Impact of Embedment Depth and Thickness on Behavior of Diaphragm Wall

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Abstract

In current scenario due to rapid urbanization and due to increase in population there is a demand in development of infrastructure. Horizontal development is not the solution to this problem due to scarcity of land. The only solution is the vertical development and to accommodate the vertical development larger size basement will be required for parking and for many other purposes. Diaphragm wall is a reinforced concrete structure that will support the adjacent soil. In the present research, behavior of diaphragm wall was analyzed for one and two basements. For one basement thickness of diaphragm wall is varied from 0.5 meter to 0.7 meter. For two basement diaphragm walls, the depth of embedment was varied for 4 meters to 8 meter in the ground. The analytical analysis as well as software base analysis was performed in the research. It has been concluded that with the increase in thickness and embedment depth, the stability of diaphragm wall also increases.

Keywords: Diaphragm wall, embedment depth, thickness, deflection, bending moment.

Introduction

Due to urbanization in the developing countries, there is the rapid increase in construction of building. The increase in population also requires more construction. Mostly developing countries have the scarcity of land. As a result of this scarcity horizontal development will not be possible. The solution to this is only the vertical development. Vertical development consists of construction of more high-rise buildings. When the height of building in more than 18 meters then it will be considered under the category of high-rise building. Mostly the high-rise has range of number of floors from 10, 14, 18, 22, and 25. To accommodate the residents in such high-rise building single basement will not be sufficient. To accommodate all two to three basements will be required and that can be only possible only by providing the diaphragm wall.

Diaphragm wall in a reinforced concrete wall that will be retaining the soil on the surrounding of construction site. It will be resisting the earth pressure because of surrounding soil. The construction site will be isolated from the surrounding constraints. The area available because of diaphragm wall can be used as the basement. The characteristics diaphragm wall is very much similar to the reinforced concrete slab. Diaphragm wall will prevent the effect lateral pressure that can be caused by peripheral soil and also prevent the effect of construction activity of the adjacent property.

The important parameter that effects in the behavior of diaphragm wall will be the soil condition, thickness of diaphragm wall, number of basements to be prepared, depth of excavation and depth of embedment of diaphragm wall in the soil. Many researchers had conducted research diaphragm wall. Choy, Standing and Mair [14] conducted research on outcome of construction of diaphragm wall with respect to nearby pile foundation. The research was experimental research in which the effect of construction of diaphragm wall on adjacent pile were explored and soil taken under consideration was a dry soil. C K Choy [14]-[17] conducted the centrifuge test at the Cambridge University to study the nature of construction of diaphragm wall adjacent to pile foundation. The spacing between the pile anddiaphragm wall was varied. In the experimental work the application of load was on the pile and diaphragm wall deflection was measured. It was observed in the research that level of slurry has the major impact in the deflection of pile. Choy[14] observed that reduction slurry level caused the horizontal and vertical movement of pile.

A Mohamed [13] also conducted the similar type of research in which the parameter that effect the pile foundation while installing the diaphragm wall. A Mohamed [13] observed that spacing between the pile and diaphragm wall was the major impact in deflection and settlement of pile, the pile nearer to the diaphragm all will have more sinking and deflection in all direction in comparison to the one with the greater distance. A Mohamed [13] also observed that deflection of pile was highly influenced by the length diaphragm wall in comparison to thickness of diaphragm wall. A Mohamed [13] also gone through many cases studied that shows interaction between diaphragm wall and adjacent deep foundation. A Mohamed [13] had gone through the case history of Egypt and it was observed that settlement of building with the shallow foundation was more in comparison with the deep foundation. Hamza [16] also conducted research on case study on the diaphragm wall at the Cair and he performed the analysis by plotting the settlement curve. Many researchers performed the centrifuge test on the scaled diaphragm wall model and also had performed comparative analysis between the analytical results and the experimental results. In each research, proper proof was not obtained regarding how much deep the diaphragm wall should be below the ground.

In this research work, the parameter that should we considered in finalizing the embedment was worked out. The embedment depth was founded out based on the bending moment on the diaphragm wall. There are mainly two types of bending moment acting on diaphragm wall. The one will be active earth pressure in which the soil will be moving away from the soil and passive earth pressure in which the diaphragm wall will move away from the soil.

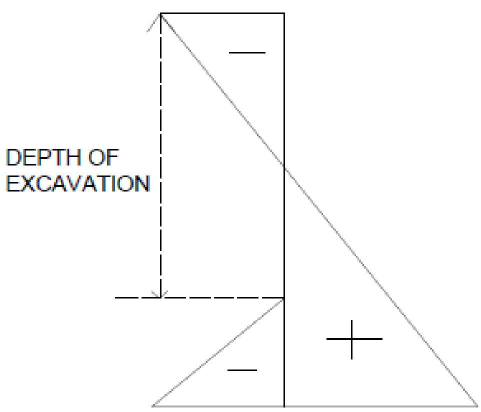

Figure 1 Line diagram of Diaphragm wall

The above figure shows the active and passive earth pressure that will be action of diaphragm wall. The passive earth pressure is designated by the negative sign and active earth pressure is designated by the positive line. Initially at the top the diaphragm wall will be having the passive earth pressure and that will be changing to active earth pressure while progressing towards bottom of diaphragm wall. Near the bottom the depth at which the embedment of diaphragm wall is starting from that point the passive earth pressure will be acting of diaphragm wall.

According to Rankin's theory cumulative earth pressure at the bottom of diaphragm wall will be as follow:

$$Pressure\ at\ bottom = (\gamma H\ Cot^2\ \alpha - 2ch\ Cot\ \alpha)$$

Now because of embedment of diaphragm wall in the soil passive earth pressure will be also acting as follow:

$$= \ \gamma\ H_1 tan^2\alpha$$

Site Condition

In the research the site was located in Gujarat at the Salal area near Himmatnagare in Sabarkantha district. The characteristics of soil is displayed in below table.

The soil was having some cohesion and it was also having some internal friction so the soil was considered as c-Ø soil.

Table 1 Soil Characteristics

Characteristics	**Value**
Bulk Density	18 kN/m³
Cohesion	07 kN/m²
Angle of internal friction	29°
α	59.5°

The soil was having some cohesion and it was also having some internal friction so the soil was considered as C-Ø soil.

Figure 2 Soil Characteristics

Modelling

The numerical modelling in the research work has been done in plaxis 2D. The soil model of 30 meters x 30 meters x 30 meters. Soil having properties as in table is allocated in plaxis. In plaxis, Mohr-Coulomb model was adopted for the soil model undrained condition. This soil has all properties in table 1. The analysis was mainly for one basement and two basement.

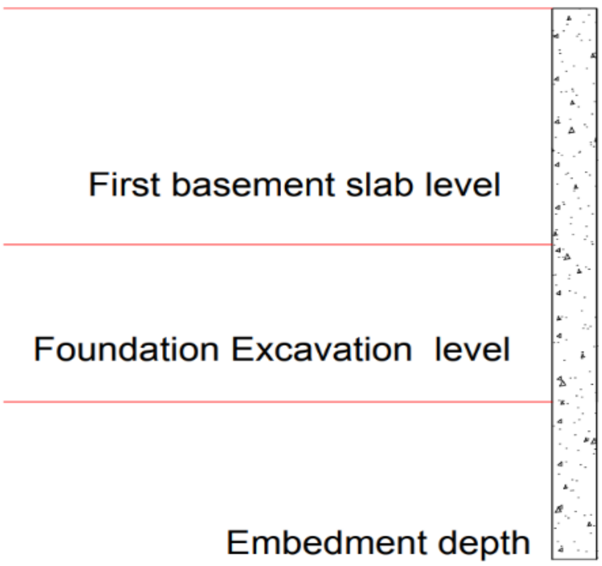

Figure 3 One basement diaphragm wall

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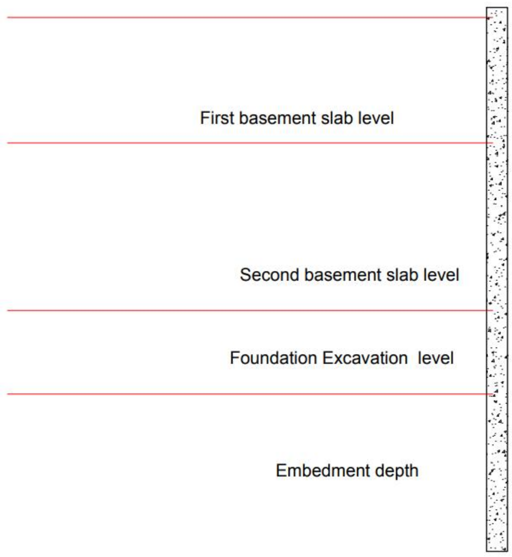

Figure 4 Two basement diaphragm wall

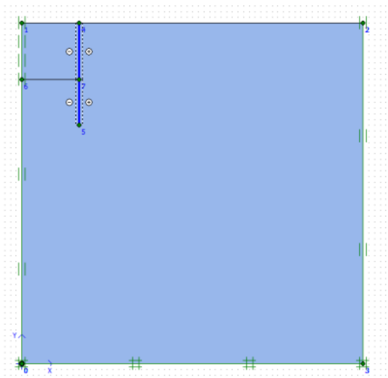

Figure 5 Plaxis modelling

Table 2 Parameters of Diaphragm wall

Sr. No.	Drawing Number	Number of basements	depth of basement excavation	Depth of embedment	Thickness in mm	Grade of concrete
1	1PH520.5		5	2	0.5	
2	1PH530.5		5	3	0.5	
3	1PH520.6	1	5	2	0.6	25
4	1PH530.6		5	3	0.6	
5	1PH520.7		5	2	0.7	

6	1PH530.7		5	3	0.7	
7	2PH930.5	2	9	3	0.5	
8	2PH940.5		9	4	0.5	
9	2PH950.5		9	5	0.5	
10	2PH960.5		9	6	0.5	
11	2PH970.5		9	7	0.5	
12	2PH980.5		9	8	0.5	

Observation

Numerical analysis of diaphragm wall was done in plaxis 2D and deflection and bending moment for both one basement and two basement diaphragm wall was obtained with varying the depth of excavation and thickness of diaphragm wall.

Table 3 One basement diaphragm wall bending moment

Sr. No.	Drawing Notation	Displacement in mm	Bending moment in kNm
1	1PH520.5	77.12	27.69
2	1PH530.5	37.92	23.14
3	1PH520.6	76.4	30.68
4	1PH530.6	37.95	23.01
5	1PH520.7	97.23	33.82
6	1PH530.7	38.94	26.46

Table 4 Two basement diaphragm wall bending moment

Sr. No.	Drawing Notation	Displacement in mm	Bending moment in kNm

1	2PH930.5	442	218
2	2PH940.5	410	225
3	2PH950.5	400	230
4	2PH960.5	375	300
5	2PH970.5	340	380
6	2PH980.5	310	492

The analytical analysis of diaphragm wall was also performed for both one and two basement diaphragm walls. This was just by finding the bending moment at the base of diaphragm wall. In this bending moment both active pressure moment and passive pressure moment was considered. Based on the observation the graphs were plotted.

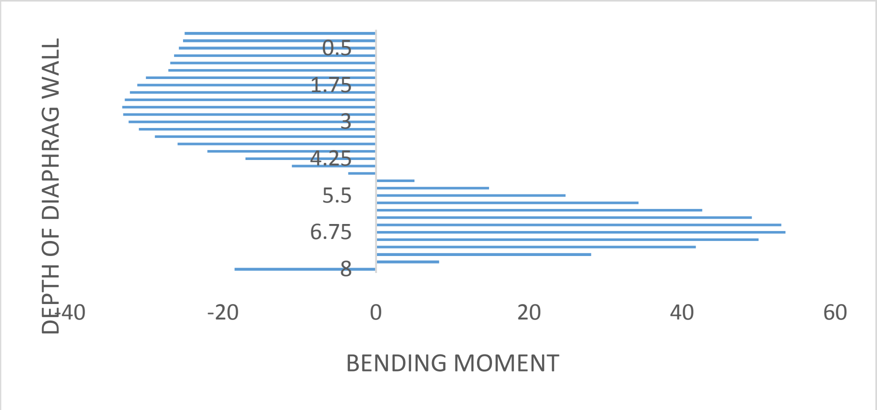

Figure 60.5-meter-thick Diaphragm wall

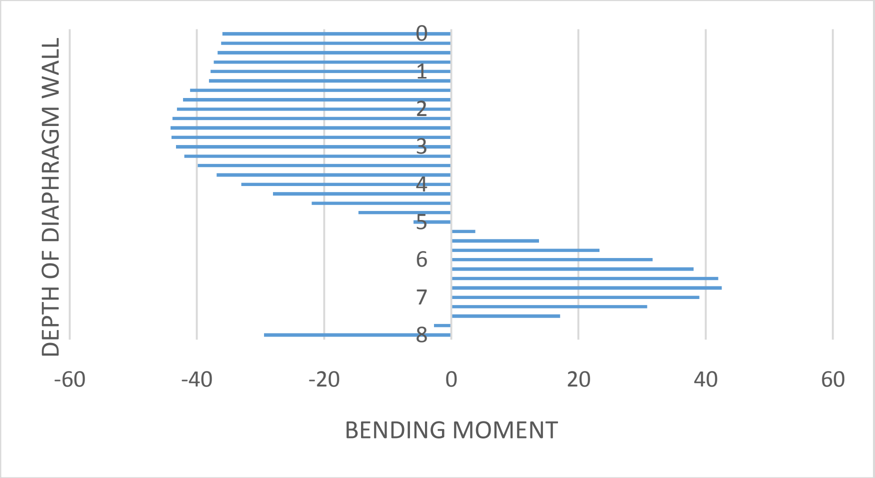

Figure 70.6-meter-thick Diaphragm wall

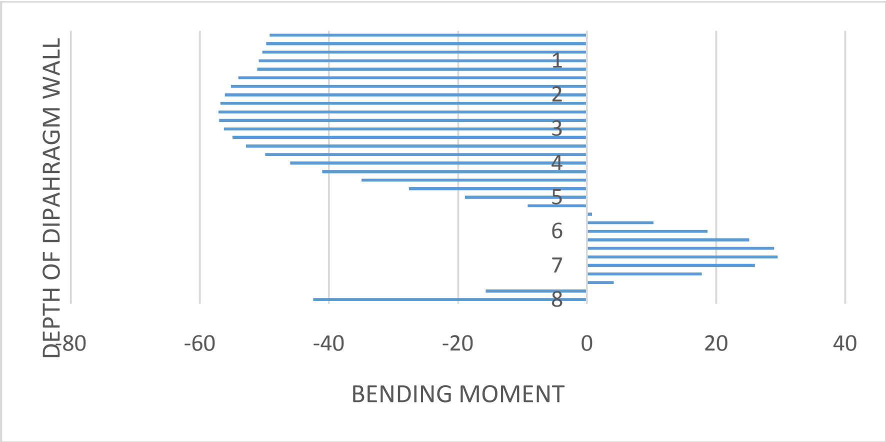

Figure 80.7-meter-thick Diaphragm wall

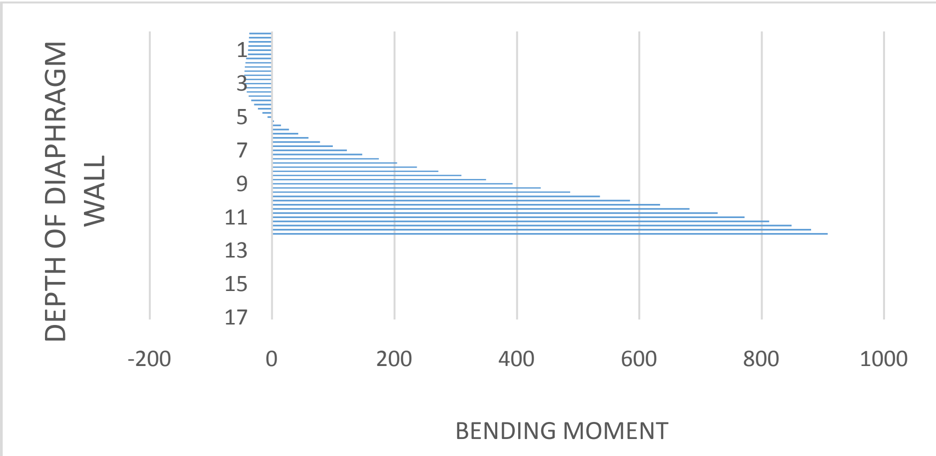

Figure 9 2-basement Diaphragm wall with 4-meter embedment

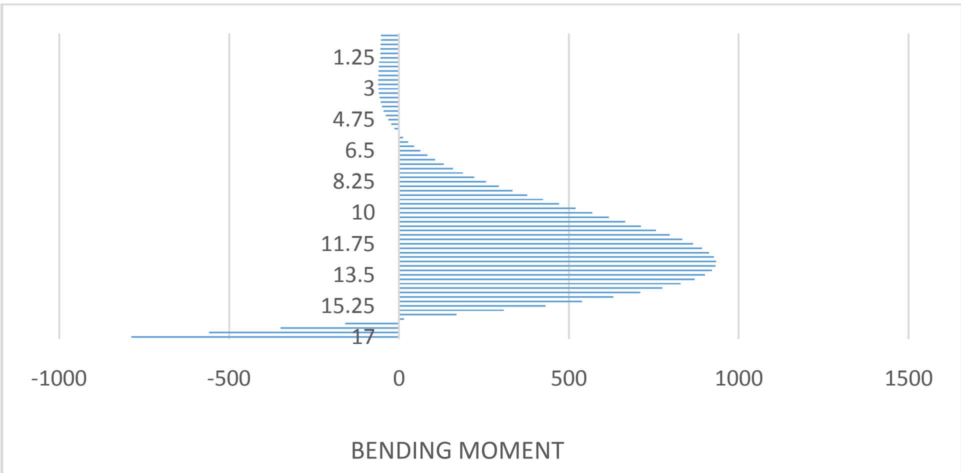

Figure 10 2-basement Diaphragm wall with 8-meter embedment

It was observed in the analytical analysis that for 1-basement diaphragm wall with the increase embedment depth from 2 meter to e meter negative moment was observer at the bottom near embedment depth. Further for 1-basement diaphragm wall for the same embedment depth of 3 meter with increase in thickness of diaphragm wall also results in increase in the negative bending moment on the diaphragm wall. The value of negative bending moment was increasing with increasing in the thickness of diaphragm wall. For the 2-basement diaphragm wall, the analysis was done for only 0.5-meter thickness. It was observed that while starting from 3-meter embedment depth no negative moment was observed. Till 7-meter embedment depth no passive pressure bending moment was observed. At 8-meter embedment depth, passive pressure bending moment was observed.

Conclusion

Embedment depth of diaphragm wall had a major impact on behavior and stability of diaphragm wall. From the research it was observed that active earth pressure causes the positive bending moment and this will move the diaphragm wall away from the soil which the passive earth pressure causes the negative bending moment that will move the wall toward the soil. Ultimately passive earth pressure increases the stability of diaphragm wall.

- Negative bending moment was observed at 8-meter embedment depth. This shows that with increase in embedment depth the causes the negative bending moment. This will prevent the overturning of diaphragm wall and diaphragm wall will remain stable.
- More the embedment depth, more the chances of occurrence of negative bending moment.
- The stability of diaphragm wall increases with increase in thickness of diaphragm wall.
- With increase in this the counteracting banding moment of diaphragm wall is increase.
- With increase in thickness of diaphragm wall, the stability of diaphragm wall also increases.

Future Scope

A practical analysis is supposed to be conducted to observe the actual behavior. An experimental work is supposed to be done to understand that actual behavior of diaphragm wall under variation made in the present research paper.

References

[1] Benny Mathews Abraham, T. G. Santhosh Kumar, A. Sridharan, Babu T. Jose, “Strength Improvement of Loose Sandy Soils Through Cement Grouting,” Indian Geotech J, July, 2013.

[2] Tavakoli Mehrjardi, Khazaei,” Scale effect on the behavior of geogrid-reinforced soil under repeated loads” , Geotextiles and Geomembranes, volume 45, August,2017.

[3] Ahmed Mohammad, Marawan Shahin, Herbert Klapperich, “Influence of trenching Diaphragm wall panels on Deflection and Bending Moment of existing piles within pile foundation” Innovation.

[4] Solution, Springer interntioal Publisher, August, 2017.

[5] Enrico Conte, Antonello Troncone, “Simplified analysis of cantelevered diaphragm wall in cohesive soil,”Soil and Foundation 58,pp 1446-1457 November, 2018.

[6] Kawa,Pula, Truty, “Reliability assesment of serviceability limit state for diaphragm wall hardening soil (HS) model”, XVII Europeon conference on soil mechanics and geotechnical engineering,2019.

[7] Askar Zhussupbekov, Abdulla Omarov, Gulzhanat Tanyrbergenov, “Design of anchored diaphragm wall for deep excavation,” International Journal of GEOMATE, vol. 16, pp. 139-144, June, 2019.

[8] Hui Qin, Xiongyao Xie, Yu Tang, Zhengzheng Wang,”Detection of Diaphraagm wall using cross hole defect”,IEEE journal,2018.

[9] Bahrami, Imam Khodakarami, Abdolhosein Haddad,”Seismic behaviour and design of dtrutted diaphragn wall in sand"Computer and Geotechnics, volume 108, pp 75-87, December ,2018.

[10] Haiyang Zhauang, Rui Wang, Peixin Shi, Guoxing Chen,”Seismic response and damage analusis of underground structures considering the effect of concrete diaphragm wall”,Soil dynamics and earthquake engineering, volume 116, pp 278-288, September.2018.

[11] Ming-Guang Li, Zhong-Jie Zhang, Jin-Jian Chen, Jian-Hua Wang, An-Jun Xu,"Zoned and staged construction of an underground complex in Shanghai soft clay ",Tunnelling and Underground Space Technology.

[12] Li Wang, Yong Liu, Yutao Pan, William Danovan, Jeyatharan Kumarasamy, and Fook-Hou Lee, "Measure for Reducing the Tensile Stress in Cement-Treated Soil Layer in Deep Excavation in Soft Clay", KSCE Journal of Civil Engineering,2019.

[13] A. Mahamed and H Klapperich,”Parametrs influencing piled foundationa due to slurry trenching”, Conference paper”, 2016.

[14] Choy; J. Standing & R. Mair, “The installation effects 'of a diaphragm wall on an adjacent piled foundation”, "Geotechnical Aspects of Underground Construction in Soft Ground, Kastnen Emeriault, Dias, Guilloux (eds), page 645-650.

[15] Hamza, Atta and RO, A. (1999): Ground Movements Due to the Construction of Cut-and-Cover Structures and Slurry Shield Tunnel of the Cairo Metro. In Tunnelling and Underground Space Technology 14 (3), pp. 281–289.

[16] Hamza, Atta, Roussin, “Ground Movements Due to the Construction of CutandCover Structures and Slurry Shield Tunnel of the Cairo Metro”, Tunnelling and Underground Space Technology Vol. 14, No.3, 281-289, 1999.

[17] Choy, C. K.: Installation effects of diaphragm walls on adjacent piled foundations, PhD dissertation, University of Cambridge, UK, 2004.