The Development of the ‘Pile-wall Interaction’ Technology

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ABSTRACT

The ‘pile-wall interaction’ is a new foundation technology in geotechnical engineering and it has not been widely used in the structure design, neither at home or abroad. Besides, the corresponding domestic design specifications are still relatively lacking, which leads to a huge difference of design in different regions. Therefore, the authors pay attention to analysis and summary of the project about ‘pile-wall interaction’ from different countries and areas in the world, and point out some problems about this emerging technology. They hope that this study can promote the application and development of ‘pile-wall interaction’ technology.1

INTRODUCTION

In modern society, the available amount of land resource for new buildings has become tense increasingly. As a result, how to make full use of underground space has become an important issue during engineering design, especially in domestic first-tier cities, such as Beijing, Shanghai, Guangzhou and Shenzhen. For property developers, creating more underground space means getting more income in those modern cities. At the same time, the proprietor hope that the supporting piles can be more and more fine and the basement wall can become thinner while chasing

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economic benefits and more space utilization rate, but this is bound to cause problems about structure safety and underground waterproof. The emergence of ‘pile-wall interaction’ technology perhaps could properly balance this contradiction.

THE DESIGN CONCEPT OF PILE-WALL INTERACTION TECHNOLOGY

Reflection From Traditional Foundation Pit Supporting System

In recent years, the quick process of China's urbanization leads to an increasingly decrease in land resources. Thus, developing the underground space efficiently has become a major trend in construction industry. Some advanced information technologies like BIM (Building Information Modeling) [1] are being applied in underground space design widely.

In order to make sure the safety of foundation pit, the traditional method is to use the rowed piles that strengthened by lateral shoring or anchor-bars. This kind of temporary structure will be discarded after completion of construction and becomes obstacle like rock. Although part of the water and earth pressure are undertaken by those rowed piles, this positive effect is seldom to be taken into account in design. Thus the thickness of basement wall is often designed into a thicker shape, which leading to many problems, such as resource waste and environmental pollution.

The ‘pile-wall interaction’ technology probably could be a good way to solve those problems. Making full use of the stiffness and bearing capacity of rowed piles, it should be designed as permanent structure so that it can efficiently resist the lateral pressure with basement wall. The rowed piles can also share the load from upper structure and work as anti-floating piles, which can reduce the project cost and increase the basement space.

The Design Principle of ‘Pile-Wall Interaction’ Technology

The ‘pile-wall interaction’ can be divided into two stages, which are called the construction stage and the normal use stage. The first stage starts with the excavation of foundation pit and ends up with the accomplishment of underground structure. During this period, the active earth pressure and water pressure have a direct impact on rowed piles while digging, and gradually shared by the underground structure as building process continuing.

The normal use stage is from the completion of the underground construction to the end of the building life. In this stage, active earth pressure and water pressure act directly on the piles when the waterproof system is valid. After the waterproof system loses effect, the water pressure act on the basement wall completely while earth pressure still be absorbed by piles. Then some parts of earth pressure transfer to basement wall through ‘pile-wall interaction’ system.
There is a soft interlayer [2] between the piles and wall. If the soft interlayer is set from basement floor to roof, active earth pressure and water pressure may be difficult to transfer to the basement wall evenly. Gradually, retaining piles may occur large lateral displacement, and the heat insulating material could be destroyed under the action of water and soil pressure. Therefore, it is necessary to set up the force transmission plate (Figure.1) that is made of reinforced concrete, which plays a key role in balancing force between piles and basement wall.

![Figure 1. The profile of ‘pile-wall interaction’ structure.](image)

**Domestic and Foreign Research Situation**

The research on the technology of ‘pile-wall interaction’ is being deepened and perfected continuously by scholars in China, and some relative engineering researches have been used to reality through various means.

Yinlan Liu put forward the design and construction method that connecting slope protection piles and the basement wall closely in a practical project as early as 1998. Both of these structures jointly bore the load, which greatly saving the cost of the project.

In 2008, Jianxun Di used ANSYS to establish the three-dimensional finite element simulation model [3] of ‘pile-wall interaction’ during the design of Heilongjiang University metro station in Harbin. He found out that piles could bear most load so the basement wall only needs to be reinforced with an economic way, which provided a theoretical basis for the ‘pile-wall interaction’ technology.

The latest news about the ‘pile-wall interaction’ is a project called Guangzhou Unlimited Plaza in Guangzhou in 2017. It covers an area of 45280 square meters, and the two-story basement is supported by pile foundation. The specific research methods are as follow. Firstly, the piles and wall share vertical and horizontal load proportionally. Installing stress sensor on longitudinal main reinforcement of piles and adjacent basement wall to monitor its stress condition is necessary. Then, the formula about deformation coordination could be found through setting up
observation points in piles and wall previously. Finally, the formula could be modified through comparing the 3D simulation result with field measured data.

At present, foreign scholars have not made a deep exploration upon this new structure or formed certain theory and technical specifications.

The Singapore Maritime Experiential Museum, which was built in 2012, covers an area of 6000 square meters and is located on Sentosa Island. The surface building is elliptical dome that is consisted of large span steel structure and glass curtain wall, while the underground structure is reinforced concrete frame structure. The underground support structure basically takes the ‘pile-wall interaction’ technology [4] as the core. This technology combines piles and wall properly, which means that they could bear earth pressure, water pressure and upper load together. It simplifies the construction process and saves money.

CONCLUSIONS

At present, scholars have different opinions on this new structure and take different ways to calculate its inner stress. It is urgent to figure out the load sharing mode between retaining pile and basement wall, the design of force transmission plate, the waterproof problem and the durability of this technology.

In addition, the rowed piles and basement wall have stable connection node, so the anti-floating function is responsible by retaining piles and engineering piles. The anti-floating ability [5] may come from two aspects when piles are working, which are called the lateral friction resistance and pile bottom suction from pile displacement. Lateral friction is dominant while suction of pile bottom disappears as the piles upward moving, because pore pressure fades away during this process.

Actually, the ‘pile-wall interaction’ technology is still in its infancy stage, so great effort needs to be put into this area continuously to improve and perfect this theory.

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