Use of Strut Free Systems in Deep Excavations

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ABSTRACT: This paper presents the performance of cross walls, buttress walls and their combination in reducing wall deflection and ground settlement in excavations. Three dimensional finite element method was used to evaluate the performance. Cross walls have a very good effect in reducing the movement but expensive. Buttress walls have a moderate effect in restraining the wall deflection. With proper combination of cross wall and buttress walls, both the wall deflection and cost can be reduced significantly, even to achieve a strut free excavation condition.
Keywords: Excavation, cross wall, buttress wall, strut free system.

1. INTRODUCTION

The huge population in urban areas due to economic development has caused situations such as much denser buildings and deeper foundation excavations than ever before. Construction disasters and adjacent building damage often occur due to ground settlement as a consequence of deep excavation, which not only affects construction progress, but also increases public nuisance. The protection of adjacent buildings has become a major concern for designers and contractors of deep excavations. It is thus an important hazard prevention task in geotechnical engineering to conduct a study on protection of adjacent buildings when deep excavations are carried out. The integrity of adjacent buildings can be protected by underpinning. Nevertheless, it is not practical to underpin a large number of target buildings, either from a financial or political point of view. Therefore, reducing excavation induced movements to a tolerable amount by auxiliary measures is a viable alternative. This paper presents the performance of cross walls, buttress walls and combination of cross walls and buttress walls in reducing the wall deflection or ground settlement. Moreover, a strut free excavation system is presented using a combination of cross walls and buttress walls.

2. CROSS WALL

The basic configuration of a cross wall is shown in Figures. 1(a) and 1(b), which refers to the construction of a wall, connecting two retaining walls opposite each other, prior to excavation.

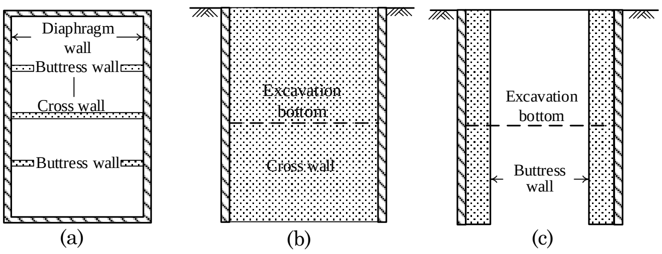

Figure 1 (a) plan (b) cross walls (c) buttress wall

The cross wall functions as a strut-like component, which exists before excavation. Along with excavation, cross walls provide a powerful resistance to counteract the lateral displacement, so as to resist the lateral earth pressure on the back of the retaining walls. In theory, movement of the retaining walls near the cross wall will be restrained during excavation, and the lateral displacement of retaining walls will decrease. Ground settlement outside the excavation will be reduced too, which therefore achieves the protection of adjacent buildings.

Figure. 2(a) shows the UPIB excavation, which was installed with cross walls in the north-south direction. The excavation was completed using the top–down construction method (Figure. 2(b)). The thickness of the diaphragm wall (t) was 1.5 m. The depth of the wall (Ht) was 57.5 m. To reduce the lateral wall deflection and ground settlement induced by excavation, 3 cross walls of 1.0 m thickness and 26 m intervals were constructed and their depths were between GL-1.5 m and GL-45 m in the north–south direction. The cross walls between GL0 m and GL-1.5 m were backfilled with the in situ soil, those between GL-1.5 m and GL-22 m were cast with 13.7 MPa concrete, and those below GL-22 m were cast with 24.0 MPa concrete. The cross wall were demolished with excavation.

Figures. 3(a) and 3(b) show that the analyzed wall deflections at SO-1 and SI-8, respectively, for stages 7 and 9. For comparison, analysis with assumption of no cross walls was also performed. The maximum wall deflection at the midpoint of two cross walls was predicted to have a 67% reduction by the installation of such walls (SO-1) whereas 77% at the cross wall section (SI-8). Installation of cross walls can significantly reduce lateral wall deflections [3].

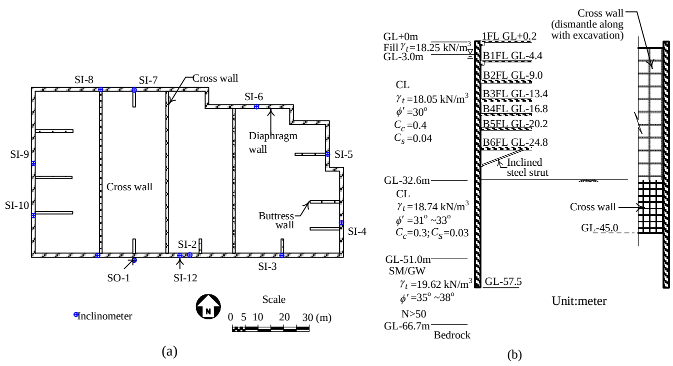

Figure 2 The UPIB excavation project (a) plan (b) profile

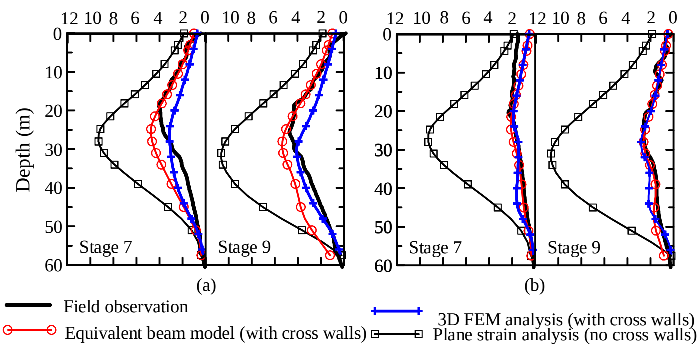

Figure 3 Comparison of analyzed and measured wall deflection (a) SO-1 (b) SI-8

3. BUTTRESS WALL

The basic configuration of a buttress wall is depicted as shown in Fig. 4(a). A buttress wall is similar to a cross wall in terms of construction. It is a concrete wall perpendicular to the diaphragm wall constructed before excavation, but not connected to the opposite diaphragm wall. The location of the counterfort can be arranged either at the inner or the outer side of the retaining wall as shown in Figure. 4(a).

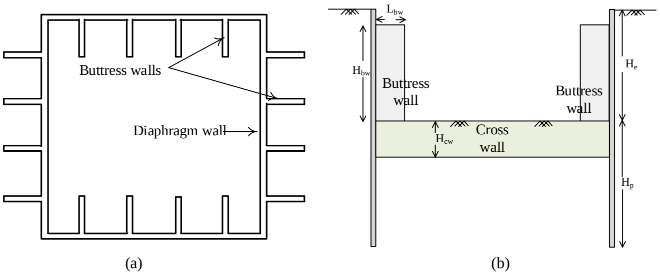

Figure 4 Locations of buttress walls (b) Combination of Cross and buttress walls

The author and his group have demonstrated that if the buttress walls were demolished with excavation, the main mechanism of buttress walls in reducing the wall deflection comes from the frictional resistance between buttress walls and adjacent soil [4] The combined stiffness of buttress walls and diaphragm walls play little contribution in reducing the wall deflection. Figure. 2 also shows three buttress walls with 12 m in length and 15 m in length were allocated in the west and east sides, respectively. The analyzed wall deflection and ground settlement agreed well with the monitored values (Figure. 5). The analyzed wall deflection and ground settlement for the case of buttress walls were moderately smaller than those without buttress walls. Installation of buttress walls certainly has some effects in reducing the wall deflection and ground settlement. The amount of reduction in wall deflection was 67.7 mm at SI-9 and 52.6 mm at SI-10, almost one third of wall deflection and ground settlement reduced.

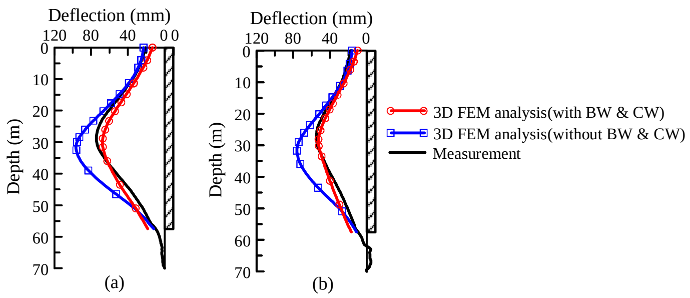

Figure 5 Measured and computed wall deflections at the final stage for UPIB (a) SI-9 (b) SI-10

The author and his group also demonstrated that when buttress walls maintained during excavation, i.e., no demolish with excavation, the combined stiffness of buttress walls and diaphragm walls plays a major role in reducing the wall deflection and ground settlement and frictional resistance between buttress walls and soil play little role. The retaining wall behaves as a rigid stiff retaining wall and all of the wall, from top to bottom would move laterally. Fig. 6 shows the analyzed wall deflections at the final stage for the cases of buttress wall demolished with excavation, inner buttress wall but maintains during excavation and outer buttress walls. The wall deflection can be reduced to a certain amount but its effect is still less than those of cross walls.

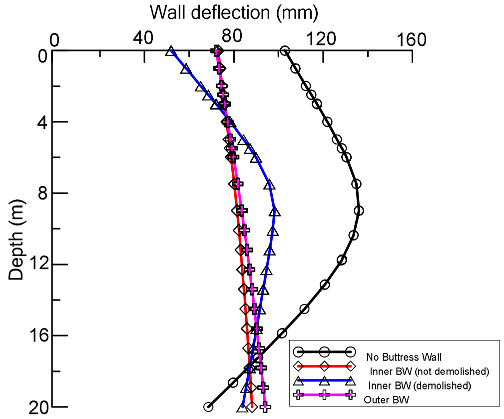

Figure 6 Wall deflections for excavation with inner and outer buttress walls

4. COMBINATION

The buttress and cross walls can be combined to obtain more effect in reducing the wall deflection and cost. Fig. 4(b) shows a possible of combination. The effect depends on the buttress wall length (L_{bw}), cross wall depth (D_{cw}) and cross wall spacing (s_{cw}). Figures. 7(a) and 7(b) show the wall deflection at the middle of two BW/CW for demolished buttress wall and maintained buttress wall for the 28 m and 8 m spacing, respectively. The wall deflection can be reduced significantly [5].

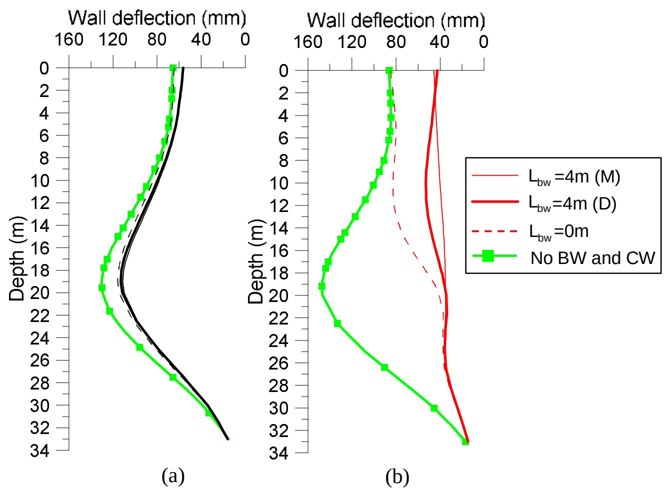

Figure 7 Spacing of BW/CW (a) 28 m (b) 8 m

5. STRUT FREE EXCAVATION SYSTEM

Different types of Cross walls and cross walls can be combined to have more effect in reducing the wall deflection and ground settlement. Figure. 8 shows an excavation with different arrangements of buttress wall where the excavation depth was 9.2 m. The maximum wall deflection at the final stage was about 50 mm [6].

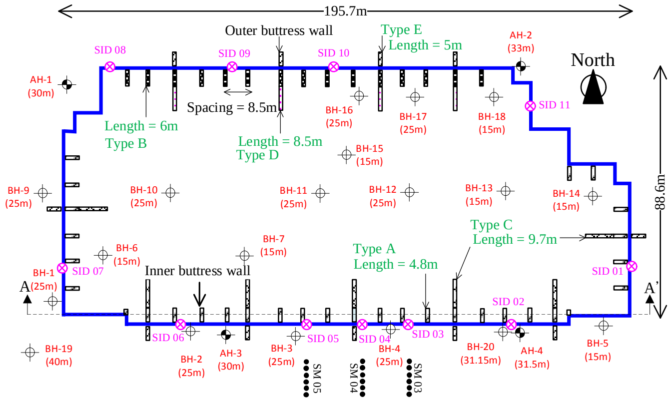

Figure 8 A strut free excavation system by combination of different shapes of buttress walls

Figure. 9 shows the RFD system, which comprises four main structures; namely, diaphragm walls, rib-walls, cross walls, and buttress walls; and a complementary structure; namely, the cap-slab. The characteristics of the RFD system were (1) forming a continuous earth retaining wall by constructing diaphragm walls along a circumference of the excavated zone; (2) forming a rigid and fixed retaining wall system by a series of rib-walls and cross walls as shown in Fig. 9(a); (3) forming a rigid retaining wall by buttress walls and the cap-slab. Fig. 10 shows the maximum wall deflection at the center of the long side is 165.4 mm, which is slightly larger than that of the top-down construction. However, the maximum wall deflection at the center of the short side is 50. 3 mm, which is much small than that of the conventional top-down construction. The amount of the wall deflection is related to several factors such as the depth of the cross wall, length of the buttress, and length of the excavation side. Interested readers can refer to the references [7, 8].

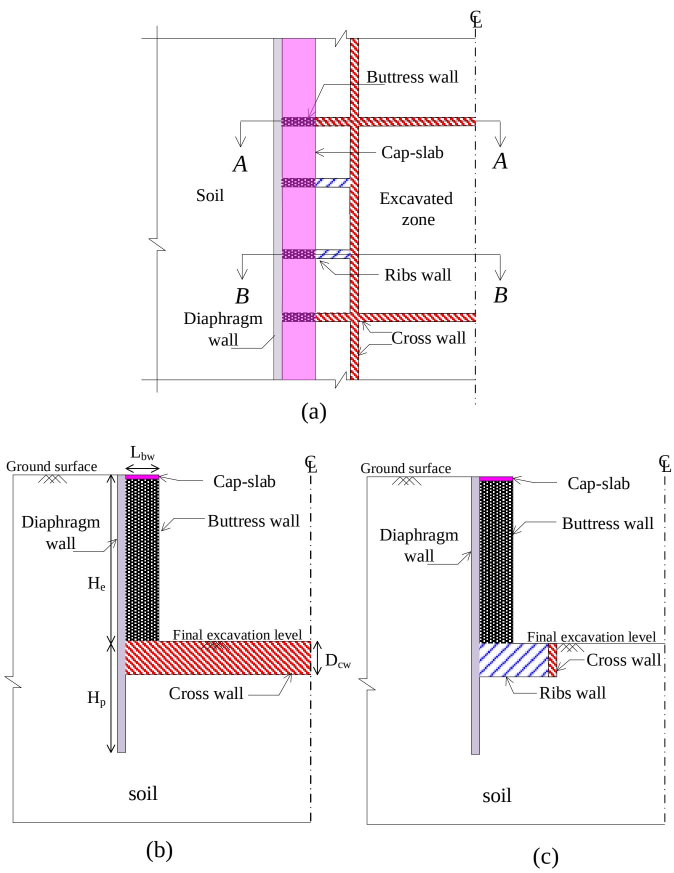

Figure 9 The RFD strut free excavation system

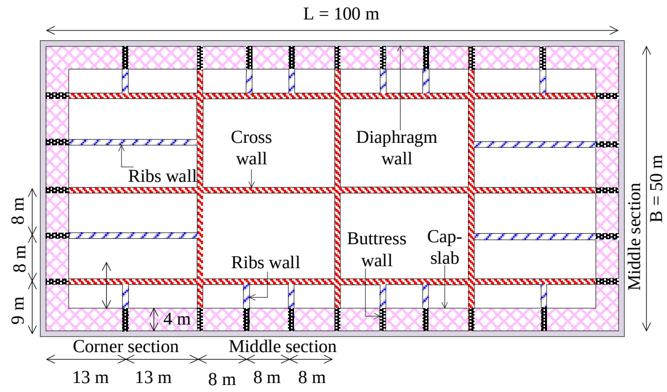

Figure 10 Plan view of the RFD strut free excavation system

6. CONCLUSION

This paper presents the performance of cross wall, combination of buttress wall and cross wall in deep excavations. Cross walls function as lateral struts but exist before excavation. Installation of cross walls in deep excavations can reduce the wall deflection to a very small amount. However, use of cross walls in a very wide excavation would be costly. Buttress walls can provide moderate improvement in reducing the wall deflection or ground settlement. The mechanism of buttress walls in reducing wall deflections mainly come from the frictional resistance between the side surface of buttress wall and adjacent soil when buttress walls demolished with excavation. When buttress walls are allocated outside the excavation, i.e., outer excavation, or buttress walls inside excavation but not demolished with excavation, the combined bending stiffness from both diaphragm and buttress walls is very large, so that the wall can deform linearly as a rigid retaining wall. Combination of cross wall and buttress wall can have good effect in reducing the wall deflection and ground settlement. With proper arrangement of buttress wall or cross wall in excavations can even reach a strut free excavation.

7. ACKNOWLEDGEMENTS

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