Experiment study of vibration isolation by multi-rows of piles

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Abstract. Pile barriers have been broadly used to decrease the effect of ground vibration generated by machines or traffic. However, so far, the research about the model test of vibration isolation of pile barriers is very few. In the present paper, the basic properties of the soil in the concrete model box are determined by the basic properties test of the soil firstly. Secondly, through the model tests with two types of piles under different vibration frequencies, the influences of different factors on the vibration isolation effect of pile barriers are studied. The results show that the multi-row pile barriers can effectively isolate the vibration. The main factors influencing the isolation effect are the pile diameter, the number of rows of piles and the vibration wave frequency.

1. Introduction
With the rapid development of the economy, the environmental vibration caused by the transportation, machines and construction is becoming more and more serious. How to reduce the influence of vibration has received much attention in these decades. Theoretical study and engineering application demonstrates that pile barriers can effectively isolate ambient vibrations.

The use of piles as wave barriers was first introduced by Richart et al. [1]. Based on the frequency domain boundary element method (BEM), Kattis et al. [2,3] numerically studied the vibration isolation by a row of piles in a three-dimensional context and concluded that the effectiveness of pile barriers increases with increase of the number of piles in a row. Pu and Shi [4] investigated the propagation of surface waves in both one- and two-dimensional periodic structures and suggested a new method for identifying surface wave modes. Combining with engineering project of multi-rows of piles for vibration isolation, the vibration isolation effects of the multi-rows of piles at different distances from the railway were measured by Sun and Gao [5], and the influence of pile row number on the vibration damping effects was measured and discussed. Combined the finite element boundary and infinite element boundary, Liu et al. [6] establish a numerical model and the vibration isolation effect was then investigated based on the perpendicular method.

In this paper, based on model test study, polyvinyl chloride (PVC) pipe pile used as pile barriers to mitigate vibration, vibration isolation effects and influence factors are analyzed and evaluated.
2. Experimental program

The size of concrete model box used in experiments is 3.0m×2.0m×2.0m, foam with a thickness of 30mm was used on the bottom and side walls of the box to eliminate reflections and refractions of vibration waves. Based on the basic properties tests of the soil, the soil substrate in box is determined to fine sand with density of 1.66 g/cm³ and moisture content of 2.72%. The test instruments include a wave generator (EM32003A), a power amplifier (GF1000), a electromagnetic dynamic shaker (JZQ-100), a signal acquisition (DEWE-43-A), and several piezoelectric accelerometers (LC0106). The test instruments are placed on the model box, as shown in Fig. 1.

Two diameters of piles made of PVC tubes was used in this experiment, the diameters of PVC tubes are 110mm and 160mm, and the thickness of PVC tubes are 2.5mm and 3.0mm. The pile barriers are arranged in a square configuration, there are four rows of piles and each row has four piles. The center distance of piles is 360mm. The accelerometer A2, A3, A4 and A5 are placed 180mm behind the center line of the row pile. The layout of pile barriers is shown in Fig. 2.

First of all, a single harmonic wave with frequency from 10Hz to 100Hz is generated by the electromagnetic dynamic shaker. When the vibration signal stabilized, the signal acquisition and the accelerometers were used to measure the dynamic response of the model. The last, through data analysis, the main factors influencing the isolation effect are determined.
3. Data analysis

Fig. 3 show the dynamic response of using piles and without piles respectively. Fig3(a) represents the response of piles with a diameter of 110mm, Fig3(b) shows the another result. It can be seen that they all have better effect of vibration isolation. The acceleration was reduced by 15% compared to the acceleration without piles.

(a) diameter =110mm , frequency=75Hz
(b) diameter=160mm, frequency = 65Hz

Fig.3 Dynamic response of using piles and without piles

The horizontal ordinate in Fig. 4 represents the distance between the piezoelectric accelerometer and the electromagnetic dynamic shaker, and the vertical ordinate represents the acceleration. Fig.4 shows the results that if the pile length, pile diameter and form of decorate are same, the vibration response is reducing with the increase of the number of pile rows, the more pile rows, the better the performance to vibration isolation.

(a) frequency = 80Hz
(b) frequency= 110Hz

Fig.4 The acceleration varies with the distance to the electromagnetic dynamic shaker

In order to obtain the vibration response of pile barriers at different frequencies, the frequency response function (FRF) is defined by $FRF = 20 \log_{10} \frac{A}{A_0}$. In this definition, $A$ is the average amplitude of acceleration response at test point A5 for the model with four rows of piles; $A_0$ is the average amplitude of acceleration response at reference point A1. In the test, amplitude of the vibration response at the electromagnetic dynamic shaker (the reading of A1, as shown in Fig. 1) is taken as the reference point, and the reading of A5 (as shown in Fig. 1) is used as the control point.

Fig.5 shows the result, most of the surface waves within the range of 10Hz-110Hz attenuate after passing through the pile barriers. Further more, for the frequency of 30-38Hz, 45-60Hz and 100-110Hz,
the surface wave has more larger attenuation amplitude. It shows that the vibration isolation effect of pile barriers is better for these frequencies. In addition, the trend of attenuation on the two kinds of pile barriers is roughly the same. Particularly, under high frequency vibration, multi-rows of piles with larger diameter can better isolate the vibration.

![FRF curve of pile barriers](image)

**Fig.5 FRF curve of pile barriers**

4. **Conclusion**
In this paper, experiment study of vibration isolation by pile barriers was carried out. The results show that the multi-rows of piles with diameter of 160mm and 110mm can effectively isolate the vibration within the range of 10Hz-110Hz. The more the number of rows of piles, the better the vibration isolation effect will be. Maybe due to the small difference between the two piles, for the most vibration, the influence of pile diameter on vibration isolation effect is small. However, for the vibration of high frequency, the vibration isolation effect of larger pile diameter is better than the smaller one.

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