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Indoor model test study on the interaction between existing building renovation and adjacent foundation pit excavation

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Abstract
Based on the background of the renovation of Shanghai Gymnasium and the adjacent deep and large foundation pit project, this paper designed an indoor model test device for the impact of the interaction between the renovation of existing buildings and foundation pit excavation on the surrounding environment of the foundation pit. Considering the interaction between the renovation of buildings and foundation pit excavation, the response of the building foundation pit retaining structure was studied. The research results show that the internal force and deformation of the foundation pit retaining structure vary with the excavation depth. Compared to unloading transformation, loading transformation has a greater impact on the deformation of the retaining structure.

Keywords: *Laboratory model test; Building renovation; Interact; Foundation pit works*

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I. INTRODUCTION

With the continuous development of China's economy and society, urban construction has shifted from rapid development and construction to a development stage where both stock upgrading and incremental structural adjustment are emphasized. Urban renewal, with the renovation of existing buildings as the main content, will become an important way for urban development transformation and upgrading. While large-scale public buildings are being renovated, there will also be construction of foundation pits around them. During the excavation process of foundation pit engineering, the renovation of surrounding buildings will inevitably affect the safety of foundation pit engineering. Therefore, it is of great significance to study the interaction between unloading and reloading and foundation pit excavation during the renovation of existing buildings.

In the research of foundation pit engineering, scaled model tests have the characteristics of cost effectiveness and ease of fabrication. Their model materials and dimensions are designed using similarity theory, which can better reflect the settlement of surface soil and the deformation of retaining structures. Therefore, they are widely used.

Domestic and foreign scholars have conducted a lot of research on indoor model tests of foundation pit excavation [2-11], but there is less research on indoor model tests of the coupling effect of loading and unloading and foundation pit excavation during the renovation of existing buildings.

Therefore, based on the renovation of Shanghai Gymnasium, Shanghai Natatorium, and the deep and large foundation pit project of the newly built sports complex, this paper uses indoor model test methods to study the response of the foundation pit retaining structure under the condition of unloading and reloading during the renovation of existing buildings.

II. PROJECT REVIEW

In this paper, an indoor model test is used to simulate the interaction between the excavation of the foundation pit in Zone 2 and the "unloading loading" process during the demolition and reconstruction of the Shanghai Gymnasium. Figure 1 shows the plan of foundation pit in Zone 2. The excavation depth of the foundation pit in Zone 2 is 11.95 m to 12.3 m, with an area of approximately 10594 m2 and a perimeter of approximately 503 m. The north side is adjacent to the Shanghai Gymnasium, with a distance of 3.4 m from the foundation of the Shanghai Gymnasium, and a distance of 74 m from the subway line 1. The foundation pit adopts the support form of 1.0 m thick underground continuous wall+2 concrete supports.

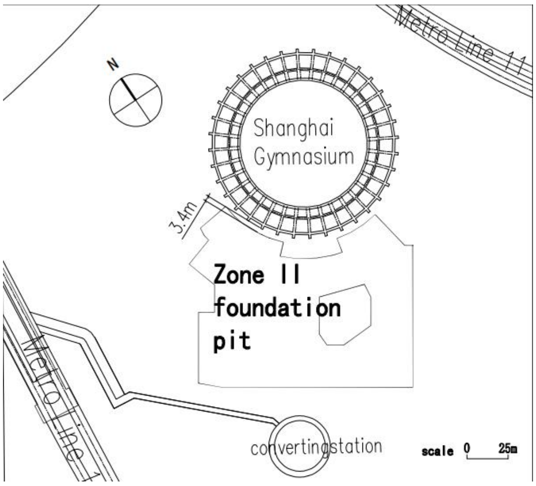
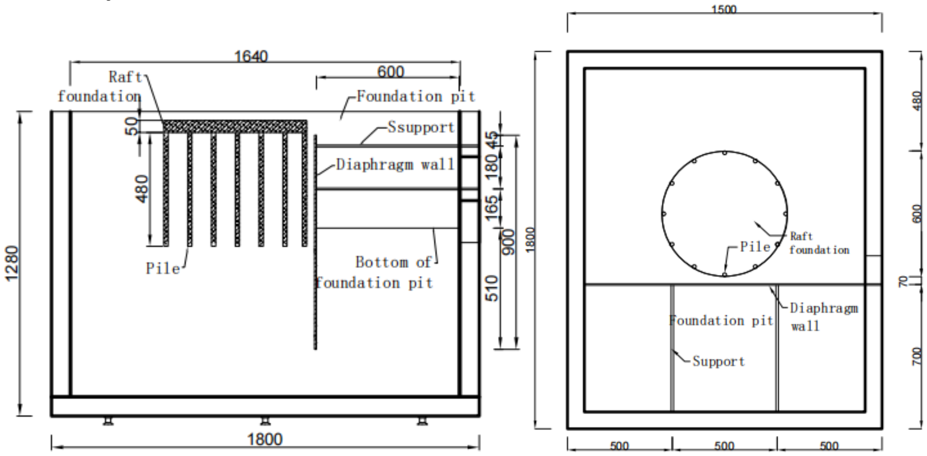


Figure1Plan of foundation pit in Zone 2

III. INTERIORMODELTESTDESIGN

3.1 Model box design

In this paper, the experimental design of indoor scale-down model is carried out according to the principle of similarity[12-16], and the foundation size of the pile raft, the distance between the building and the envelope, the excavation depth of the foundation pit and the depth of the support arrangement are determined according to the principle of geometric similarity. Determine the size of the envelope according to the principle of mechanical similarity.



（a）Model box profile (b) Top view of the model box

Figure2 Schematic diagram of model box

The size of the model box is 1.8 m × 1.5 m × 1.2 m, with a foundation pit size of 1.5 m × 0.65 m × 0.39 m。 Figure 2 is a schematic diagram of a model box. The model of Shanghai Gymnasium has a diameter of 600 mm, a minimum distance of 70 mm from the foundation pit, a raft foundation thickness of 50 mm, and a pile length of 480 mm; The underground continuous wall model is an 8 mm thick LY12 aluminum alloy plate; The support material in the foundation pit is 304 stainless steel, with an outer diameter of 7 mm and a wall thickness of 1 mm for the upper support, and an outer diameter of 9 mm and a wall thickness of 1 mm for the lower support. The excavation depth of the foundation pit is set to 390 mm, with an upper support arrangement depth of 45 mm and a lower support arrangement depth of 225 mm.

3.2 Loading system design

The jack reaction method is used in the design to load, unload and reload. According to the geometric similarity ratio of 1:33, the load is loaded to 10.2 MPa. The load is unloaded from 10.2 MPa to 5.1 MPa through the pressure retaining valve in three stages. Each stage is unloaded to 1.7 MPa, and then loaded to 10.2 MPa. The composition of the loading and unloading system is shown in Figure 3.

Figure3Composition diagram of loading and unloading system

3.3Preparation of foundation soil

In this indoor model test, it is assumed that the soil mass is homogeneous sand, and the fill in the model is dry sand[17-20], and the controlled dry density is 1.55 g/cm^3. Its physical and mechanical parameters are shown in Table 1.

Tab. 1Physical and mechanical indexes of soil

Density $\rho / 10^3\ \mathrm{kg \cdot m^{-3}}$	Compression modulus E_s / MPa	Poisson's ratio μ	Cohesion c / kpa	Internal friction angle φ / °
1.73	2.18	0.32	0	25

3.4Layout of monitoring points

This article monitors the bending moment of the diaphragm wall, the horizontal displacement of the top of the diaphragm wall, and the axial force of the support. The number of monitoring points arranged is shown in Table 2 below.

Tab. 3List of monitoring points

Monitoring items	Arrangement quantity
Moment of diaphragm wall	18
Horizontal displacement of top of diaphragm wall	1
Support axial force	16

The monitoring arrangement for the bending moment, deep horizontal displacement, and support axial force of the diaphragm wall is shown in Figure 4:

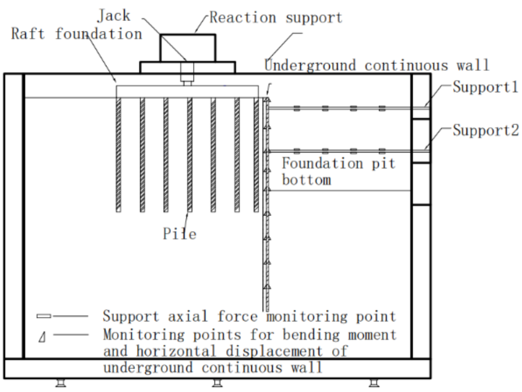


Figure4 Layout of monitoring points

3.5Test conditions

The simulated construction conditions of this foundation pit model test are shown in Table 3:

Tab. 3Table of construction conditions

Construction sequence
Excavate to the first support → construct the first support → unload to 8.5 MPa → unload to 6.8 MPa → unload to 5.1 MPa → excavate to the second support → construct the second support → load to 10.2 MPa → excavate to the bottom of the foundation pit

IV ANALYSIS OF TEST RESULTS

4.1Moment of diaphragm wall

Figure 5 shows the change rule of bending moment at the center of diaphragm wall under three working conditions.

As shown in Figure 5, the bending moment at each point at the center of the underground continuous wall increases with the increase of the excavation depth, and is distributed in a "M" shape along the depth at different excavation stages. Affected by the three-level unloading, after unloading to 5.1 Mpa, the bending moment of the underground continuous wall buried below the bottom of the foundation pit significantly decreases, but after the second support is loaded after construction, the bending moment at each point significantly increases, indicating that the building reconstruction loading has a significant impact on the bending moment of the underground continuous wall. The bending moment of the diaphragm wall reaches its peak value when it is excavated to the bottom of the foundation pit. The maximum positive bending moment occurs at a depth of 0.591 m, reaching a peak value of 163.50 N · m. The maximum negative bending moment occurs at a depth of 0.385 m, reaching a peak value of - 249.92 N · m.

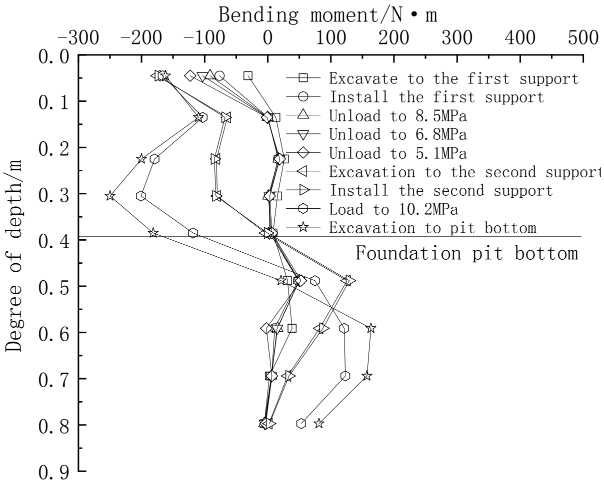


Figure5Bending moment variation diagram of diaphragm wall

4.2Horizontal displacement of diaphragm wall

Figure 6 shows the variation pattern of horizontal displacement at different depths of the center of the underground continuous wall. A positive horizontal displacement of the diaphragm wall indicates that the diaphragm wall is displaced towards the foundation pit side.

As can be seen from Figure 6, when excavating to the first support, the horizontal displacement of the underground continuous wall gradually decreases with increasing depth. When the first support is completed, the horizontal displacement of the underground continuous wall remains basically unchanged, and the upper support effectively controls the horizontal displacement of the underground continuous wall. When excavating to the second support, the horizontal displacement at each depth of the diaphragm wall increases sharply. When excavating to the second support after unloading to 5.1 MPa, due to the halving of the building load, the maximum increase in horizontal displacement of the diaphragm wall at a depth of 0.045 m reached 63.8%. When the excavation reaches the bottom of the foundation pit, the horizontal displacement of the underground continuous wall at each depth reaches the maximum. Due to the limitation of the upper and lower supports, the increase in the horizontal displacement of the underground continuous wall is much smaller than the previous excavation step. The maximum horizontal displacement of the underground continuous wall occurs at a depth of 0.045 m, and the maximum horizontal displacement reaches 7.48 mm.

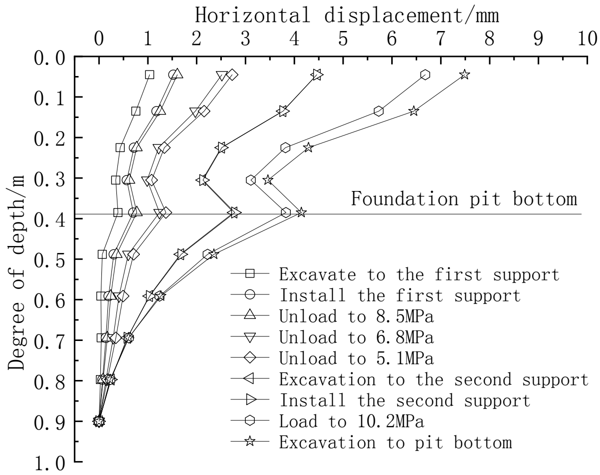
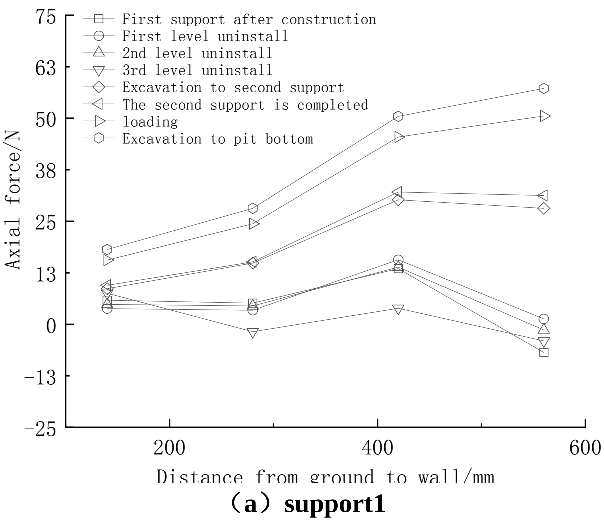


Figure6Horizontal displacement variation diagram of diaphragm wall

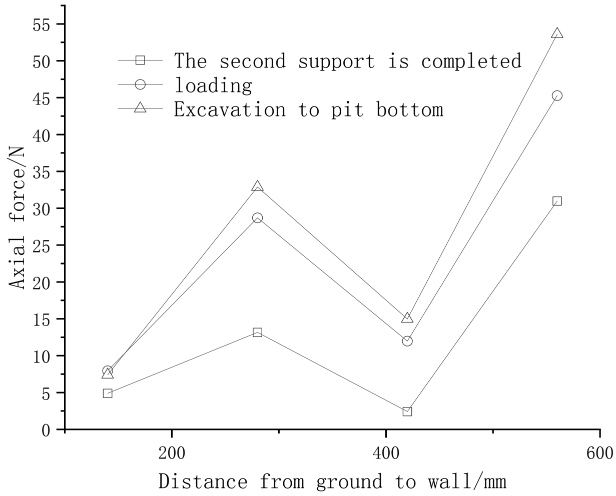
4.3Support axial force

Figure 7 shows the change of support axial force.

As can be seen from Figure 7, the changes in axial forces of support models 1 and 2 gradually increase with the increase in the excavation depth of the foundation pit. After erecting the two lower supports, the erection of the lower support better limits the horizontal displacement of the soil mass and shares the pressure of the upper support. The axial force of the upper support increases slightly but tends to stabilize overall. The axial force of support 1 is not significantly affected by unloading, and decreases with unloading. However, when the excavation reaches the second support, the peak axial force of support 1 rises sharply, and subsequently, as the excavation depth of the foundation pit increases, the axial force of support 1 gradually increases. After reloading, the axial force of the support continues to increase, and the excavation of the foundation pit has broken the stress equilibrium state of the original foundation. The soil behind the wall above the excavation surface generates stress release as a load increment, causing horizontal displacement of the underground continuous wall, causing axial compression of the support, resulting in an increase in the axial force of the support. The loading occurs after the second support is erected, and the axial force of support 2 increases significantly. However, due to the sharing of support 2, the axial force of support 1 increases slightly. After excavation to the bottom of the foundation pit, the maximum axial force of the support reaches 57.25 N for the upper support and 53 N for the lower support.



（a）support1



（b）support2

Figure7Variation of horizontal displacement in deep soil layer

V. CONCLUSION

1) The internal force and deformation of the foundation pit retaining structure vary with the depth of excavation. Compared to unloading transformation, loading transformation has a greater impact on the deformation of the retaining structure.

2) The unloading and reconstruction of buildings has a significant impact on the internal force and deformation of the retaining structure. With the unloading of buildings, the bending moment and deformation of the underground continuous wall and the axial force of the upper support significantly decrease.

3) When the loading transformation is completed, the internal force and deformation of the foundation pit retaining structure increase sharply, and the actual project should closely monitor the impact of the building loading transformation.

REFERENCES

[1]. WANG Jun．Thinking of comprehensive performance improvement and renovation of existing public buildings in China［J］. Building，2020（17）：12-15.

[2]. G.J.YUN，M.F.Bransby，British Geotechnical Association（BGA）. Centrifuge modeling of the horizontal capacity of skirted fo undations on drained loose sand［C］. Foundations：Innovations，Observations，Design and Practice．2003：975-984.

[3]. Tang Yiqun，Yan Xuexin，Wang Jianxiu，et al．Model test study of influence of high-rise building on ground subsidence［J］. Journal of Tongji University（Natural Science），2007（03）：320-325.

[4]. Hu Xin．Influence of foundation pit excavation under different conditions simulating by model test on existing tunnel［J］. Subgrade Engineering，2015（06）：151-155.

[5]. Huang Dawei，ZHOUShunhua，FENGQingsong，etal．Scaled model test design for interaction between shield tunnel and stratum［J］. Journal of China Railway Society，2018，40(06)：127-135.

[6]. Xu Qianwei，MaXianfeng，ZhuHehua，etal．Centrifugal model test on extra-deep foundation pit excavations in soft ground［J］. China Civil Engineering Journal，2009，42（12）：154-161.

[7]. Wang Baocun，ZhuDayong，WangXiaojin，etal．Laboratory model test for the excavation of foundation pit close to river［J］. Journal of Hefei University of Technology（Natural Science），2016，39（06）：790-794.

[8]. Ma Xianfeng，CaoMingyang．Centrifuge model tests on excavation in Shanghai soft soil layers using in-flight excavation tools［J/OL］. China Civil Engineering Journal：1-11［2022-10-27］.

[9]. Wei Shi，DengChenglong，LiangRongzhu，etal．Model testing on deformation characteristics of the locking steel pipe pile retaining structure by using 3D printing ［J］. Chinese Journal of Rock Mechanics and Engineering，2020，39（S2）：3676-3686.

[10]. Shi Xiaojun，YueQingxia，LiJie．Influence factor analysis of foundation model in shaking table test considering soil-structure dynamic interaction［J］. Journal of Architecture and Civil Engineering，2007（04）：50-53+59.

[11]. SHI Chenhua，CAOChenyong，LEIMingfeng，etal．Effects of lateral unloading on the mechanical and deformation performance of shield tunnel segment joints［J］. Tunnelling and underground space technology，2016，51（Jan.）：175-188.

[12]. Song Yu．Test principle of similitude model［M］. Beijing: China Communications Press，2016.

[13]. ZuoDongqi．Theory and method of model test［M］. Beijing：Water Resources andElectricPowerPress，1984.

[14]. Yang Shantong，ChenNa，ChenFeiyu，etal．Research on similar materials used in model test for deep foundation pit［J］. Railway Engineering，2015（09）：78-81.

[15]. Zhang Jinqian，LiuZiqi．Lecturethree：The law of similarity in model experiments［J］. China Harbour Engineering，1983（03）：66-71.

[16]. Ma Wenjie，JiangDaijun，WangBolin，etal．Experimental study on the influence of pile with aspect ratio on the bearing capacity of pile foundation［J］. Sichuan Building Science，2018，44（6）：69-73.

[17]. Cong Yu，MaXianfeng，YuanJuyun，etal．Study on sample preparation with sand pourer in centrifuge test［J］．Subgrade Engineering，2014（05）：77-80．
[18]. Zhao Fan，HuHesong，YangGuangshu，etal．Development of the model box design and soil sample preparation technology for pile-soil model test［J］．Low Temperature Architecture Technology，2017，39（07）：66-70．
[19]. Standard for geotechnical testing method：GB/T 50123—2019［S］．Beijing：China Planning Press，2019
[20]. Liu Guobin，Wangweidong．Deep excavations engineering handbook［M］．Beijing：China Architecture and Building Press，2010：48-50．