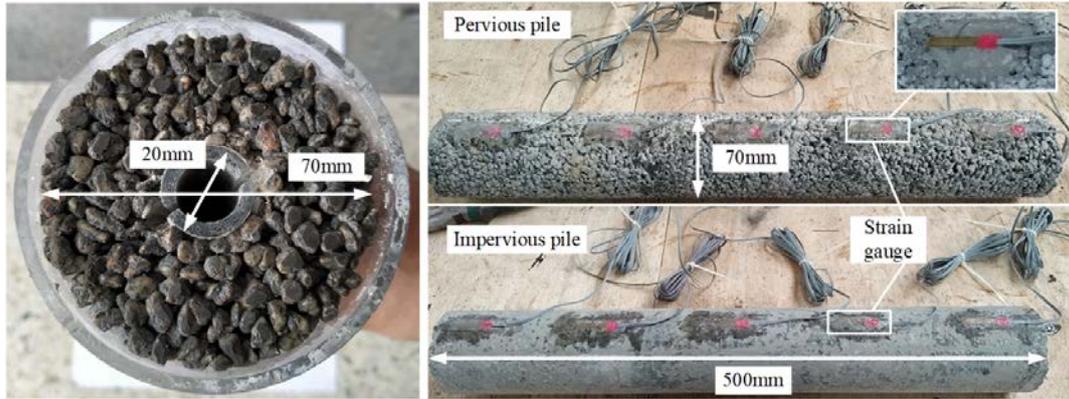


Fig. 2. Pervious pile and impervious pile

The strength is obtained by uniaxial compression test, and the permeability coefficient was got by the constant head permeability test, the permeability coefficient was got by

$$k_T = \frac{QL}{AHt} \quad (2)$$

where k_T is the permeability coefficient at T °C; Q is the average volume of water outflow for 5 min; L is the thickness of specimen, A is the pervious area of specimen water; H is the water head difference and t is the recording time. So the results are in Fig. 1. As the pervious concrete needs both strength and water permeability, and the two curves intersect when porosity is 30%, so porosity is 30%, with the size of aggregate being 3-5mm.

According to the Chinese Technical Code^[7], pile diameter is recommended to set as 300-500mm, even the pervious concrete pile is cast-in-place, the diameter is also advisable. So the ratio of similitude is set as 1/5, pile diameter of model test is 70mm, as the figure 2 shows, and the impervious pile was made by applying a cement layer on the surface of the pervious concrete pile.

2.2 Soil properties

Silt soil was taken from Jiangsu province. The sand used in this experiment was from Nanjing section of the Yangtze River. The silt was made with the moisture content being 30%. The slurry was laid in layers, after each layer was laid in static for 12 h, it was consolidated under gravity. Table 2 shows the parameters of the silt in the model box.

Table 2. Parameters of the silt in the model box

Density (g/cm ³)	Dry density (g/cm ³)	Water content (%)	Pore ratio	Saturation (%)
1.919	1.482	29.5	0.849	95.2

3 Testing facility

3.1 Test units and sensor

The experiment facility was a soil box with the dimensions of 1 × 1 × 1.2 m. The loading plate is made of steel with a diameter of 0.46m, standard weights (20kg) are used for multi-stage loading. Fig. 3 is the arrangement of soil stress sensor, pore water pressure and strain gauge.

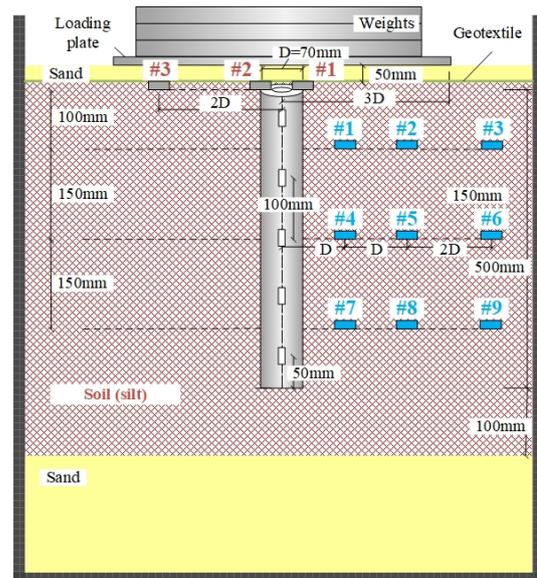


Fig. 3. Instrumentation for the test

3.2 Loading sequence

After the pile was pressed into the soil, the model box was placed for about a week, and the excess pore-water pressure dissipated completely, the composite foundation was loaded. Geotextile was placed on the silt soil, medium and coarse sand was laid on the geotextile, and it is the drainage sand mat (50mm thick). During the test, according to the Chinese Technical Code for composite foundation^[8], the test load was applied step by step, and it was divided into 14 steps.

4 Test results

Fig. 4 is the comparison of consolidation settlement between pervious pile and impervious pile, the consolidation time of impervious pile composite foundation is 49.5 h, while that of pervious pile composite foundation is 34.5 h, so the consolidation time has been shortened by 30.3%. With the increase of load, the foundation soil becomes more and more compact, and the permeability decreases, so the two consolidation time increases. But in the end, the ultimate settlement under the two conditions are the same. It can be concluded that, compared with impervious pile, pervious pile can accelerate consolidation of composite foundation, shorten consolidation time.

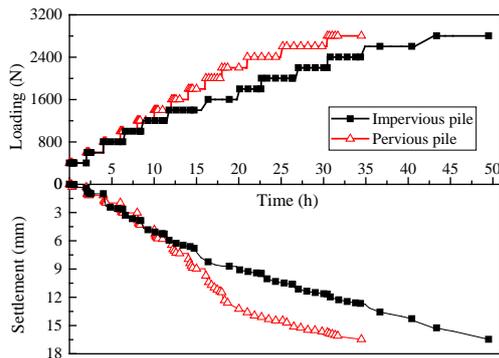
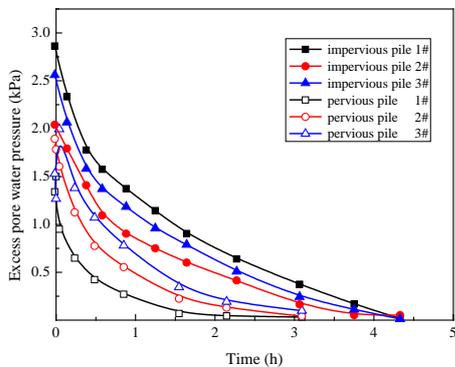
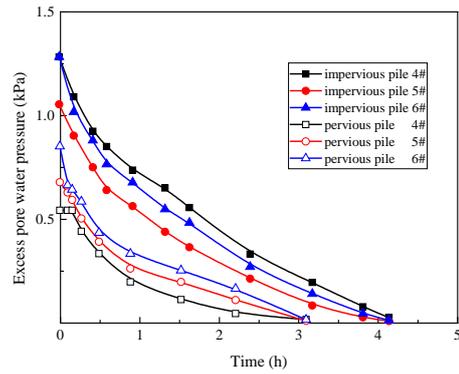


Fig. 4. Load-settlement comparison of pervious and impervious pile

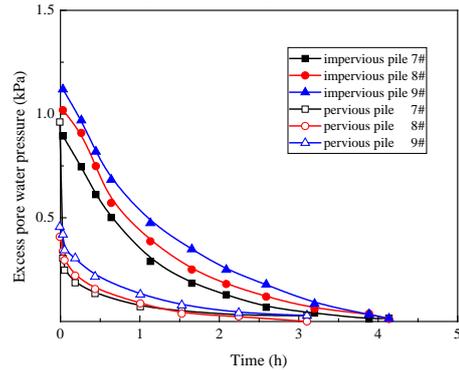
Fig. 5 is the result of excess pore water pressure, and the number of the point is in Fig. 3. When loading, the peak value of excess pore water pressure in pervious pile is smaller than that of impervious pile. The horizontal distance between monitoring point and pile becomes closer, the difference of excess pore water pressure between pervious pile and impervious pile becomes larger. Since the impervious pile composite foundation is mainly consolidated by vertical drainage, the pervious pile composite foundation can be drained both vertically and radially, which increases the drainage path and shortens the drainage distance, thus accelerates consolidation.



(a) Excess pore water pressure for point: 1#, 2# and 3#



(b) Excess pore water pressure for point: 4#, 5# and 6#



(c) Excess pore water pressure for point: 7#, 8# and 9#

Fig. 5. Excess pore-water pressure variation during loading stage 13

As shown in Fig. 6, the pile-soil stress ratio of the two composite foundation increases first, then decreases and gradually flattens, the value increases from 10.0 to 18.04 and then gradually stabilizes to about 14.6. During the initiation of loading, the settlement difference between pile and soil is small, so the pile-soil stress ratio is small, with the increase of loading, the soil settlement increases, the settlement difference between pile and soil increases, pile-soil stress ratio increases, because of the geotextile and sand soil, pile-soil settlement is coordinated, the composite foundation share the load of piles and soil, then it flattens. When the pile-soil stress ratio increases, the value of pervious pile is greater than that of impervious pile, it means the side friction of pervious pile is greater, and the bearing capacity of pervious pile is greater.

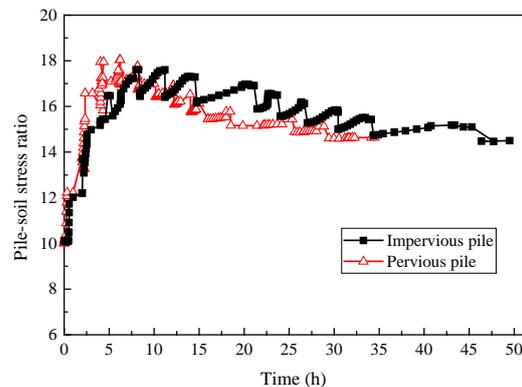


Fig. 6. Pile-soil stress ratio comparison

5 Summary and conclusions

In this article, the load-bearing characteristics of pervious concrete pile composite foundation was analysed, first the pervious concrete mixture ratio was selected, second the model test comparison between the pervious concrete pile and impervious concrete pile composite foundation was carried out, then the settlement, excess pore water pressure and stress in the process of loading was analysed, the conclusion are as follows:

(1) Taking both the strength and permeability of the pervious concrete into consideration, specimens with different particle size (3-5mm and 4-6mm) and porosity (20%, 25%, 30% and 35%) was prepared, the optimal particle size of pervious concrete is 3-5mm and porosity is 30%.

(2) Analysing the settlement and excess pore water pressure dissipation, compared with impermeable concrete pile composite foundation, pervious concrete pile composite foundation can accelerate the soil consolidation, and shorten the consolidation time 30.3%. During the loading process, pervious concrete pile can significantly reduce the peak value of excess pore pressure. The closer to the pile in the horizontal direction, the smaller the excess pore water pressure, the faster the pressure dissipates.

(3) With the increase of load and consolidation of soil around the pile, the pile-soil stress ratio increased from 10.0 to 18.04 and then gradually stabilized to about 14.6. Compared with impervious concrete piles, pervious concrete piles can accelerate the consolidation of foundation soil, improve the strength and bearing capacity of soil around the pile.

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