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Performance Evaluation of Anchored Diaphragm Walls under Service Loads

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ABSTRACT: Nowadays, RC or combined diaphragm walls are vastly used for deep excavation. This type of retaining structures consists of some piles, which are tied-back using the anchors and anchored from their toe to the ground. Concrete or wood plates were used between them. In order to evaluate the effects of some parameters on wall deflection and its internal forces, several models of combined diaphragm walls were selected and analyzed using FLAC software. Before developing the models, Lim and Braiud (1999) case study was modeled with FLAC2D and results were compared with the experimental results indicating acceptable accuracy of the modeling. The numerical model simulated the soldier piles with beam elements and the anchors with cable elements. The soil model used is a modified hyperbolic model with unloading hysteresis. The complete sequence of construction was simulated including the excavation and the placement and stressing of the anchors. The numerical model was calibrated against an instrumented case history. Then a parametric study was conducted. The parameters which was evaluated were: distance and stiffness variation, the bonded and un-bonded length of the anchors, the angle of the anchors and the first raw anchor location. By comparing the different parameters it was observed that the variation of the flexural stiffness of the soldier piles and variation of the bond length of the anchors contained the highest and lowest effect on the maximum horizontal displacement of the wall, respectively. Other analytical results consisting wall deflection vs. geometric characters of the wall were presented and discussed.

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1- Introduction

Diaphragm walls are widely used in the construction of underground structures and deep excavations. In the reinforced diaphragm wall, rationally by increasing the depth of excavation, the wall thickness which is required for stabilization is increasing.

Steel and concrete have a complementary relationship in civil engineering and construction. Otherwise, steel-concrete composite structures generally are more logical and economical for building structures.

In recent years, composite diaphragm wall was introduced as an economical and appropriate option for deep excavation in soils (specifically problematic soils). In this system, a combination of steel profiles used in the concrete wall and the steel profile play a role of soldier pile.

Sakai and Tazaki in 2000, invented a type of CD Walls (Composite Diaphragm Walls) by using steel profiles with specific connections inside a concrete wall diaphragm. The advantage of this type of wall was to increase the stiffness of the walls by using steel profiles. As a result, both the volume of consumable materials and the horizontal displacement of the wall would be decreased with increasing the stiffness [1]. Kunihiko and his colleagues in 2011, presented a new system of the composite diaphragm wall. In this system, a new rolled steel profile which had specific excrescence was introduced and this new steel profiles had better performance in composite structures [2].

According to the available information about the high performance of composite diaphragm wall, and significantly reduction in the thickness of the wall, there is the need to evaluate deformation behavior of CD walls by parametric study and achieve to the better understanding about behavior of this type of retaining walls.

2- Methodology

The FLAC2D software is used to simulate the TEXAS A&M excavation case study and verify it [4]. In this model, the modified Duncan-Chang model was used for soil behavior model [3]. The Duncan-Chang model was for calculate the stress state of soil in different parts and assign the unloading-reloading modulus to them.

Doing stage construction was tried to achieve better and realistic results from the simulation. You can see the results of the simulation and compare it by case studies results in the Figure 1.

The FHWA recommendation details was used for anchored walls [5].

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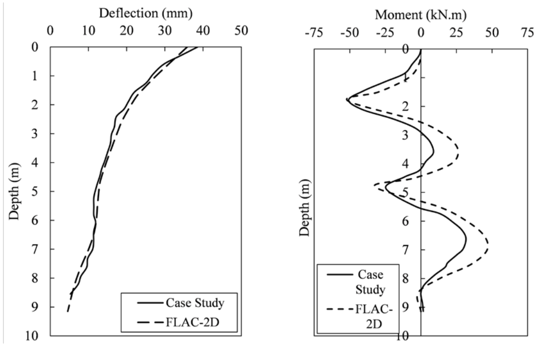

(a) (b)

Figure 1. Comparison between case study and simulation results a) deflection b) moment

3- Results and Discussion

After verification of the numerical model, the parametric study was performed. The parameters which were studied included horizontal angle of the anchors, bond and un-bond length of the anchors, horizontal distance of the soldier piles, flexural stiffness of the soldier piles and the first raw anchor distance from the top of the excavation.

Firstly, the stiffness of the piles was studied and the rational range of the flexural stiffness considered. By variation of the stiffness, it was observed that with increasing stiffness, the flexibility and the horizontal displacement of the wall was decreased and the moment in the wall was increased. It was also observed that reducing the stiffness had a greater impact on the horizontal displacement.

The range of the horizontal angle of the anchors (0-30 degree) was considered and the models were performed. The effect of angle of the anchors on the horizontal displacement of the wall was inhibited by increasing the angle of the wall and the displacement was reduced. But after the angle of 15 ° up to 30 the horizontal displacement of the wall had less decrease.

The Un-bond length of the anchors were changed and it was observed that by increasing the un-bond length, the horizontal displacement of the wall was lessened and the displacement mode of the wall changed from bulging to rotating around the heel of the pile. These changes had little effect on the moment in the soldier piles.

The bond length of the anchors were changed and it was observed that by increasing the bond length, the horizontal displacement of the wall was reduced.

The first raw anchors place had significant effect on walls deflection mode. By changing the first row anchor's distance from the top of the excavation, it was observed that by decreasing the distance, the horizontal displacement of the wall was decreased and the displacement mode of the wall changed from rotating around the heel of the pile to bulging. The horizontal distance of the soldier piles had a great effect on the walls deflection and it had a significant impact on performing an economical wall. By changing the horizontal distances of the soldier piles, it was proved that rotary mode would not change much, and just the horizontal displacement of the wall by reducing the horizontal distance was reduced. By comparing the different parameters and their effects on the horizontal displacement, it was declared that changes in the flexural stiffness of the soldier pile and the bond length of the anchors, consequently, had the highest and lowest effect on the maximum horizontal displacement of the wall.

4- Conclusions

In this study, by using numerical modeling, the performance of diaphragm walls under service loads were evaluated. Firstly, the numerical model was verified by and the results of the excavation case study which was placed at Texas A&M University using the FLAC^{2D}. Then parametric study was performed by changing parameters such as horizontal angle of the anchors, bond and un-bond length of the anchors, horizontal distance of the soldier piles, the flexural stiffness of the soldier piles and the first row anchor distance. In this parametric study the horizontal displacement of wall was the evaluation criteria and in each of the parametric studies the best situations were introduced.

- By changing the flexural stiffness of the soldier pile, it was observed that with increasing stiffness, the flexibility and the horizontal displacement of the wall was decreased and the moment in the wall was increased. It was also observed that reducing the stiffness had a greater impact on the horizontal displacement.
- By evaluation of the effect of angle of the anchors on the horizontal displacement of the wall was inhibited by increasing the angle of the wall, and displacement was reduced. But after the angle of 15 ° up to 30 the horizontal displacement of the wall had less decrease.
- By evaluation of the Un-bond length of the anchors, results presented that by increasing the un-bond length, the horizontal displacement of the wall was decreased and the displacement mode of the wall changed from bulging to rotating around the heel of the pile. These changes had little effect on the moment in the soldier piles.
- By evaluation of the bond length of the anchors, it was concluded that by increasing the bond length, the horizontal displacement of the wall was decreased.
- By changing the first row anchor's distance from the top of the excavation, it was observed that by decreasing the distance, the horizontal displacement of the wall was lessened and the displacement mode of the wall changed from rotating around the heel of the pile to bulging.
- By changing the horizontal distances of the soldier piles, it was obtained that rotary mode would not change much, just the horizontal displacement of the wall by reducing the horizontal distance was reduced.
- By comparing the different parameters and their effects on the horizontal displacement, it was observed that changes in the flexural stiffness of the soldier pile and the bond length of the anchors, consequently, had the highest and lowest effect on the maximum horizontal displacement of the wall.

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