Deep Excavation in Very Soft Soil Using Cross Wall as Lateral Support

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Abstract. Deep excavation in areas with very soft clay deposits need a good soil retaining system. Using diaphragm wall as soil retaining system for deep excavation is a good choice. Diaphragm wall is expected to limit the movement that occurs in the walls and avoid leaks that may occur in retaining system, this is needed to minimize damage to adjacent buildings. The top down excavation method by utilizing the basement floor as lateral resistance can be carried out to reduce the movement that occurs on the ground. In very soft soil areas with excavation distances to neighbors very close, the movement on the ground must be limited to minimize damage to adjacent buildings. Cross walls can be used to reduce the movement that occurs on the ground. Analysis finite element using the 2D Plaxis program was carried out to investigate the performance of the retaining wall. From the results of the analysis conducted shows that using a cross wall at a location below the raft pile can reduce the movement that occurs in the retaining wall and the excavation stage can be reduced. The results of this study can be used as a reference in the development of solution lateral support of soil retaining system in deep excation especially needed in very soft soil condition.

1. Introduction
With increasing the price of land and limited availability of land especially in bid cities, it is necessary to construct high rise buildings and basement for parking facility. The construction of deep basement which means that in implementation requires deep excavation is not an easy thing to do. It requires a suitable soil retention system and soil excavation planning, especially in densely populated areas where the distance between buildings is quite close. The movement and leaks that occurs in the retaining wall due to deep excavation carried out for the construction of basement and the leaks may occurs on the retaining wall which high ground water level and very soft soil is a very critical factor that needs to be considered. This is a challenge to find an appropriate excavation method and soil retaining system so that it does not cause negative effects on buildings around the excavation and construction of basement construction can be carried out quickly. Soil retaining wall systems to maintain slope stability in excavations in this study use diaphragm wall (Dwall). In deep excavation it is certainly not possible to use a retaining wall with a cantilever system because there will be very large movements that do not meet the requirement by the code criteria [12], cracks may occur in the retaining wall which can be dangerous in basements construction and surrounding environment. So needed sufficient stiffener system and an appropriate excavation method to reduce the movement of the retaining wall that occurs. The top down excavation method utilizes the stiffness of the floor slab as a support for the retaining wall. For deep excavation areas with very soft soil properties [3], often this method still occurs quite a
large movement and the addition of the length and thickness of the retaining wall also does not help to reduce the movement that occurs and requires a very large cost. So that innovation is needed to strengthen the retaining wall of the land. The use of cross walls will be introduced in this study as a stiffener structure on the retaining wall of the soil. Analysis with the finite element method used to study the performance of the retaining wall in the deep excavation. The numerical results of the excavation method with the cross wall and without the cross wall will be compared, so it will be seen the superiority of using the cross wall in the retaining wall system for deep excavation. The use of cross walls will be studied the effect on deformation that occurs in the retaining wall and also the possibility to eliminate lateral stiffeners on the basement floor will reduced also excavation stages [16].

2. Method and Soil Parameter

2.1. Method

The deep excavation is carried out for construction of 3(three) level basement with depth of excavation 11.5m from existing ground level. Excavation method in stages from top to bottom using the basement floor as lateral resistance. To reduce the stages of excavation and reduce deformation in very soft soil parameters by using a cross wall [7],[9],[10]. The test results are then analyzed and compared to obtain small deformation and minimized stages of excavation.

2.2. Soil Parameter

Geotechnical parameter data used is the elaboration of primary and secondary data obtained from the results of field and laboratories test [2], [4], [5], [15]. Simplified soil stratification profile shown in figure 1.

![Soil Profile](image)

Figure 1. Soil Profile

In upper layer is found continuously until the depth varies between 17 ~ 21m of silty clay with very soft consistency. In Table 1 can see a summary of soil data will used in this study for undrained and drained condition.

| Layer | Depth Elevation | Soil Type     | General Model | Undrained Condition | Drained Condition | R i nter |
|-------|-----------------|----------------|---------------|---------------------|------------------|---------|
|       | m   | m   | φ' | γ unsat | γ sat | Su | Eu50 | Eu | c' | Ø | Es | Eur | k | kPa | kPa |
| 1     | 0   | 11.2 | Very Soft Clay | MC | 13.26 | 13.9 | 20 | 8000 | 40000 | 10 | 25 | 4000 | 20000 | 0.7 |
| 2     | 11.2 | 21.2 | Soft Clay     | MC | 16   | 16.5 | 25 | 12000 | 60000 | 15 | 25 | 6900 | 34500 | 0.7 |
| 3     | 21.2 | 31   | Stiff Clay    | MC | 17.5 | 17.7 | 40 | 100000 | 500000 | 20 | 30 | 50000 | 250000 | 0.7 |
| 4     | 31   | 40   | Silty Sand    | MC | 18.09 | 18.3 | 0.1 | 150000 | 750000 | 1   | 35 | 50000 | 250000 | 0.7 |
| 5     | 40   | 100  | Stiff Clay    | MC | 18.85 | 18.9 | 150 | 800000 | 4000000 | 30 | 25 | 77800 | 389000 | 0.7 |
3. Result and Discussion
3.1. Excavation stages and modeling
In this discussion research will be carried out by utilizing the use of cross walls to reinforce diaphragm walls. By using this cross wall it is expected that the excavation stage can be carried out directly reaching the bottom of the raft pile with lateral resistance only at the top of the basement floor, so as to accelerate the time of execution and reduce the movement that occurs in the ground retaining wall. The stages of excavation using the top down method (as shown in Figure 2) are carried out in stages as follows: first stage installation diaphragm wall and kingpost, second stage is excavate up to level 1 basement, third stage is casting of reinforced concrete slab and beam at basement 1 floor which also functions as permanent lateral resistance, fourth stage, after casting basement 1 floor construction is finished, then the next excavation stage is continued up to 1.5m below the elevation of basement 2 floor, the fifth stage is casting the construction of basement 2 slab and floor beam as Dwall permanent resistant at basement 2 elevation, the sixth stage of the excavation stage can be continued until cut-off level of foundation, and the seventh stage is casting raft pile and basement 3 floor construction.

![Figure 2. Excavation Section](image)

Finite element modeling using PLAXIS 2D software, the results of analysis for drained conditions indicate that the maximum movement that occurs in the retaining wall is 4.93cm. The x-direction movement pattern (horizontal) can be seen in Figure 3. Safety factor for long-term excavation is 2.16cm. Existing land subsidence in vertical direction outside excavation is 1,024cm. The internal forces that occur on the retaining wall for maximum shear is 387.13kN per meter run and the maximum moment that occurs is 740.7kNm per m run. Shear forces (V) and moments (M) that occur along the Dwall can be seen in Figure 4. In the displacement picture, it appears that there is no movement at the top of the dwall, displacement occurs at the lower end of the dwall and the greatest displacement occurs at elevation at elevation of -14m below the existing land surface.

![Figure 3. Depth (m) vs lateral deformation (m)](image)
3.2 Lateral Resistance with Cross Wall

To reduce deformation of the retaining wall and reduce excavation stages, in this method lateral resistance is only on the first floor and at the bottom of the excavation using a cross wall. The cross wall is installed with a distance between the cross wall of 13m with a size of 60cmx400cm, will function as a lateral resistance location that is placed below the face of the excavation so as not to interfere when excavation is done. The excavation stage is only carried out in 2 (two) stages, namely the first stage excavation excavates up to level 1 basement and the second stage excavation excavates up to the cut-off level of the drill pole as shown in Figure 5.

The results of the analysis using the 2D plaxis program with drained conditions indicate that the maximum movement that occurs in the retaining wall in the presence of a cross wall is 2.83cm as shown in figure 6. The internal forces that occur on the retaining wall for a maximum shear is 630kN per meter run and the maximum moment that occurs on the inside of the excavation is 541.43kNm per m run as shown in figure 7. The moment that occurs outside the excavation becomes greater than not using a cross wall of 1244.13kNm.
The results of the analysis of the three excavation methods show that the use of cross walls can reduce the movement of the retaining wall significantly, with a cross wall size of 60x400cm and the distance between the cross walls every 13m can reduce the movement of the soil from 4.9cm to 2.8cm. The compressive force on besmen 1 floor can also be reduced. It should be noted that because these adequate cross walls bear a sufficiently large compressive force, which also results in the moment occurring at the cross wall level to increase quite large, but the moments on the dwall at other elevations are reduced. Table 2 shows a summary of deformation, shear force and moment results of 3 (three) excavation methods.

Table 2. Lateral deformation, shear forces and moment of 3(three) excavation methods

| No. | Excavation Method       | \( \delta h \) deformation (m) | Shear Forces at B1 (kN) | Shear Forces at B2 (kN) | Shear Forces at cross wall (kN) | Moment (+) right side (kNm) | Moment (-) left side (kNm) |
|-----|-------------------------|---------------------------------|--------------------------|-------------------------|--------------------------------|-----------------------------|---------------------------|
| 1   | Support at B1 and B2    | 0.049                           | 139.93                   | 387.13                  | -                              | 740.60                      | -728.79                   |
|     |                         | (El. -16.84)                    | (El. -2.30)              | (El. -5.75)             | (El. -13.20)                   | (El. -5.70)                 |
| 2   | Support at B1, B2 and cross wall | 0.027                           | 120.22                   | 46.81                   | 625.42                        | 532.31                      | -1306.9                   |
|     |                         | (El. -25.72)                    | (El. -2.30)              | (El. -5.75)             | (El. -12.0)                    | (El. -18.47)                | (El. -12.0)               |
| 3   | Support at B1 and cross wall | 0.028                           | 70.78                    | -                       | 614.01                        | 541.43                      | -1244.13                  |
|     |                         | (El. -29.49)                    | (El. -2.30)              | (El. -12.0)             | (El. 18.47)                    | (El. -12.0)                 |
4. Conclusion
Technically, the method of implementation excavation top down method is complicated and need longer time. This method is good enough to be used especially for deep excavation on limited land where open excavation from the bottom up is not possible. In areas with very soft soil parameters, utilizing the stiffness of the basement floor structure which is quite rigid as lateral resistance is very helpful to minimize the movement of the surrounding soil which can disturb the environment. Cross wall as lateral resistance can be used to reduce deformation and reduce excavation stages so that the implementation time is faster and not disturb the surrounding environment.

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