

Research and Progress on Vibration Isolation of Different Pile Rows

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Abstract

With the development and progress of society, environmental vibrations generated by human transportation and construction are becoming more and more common. Excessive vibration effects will affect the safety of building structures and people's normal lives. In severe cases, it may even cause great losses of life and property. Therefore, vibration isolation research is urgent. This paper summarizes the vibration isolation effects of different pile types, providing a certain reference for the future development of pile rows.

Keywords

Multi-Row Piles; Vibration Isolation; Surface Waves.

1. Introduction

Along with the continuous progress of science and technology and the continuous development of society, various vibration phenomena appear in our living environment. The impact of vibration on people's daily lives is also increasing. Vibration isolation is increasingly becoming one of the hot topics of concern. Vibration acts directly or indirectly on the human body, affecting people's daily activities such as work, study, and rest. Due to reasons such as environmental vibration interfering with vision, affecting normal operations, and distracting people, workers often experience decreased production efficiency, fatigue, substandard product quality, and even safety accidents, endangering the health of workers. Vibration interference can cause residents to experience negative emotions such as irritability, anxiety, and depression, affecting their physical and mental health. Environmental vibration can also cause great harm to ancient buildings. Due to different intensities, frequencies, and periods of environmental vibrations, ancient buildings will bear different loads, leading to damage to their structures. In the field of precision instruments, environmental vibration can affect the accurate reading of instruments. Some instruments may even be unable to be used in a vibrating environment. If the environmental vibration is too large, it will affect the service life of precision instruments. For some precision electronic instruments, such as sensitive relays, misreading may occur in a vibrating environment, causing major safety accidents. Vibration will reduce the processing accuracy of precision lathes and increase roughness. Excessive vibration can cause damage to lathe tools. In summary, environmental vibration causes great harm and affects various fields. Therefore, researching the vibration isolation of multi-row pile barriers has strong economic effects and social values.

In the initial stage, due to the similarity between environmental vibration and earthquakes, people drew on the relevant principles and experience of earthquake isolation in vibration isolation design. Earthquakes are caused by the interaction of internal plates of the earth, local collapses, volcanic eruptions, etc. They release a large amount of energy, have a long transmission distance, and a wide influence range. Due to the characteristics of earthquakes, earthquake resistance mainly considers the bearing capacity of building structures to input

seismic waves. In design, according to the seismic fortification intensity of the region and the importance of the building structure, an appropriate form and structure are selected to meet the seismic requirements. However, the energy released by environmental vibration is much smaller than that of earthquake energy, and the transmission distance and influence range are far less than those of earthquakes. Therefore, simply drawing on the principles and experience of earthquake resistance has a large deviation in environmental vibration isolation. Due to the characteristics of small energy release and small influence range of environmental vibration. The vibration isolation of environmental vibration is to arrange barrier vibration isolation measures at the vibration source and propagation path to achieve the purpose of reducing vibration energy and isolating vibration.

2. Development Status at Home and Abroad

Abroad, at the beginning of the 20th century, barrier vibration isolation began to appear in people's vision, and some experts began to study pile row vibration isolation. Woods [1] conducted a series of in-situ tests. After analysis, he proposed the Woods criterion. The Woods criterion is an important criterion for the vibration reduction design of periodic pile rows. At the same time, the concept of amplitude attenuation coefficient (ARF) was introduced for the first time. The amplitude coefficient is still an important parameter used to measure the vibration isolation effect to this day. It is most often used to evaluate the vibration isolation effect of various barriers. The evaluation of this coefficient is more targeted. Next, pile rows and hole arrays were used for experiments respectively to study and analyze their vibration isolation effects. It was concluded that the vibration isolation effect of pile rows is related to both the radius and pile spacing of piles.

Liao [2] and others used the acoustic wave model for research. Since acoustic waves and vibration waves have similar properties, their use of acoustic waves to analyze the vibration isolation effect of pile rows also has comparative significance. They arranged piles of various different materials and measured their vibration isolation effects. They proposed the wave impedance ratio theory and obtained the basic criteria for vibration isolation design. Their research shows that the vibration isolation effect is determined by the relative softness and hardness of the pile body and the soil around the pile, that is, the relative stiffness of the pile and the soil. Among them, flexible pile rows have better vibration isolation effects, while rigid pile rows have relatively weaker vibration isolation effects.

Japanese scholar Takemiya [3] proposed a new arrangement form. The pile rows are arranged in a honeycomb shape. Through a large amount of data analysis and experimental research, it is concluded that the barrier formed by the honeycomb arrangement form has a stronger blocking effect than pile rows in general arrangement forms, and the isolation effect on low-frequency waves is more obvious.

Boroomand and Kaynia [4] analyzed the interaction between piles and soil in homogeneous soil and considered the influence of factors such as pile spacing and pile stiffness on the vibration isolation effect of piles. Experimental analysis shows that the stiffness of pile body materials is positively correlated with the vibration isolation effect of piles. That is, the greater the stiffness of pile body materials, the better the vibration isolation effect of piles.

In China, Chinese scholars have also achieved many scientific research results.

Gao Guangyun [5] and others obtained through indoor test tests and processing data and analyzing images that the size of the vibration isolation effect range of barrier vibration isolation is determined by the diffraction effect of the vibration isolation barrier. The analysis shows that the cylindrical pile row has better vibration isolation effect than other types of piles.

Wei Hongliang [6] and others analyzed the influence of factors such as pile diameter, pile spacing, and pile length on the vibration isolation effect through a dynamic analysis model. It is

concluded that single-row piles have a filtering effect on waves of different frequencies. The vibration isolation effect on low-frequency and medium-frequency waves is better, and the vibration isolation effect on high-frequency waves is relatively poor. The experimental results show that for single-row piles, pile length, pile diameter, and pile body material have a greater impact on the vibration isolation effect of pile rows and are important parameters affecting the vibration isolation effect of piles. Among them, the longer the pile length, that is, the deeper the burial depth, the better the vibration isolation effect; the larger the pile diameter, the better the vibration isolation effect; the material used for pile rows will affect its stiffness. The research finds that stiffness has a greater impact on the vibration isolation effect of pile rows. The greater the stiffness of pile body materials, the better the vibration isolation effect of pile rows. The cross-sectional form of pile rows has a certain influence on the vibration isolation effect, but it is not the most important factor. There is no obvious change in the vibration isolation effect of piles with different cross-sectional forms.

Lu Jianfei [7] and others studied a new type of pile row structure. This is a new type of periodic connected pile row structure. Through establishing a numerical model, calculating and analyzing, and simulating, the vibration isolation effect of this new pile row structure is analyzed. For the experiment, they established a boundary element model in the wave number domain of the periodic connected pile row and creatively simplified a row of piles in the spatial domain into a single pile in the wave number domain. This model greatly simplifies the calculation, effectively shortens the data processing time, makes the test cycle shorter, and does not require a computer with too much memory. Experiments show that the connected pile row is more effective in vibration isolation, while the free pile row has relatively weaker vibration isolation effect. Therefore, the connected pile row is a more effective vibration isolation facility and has higher application value.

Huang Jiankun [8] based on Bloch's theorem in periodic structures, with the help of the improved plane wave expansion method and finite element method, deeply studied the isolation effect of various pile row structures on vibration waves, enriched and perfected the periodic pile row structure theory, and strongly supported the application of periodic theory to specific practice. At the same time, it also analyzed the influence of different parameters on the attenuation domain range and determined the main factors affecting attenuation. The research results show that when the number of pile rows is small, the attenuation domain is not obvious. Once the number of pile rows exceeds three rows, the attenuation domain will be clearly displayed, and the vibration attenuation amplitude is large. As the number of rows increases, the vibration attenuation amplitude becomes larger and larger. Periodic pile rows with a large filling rate (larger sectional moment of inertia and relatively close arrangement) or other types of constructed pile rows obtain a larger attenuation domain.

Wan Jianwei [9] based on the Floquet transformation method, established a numerical model for the vibration isolation calculation of periodic pile rows, simplified and merged the calculation problem of periodic pile rows into the solution problem of a single pile in the wave number domain, reduced the solution scale of the calculation, greatly simplified the calculation, and greatly saved calculation time. Through his experimental analysis, a series of conclusions are drawn: the pile length of the pile will affect the vibration isolation effect of the pile row. The longer the pile row, the better the vibration isolation effect; the Young's modulus ratio of pile and soil has a greater impact on the vibration isolation effect of the pile row. Increasing the Young's modulus ratio of pile and soil will significantly increase the vibration isolation effect of the pile row. Finally, the pile spacing also has a relatively significant impact on the vibration isolation effect of the pile row. Reducing the pile spacing can improve the vibration isolation effect of the pile row.

Sun Liqiang [10] used a vibrator to generate vibration and set up force sensors at different positions so that their distances from the vibration source are different. In his experiment,

multiple measuring points were deliberately set up behind the vibration isolation structure, and the average value was taken to reduce the influence of test errors. The conclusion shows that the vertical acceleration of the measuring point will decrease as the distance from the vibration source increases. At a position closer to the vibration source, the attenuation speed is faster; while at a place farther from the vibration source, the attenuation speed is relatively slower.

3. Conclusion and Prospect

This paper mainly summarizes the research process of the vibration isolation effects of various pile rows at home and abroad. Most scholars at home and abroad only consider the influence of simple harmonic waves on the vibration isolation effects of different pile types and do not consider complex waveforms. This is different from the actual vibration waves in engineering. In future research, the measured waveforms can be used to study the vibration isolation effects of different pile rows. With the continuous development and application of pile row vibration isolation technology, relevant standards and specifications will gradually be perfected, providing a strong guarantee for the promotion and application of the technology. Standardization and regularization will promote the uniformity and interoperability of the technology, improve engineering quality and safety, and reduce construction costs and risks. With the continuous development of new materials, new processes, and intelligent and automated technologies, pile row vibration isolation technology will usher in more innovations and breakthroughs. For example, adopting more advanced pile foundation materials and construction technologies can improve the bearing capacity and durability of pile bodies; using intelligent control systems to monitor and adjust the vibration isolation effect of pile foundations in real time can achieve more accurate and efficient vibration isolation. At the same time, pile row vibration isolation technology will not be limited to traditional fields such as architecture and transportation but will gradually expand to emerging fields such as aerospace and ocean engineering. These fields have higher and more complex requirements for vibration isolation technology, providing a broad market space and opportunities for the development of pile row vibration isolation technology.

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