Physical model test study on the working performance of integrated foundation pit supporting structure

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Abstract: The integration of underground single structure and retaining structure is a new type of foundation pit support, and its working performance needs to be further studied. The physical model test was carried out on the diaphragm wall structure of "two walls in one" in this paper. The soil settlement and the earth pressure of the outside of the foundation pit and the stress of the integrated supporting structure were analyzed when the excavation depth is different. The analysis showed that the settlement of soil behind the wall gradually increased with the increase of excavation depth of the foundation pit. when it was 1.0 away from the diaphragm wall, the maximum of soil settlement occurred, which was 0.08%H₀ (H₀ is the maximum excavation depth). With the increase of excavation depth, the state changed from static to active. Under the same condition, the bending moment of the wall increased first and then decreased with the depth. The reverse bending point is near 1.23H₀.

1. Introduction
The integration of underground single structure and foundation pit retaining structure is a design concept that combines basement exterior wall and retaining structure, which can effectively shorten the construction period, reduce waste of resources, and has significant economic benefits[1]. At present, there have been many achievements in the research on the integrated foundation pit supporting structure. Sun et al.[2], Wu et al.[3], Chen et al.[4] analyzed the on-site monitoring data and discussed the deformation and stress state during the excavation of the "two walls in one" diaphragm wall. Chen, Zhang et al., Sun et al. [5-7] discussed the construction process and key technical problems of permanent diaphragm wall based on engineering examples. Zhong et al.[8] used finite element software to carry out detailed simulation analysis on the temperature stress of the integrated supporting structure. Hu et al.[9] calculated the strength and durability of the "pile-wall integration" structure under the working conditions of service stage and earthquake resistance. Lu et al.[10] studied the lateral movement of retaining piles, the settlement of topsoil outside the pit, and the rebound of soil at the bottom of the pit during foundation pit excavation, and believed that the combination of retaining and main structure could reduce the deformation of the foundation pit during construction.

The existing research results analyzed the field monitoring data and numerical simulation results of the integrated foundation pit supporting structure, and there are few research reports on physical model...
tests. Therefore, this paper carries out indoor two-dimensional plane strain model tests for the "two walls in one" integrated foundation pit structure and finds out the working performance of the integrated foundation pit supporting structure during excavation, which provides a scientific basis for future related research.

2. Experimental design

2.1. Model box
The size of the model box used in the test is 2370mm (Length) × 800mm (Width) × 1200mm (Depth), and the thickness of plexiglass on the sidewall is 15mm. Because the overall size of the foundation pit is too large, one area is specially selected as the model test for excavation of the foundation pit, with the size of 1500mm (Length) × 400mm (Width) × 800mm (Depth).

2.2. Test material
The model test soil is undisturbed soil collected on site. Due to changes in moisture and compactness during transportation, before the test, soil materials were screened, large soil particles were crushed to make their particle size less than 5 mm, and the initial moisture content and density of the soil were realized through compaction test. During filling, the soil was filled in layers of 10cm and compacted. The compacted soil parameters are shown in Table 1. PVC material was used to simulate the components of an integrated foundation pit supporting structure. The elastic modulus of PVC material is 3Gpa and Poisson's ratio is 0.4.

Table 1. Soil parameters.

| Soil type  | Moisture content (%) | Density (g•cm⁻³) | Cohesive force (kPa) | Internal friction angle (°) |
|------------|----------------------|------------------|----------------------|---------------------------|
| Silty clay | 20                   | 2.018            | 15.99                | 14.21                     |

2.3. Test procedure
(1) To eliminate the friction effect between the supporting structure in the middle of the foundation pit and the inner wall of the model groove, a double-layer plastic film was pasted on the inner wall of the model groove. (2) Place the integrated supporting structure model in the model groove, stick strain gauges on the beams and walls of the model structure, and the bridge road was a half-bridging method. Place an earth pressure box outside the diaphragm wall. See figure 2 for the layout of the monitoring original. (3) Filling soil in layers on both sides of the model, uniformly compacting according to compaction test steps, simulating the bulk density of soil on-site, placing sand filled in plastic bags into the model and compacting at the same time, and filling gaps with fine sand. (4) After settlement for three days, debugging the instrument, excavating in layers according to Table 1, and recording the displacement and strain, and earth pressure values of corresponding positions during excavation.
3. Analysis of test results

3.1. Settlement Analysis of Soil Behind Wall

Figure 3 is the settlement distribution curve of the soil outside the foundation pit. As can be seen from figure 3, with the increase of excavation depth, the vertical displacement of the soil outside the diaphragm wall does not change much. When the excavation reaches the bottom of the foundation pit, the soil slightly bulges upward, with a size of 0.05mm. For the soil 10cm, 20cm, 30cm, and 35cm away from the diaphragm wall, from working condition 2, the soil at each position has a certain settlement, which gradually increases with excavation depth. Starting from working condition 3 (excavation depth is 15cm), the settlement of the soil 30cm away from the diaphragm wall is the largest compared with other positions, and the maximum settlement after the completion of all foundation pit excavation is 0.236 mm, which is 0.08% $H_e$ ($H_e$ maximum excavation depth).
3.2. Earth pressure analysis
Figure 4 shows the distribution of earth pressure at different depths outside the diaphragm wall under various working conditions. Under working condition 1 (excavation depth is 1.2cm), the soil shows the characteristics of static earth pressure, and the distribution of earth pressure at different depths outside the foundation pit is roughly straight. From working condition 2 to working condition 7, with the increase of excavation depth, the static earth pressure gradually transforms to the active earth pressure, and the diaphragm wall produces a certain deformation, which makes the curve begin to shift to the left, and the earth pressure above the excavation face of the foundation pit gradually decreases. The earth pressure at a depth of 10cm and 20cm is 0.083 kPa and 0.121 kPa respectively. When the depth is greater than 20cm, the earth pressure gradually increases with the depth.

3.3. Bending moment analysis of wall body
Figure 5 shows the wall bending moment values under different working conditions. As can be seen from the curve in figure 5, the bending moment distribution along the depth direction is "S" shaped. Under the same working condition, the bending moment of the wall body increases first and then decreases with the depth. The bending moment value is the largest at 20cm (0.67 \( He \)), and the reverse bending point appears near 37cm (1.23 \( He \)). The negative moment value is the largest at the depth of 40cm (1.23 \( He \)). Under working condition 7, the maximum bending moment value and the maximum negative bending moment value of the diaphragm wall are 0.76N\( \cdot \)m and -0.26N\( \cdot \)m respectively.
4. Conclusion
The integrated foundation pit supporting structure can reduce resource consumption and construction time, and there are few results in laboratory test research on this structure. This paper studies the working performance of the two-wall integrated foundation pit supporting structure under different excavation depths through physical model tests. The test indicates that with the increase of foundation pit excavation, the settlement of soil outside the integrated foundation pit supporting structure gradually increases, and the settlement of soil at 30cm away from the diaphragm wall is the largest, reaching 0.236mm under working condition 7. After working condition 3, the earth pressure behind the wall decreases first and then increases with the increase of depth, and the earth pressure above the excavation face decreases with the increase of excavation. The bending moment of the diaphragm wall is distributed in an "S" shape with the increase of depth. Under the same working conditions, the bending moment of the wall increases first and then decreases with the depth, with the maximum bending moment near 37cm, and the maximum negative bending moment at 40cm depth. The research results of this paper have reference value for the research of integrated foundation pit supporting structure.

In the future, parameter sensitivity analysis of integrated foundation pit supporting structure will be carried out.

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