

# Analysis of influence of inner walls on deformation characteristics of retaining structures and adjacent soil

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**Abstract :** A retaining structure induces a specific spatial effect because of differences in its stiffness at different locations. When a partition wall is placed inside a retaining structure, it can significantly influence the development of the deformation of the retaining structure and the adjacent soil. In this study, a three-dimensional finite element analysis was performed on the deformation of the retaining wall, and the result revealed that a partition wall at the center of a retaining wall can significantly reduce the maximum lateral displacement of the retaining wall. The maximum lateral displacement of the retaining wall without and with a partition wall was 68.1 mm and 45.2 mm, respectively. The lateral displacement reduced by 33.6% in the presence of partition wall. Before and after the introduction of the partition wall, the maximum displacement of lateral displacement was 64.6 mm and 44.4 mm, respectively, the reduction being approximately 31.3%; the corresponding maximum settlement of soil was 19.8 mm and 10.6 mm, the reduction being approximately 46.5%. The placement of partition walls near the bottom of an excavation can significantly reduce the lateral displacement of a retaining wall. When the partition spacing is greater than 30 m, one can control the deformation of the retaining wall by reducing the spacing of the partition.

## Introduction

At present, the design of foundation pit usually simplifies the design problem to the problem of plane strain state, and the deformation of foundation pit shows a significant spatial effect during excavation. The study of deformation characteristics by a three-dimensional method can better recognize actual deformation characteristics of a retaining wall for use in a retaining wall design. The three-dimensional effects of retaining structures are mainly due to different system stiffness at positions of the retaining structure.

Many researchers [1-4] have analyzed the spatial effect of retaining structures through numerical analysis and compared it with experimental data. At present, supporting retaining structure systems are widely applied in soft soils. Fook [5] combined numerical simulation and field test data to study the spatial effect of multilayer support excavation. He summarized the factors that influence the three-dimensional effect of retaining structures; namely, excavation length to depth ratio, depth of soft soil, and support system stiffness. Finno [6] and Roboski [7]

combined a large number of numerical model analysis results to derive the empirical formula of soil displacement at different positions of the foundation pit under three-dimensional conditions from the displacement of soil under plane strain.

At present, depth and scale excavations are on the rise; thus, the deformation of retaining structures and the adjacent soil is increasingly extensive. The means of using the deformation characteristics of the spatial effect of foundation pits for deformation control have important practical significance.

## **Project background**

This project is an old urban renewal project involving five floors and four underground floors. The total construction area is approximately 21900 m<sup>2</sup>, with an underground construction area of approximately 12900 m<sup>2</sup>. The foundation pit support comprises four concrete supports, and a foundation pit retaining structure has any of the following main features:

(1) The excavation depth of the foundation pit is large, and the number of basement floors is four. The excavation depth of the foundation pit is 21.65 m, which is an ultra-deep foundation and, therefore, the influence area of the excavation is large.

(2) The excavation area of the foundation pit is not large, the floor area of the whole foundation pit is approximately 6000 m<sup>2</sup>, and the size of the foundation pit is approximately 100 m × 60 m.

(3) The foundation soil in the depth range of the foundation pit is mainly filled with soil, silty clay and muddy silty clay. The filling composition is complex, the strength of muddy soil is low, the compressibility is high, and the thickness is large. The internal forces and deformation control is very unsuitable for design purposes.

(4) The surrounding environment of the foundation pit is complex, and there are several buildings under historical protection, all located within the main influence zone of the excavation. Therefore, in addition to guaranteeing the stability and safety of the foundation pit, the key and most difficult issue lies in minimizing the deformation of the foundation pit and the influence of the deformation of the foundation pit on the surrounding environment.

Plaxis 3D software was used in this project to perform finite element analysis on a partition wall inside an envelope in order to simulate the influence of excavation on the envelope and settlement of the surrounding surface. Through the pre-analysis and calculation of the corresponding construction and design, we were able to ensure the safety of the foundation pit and surrounding buildings.

## **Results of numerical simulation**

**Case 1.**(1) Close to the center of the long edge plus an intermediate retaining wall of height 20 m, and placed at 20 m below the surface.

As can be seen from Figure 1, the changing trend of the retaining structure and the soil deformation is obviously different after the application of the intermediate partition wall. Prior to the application of the intermediate partition wall, the deformation of the retaining structure and the settlement of the soil mostly occurred near the center of the retaining structure; however, with the application of the middle wall, the maximum lateral displacement of the envelope occurred between the middle wall and the outer wall of the envelope. Subsidence also exhibits a similar tendency. It can be inferred that the middle partition wall obviously influenced changes to the

envelope and soil settlement.

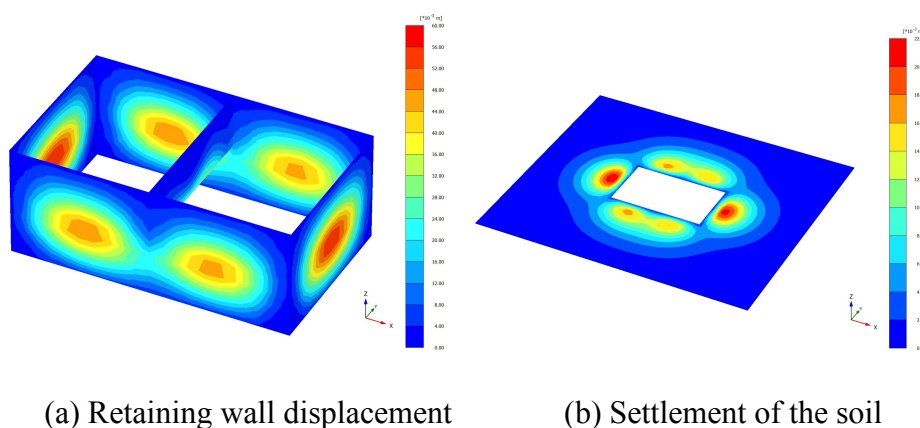


Fig. 1 Retaining wall structure and soil displacement cloud with inner wall

(2) The influence of the partition wall on the lateral displacement of the envelope.

As can be seen from Figure 2, when a retaining wall is applied at the center of the longer side of a retaining structure, the lateral displacement of this side is significantly reduced, and the maximum lateral length of the retaining structure without and with the partition were 68.1 mm and 45.2 mm, respectively, and the lateral displacement after the application of the central partition was reduced by 33.6%. The maximum lateral displacements of the shorter side without and with walls were 58.5 mm and 55.0 mm, respectively. It can be seen that the application of a retaining wall has a significant impact on the longer side but less on the other side. The effect of the partition wall on the building envelope and the settlement of the soil is mainly reflected in two aspects: 1) The application of the partition wall is conducive to improving the integrity of the envelope system, and then to better control the envelope and soil settlement deformation; 2) The stiffness of the envelope system is often larger at the corners, and smaller near the center when the partition wall is located near the center of the envelope structure.

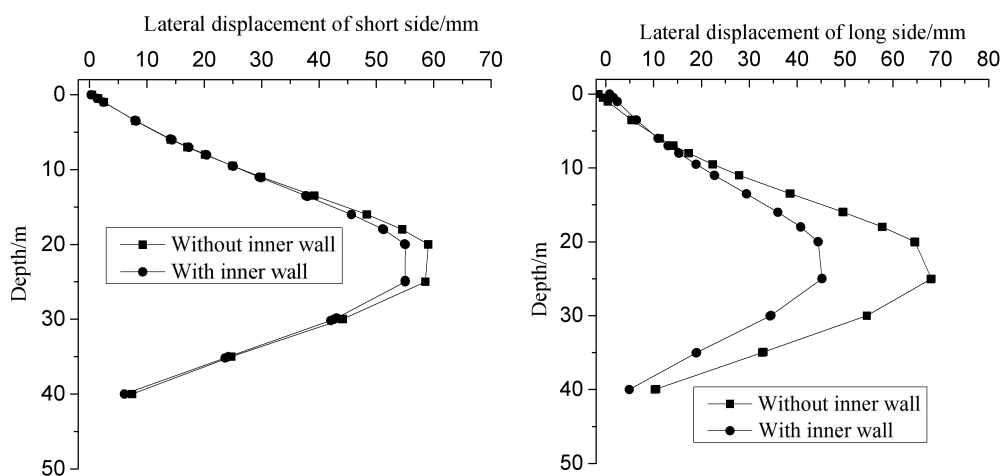


Fig. 2 Comparison and analysis of maximum lateral displacement of long and short sides

### (3) Effect of partition wall on lateral displacement of retaining structure and surrounding surface subsidence

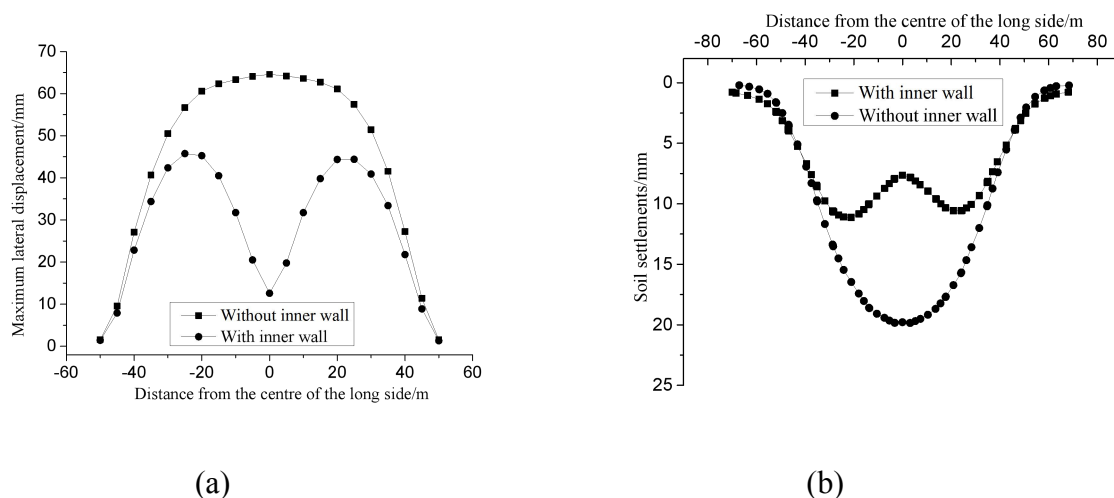


Fig. 3 Comparison of retaining structure and soil settlement:

- (a) Lateral displacement of the retaining wall at the bottom of the excavation
- (b) Surface subsidence at a distance of 15 m from the parallel retaining wall

In order to better study the influence of the partition wall on the lateral displacement and soil settlement, the lateral displacement along the longer side of the bottom of the excavation, and the soil settlement at a distance of 15 m (0.75 He) parallel to the retaining structure were selected for analysis. It can be seen from Fig. 3 that the application of the intermediate partition wall has a significant effect on the maximum lateral displacement and trend of soil settlement. The lateral displacement of the retaining structure and settlement of soil mass tend to increase with the increase of the distance from the corner, reaching a steady state at a distance of more than 35 m; additionally, the application of the intermediate wall significantly inhibits the lateral displacement of the retaining structure. The soil settlement tends to increase according to an increase in distance from the corner. It can be seen that the lateral displacement of the retaining structure and the maximum settlement of soil mass decrease as well. The maximum lateral displacement of the retaining structure prior to and after the application of the partition walls were, respectively, 64.6 mm and 44.4 mm, decreasing by approximately 31.3%. The corresponding maximum values of soil subsidence were 19.8 mm and 10.6 mm, respectively, corresponding to a reduction of 46.5%.

**Case 2.** Up to three partition walls of height 10 m are placed along the longitudinal direction of the envelope for the final excavation. For a single wall, it is located at the center of the long edge; for two walls, they are located symmetrically 15 m from the center; and for three walls, one is placed at the center of the long edge, the other two are located 20 m from the center.

#### (1) The influence of the partition wall on the lateral displacement of the retaining structure

As can be seen from Figure 4, when a lot of partitions are placed at the bottom of the excavation, the lateral variation of the retaining structure at the excavation bottom is different. It can be seen that the maximum value of lateral displacement is often located in the middle of the partition wall or at the center of the partition wall and the retaining wall. The more the number of partition walls, the smaller the maximum lateral displacement of soil.

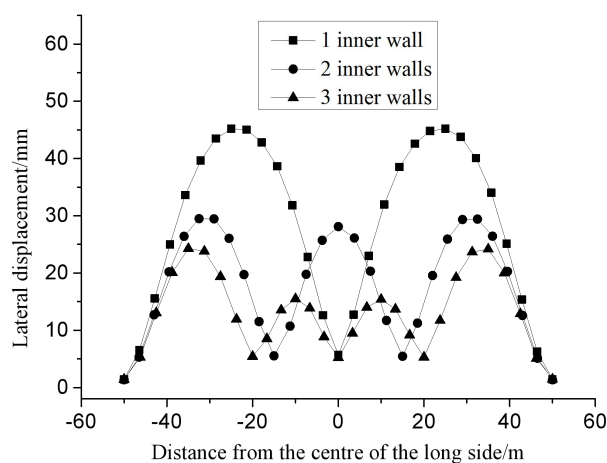


Fig. 4 Effect of different numbers of partition walls on lateral displacement at the bottom of excavation

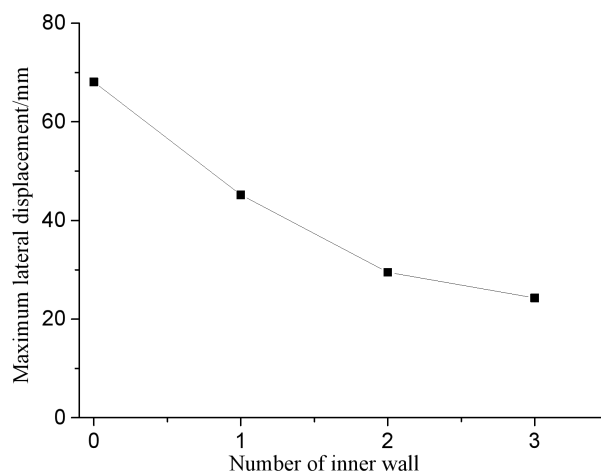


Fig. 5 The effect of the number of partitions on the maximum lateral displacement

It can be seen from Fig. 5 that the maximum lateral displacement of the retaining structure decreases rapidly and then decreases slowly when the number of retaining walls increase. Corresponding to no partition, one partition, two partitions, three partition walls, the maximum lateral displacements were 68.1 mm, 45.2 mm, 29.5 mm and 24.3 mm, respectively. It can be seen that we can carry out deformation control of the retaining structure by increasing the number of partition walls. We need to make a wise decision to improve its economic efficiency. From the above results, it can be found that when the distance between partitions is greater than 30 m, the deformation of the envelope can be reduced by reducing the distance between the partitions. When the distance between partitions is less than 30 m, the change in lateral displacement of the envelope with partition wall spacing is not obvious.

## Conclusion

We make the following concluding remarks based on the results obtained in this study:

1. Placing a partition wall at the center of an envelope structure can significantly reduce the maximum lateral displacement of the envelope wall. The maximum lateral displacement of the enveloping structure without and with the partition wall was 68.1 mm and 45.2 mm, respectively. The lateral displacement was reduced by 33.6% after applying the middle wall.
2. Prior to and after the application of the partition wall, the maximum lateral displacement of the retaining structure was 64.6 mm and 44.4 mm, respectively, decreasing by approximately 31.3%. The corresponding maximum settlement of the soil mass was 19.8 mm and 10.6 mm respectively, decreasing by approximately 46.5%.
3. Building a partition wall near the bottom of an excavation can significantly reduce the lateral displacement of the enveloping structure. When the partitioning distance is more than 30 m, the deformation of the enveloping structure can be controlled by reducing the partitioning distance of the partition wall.

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