Three dimensional effect of discontinuous berms for enhancing the performance of diaphragm walls

Muhammad M. El-Sherbiny[1], MSc; Rami M. El-Sherbiny[2], PhD; and Hussein H. El-Mamlouk[3], PhD

[1]Geotechnical Engineer, Dar Al-Handasah (Shair and Partners), Cairo; e-mail: mohammed.elsherbiny@dargroup.com, muhammad.mounir89@gmail.com

[2]Associate Professor of Geotechnical Eng. and Foundations, Faculty of Engineering, Cairo University; e-mail: rsherbiny@eng.cu.edu.eg

[3]Professor of Geotechnical Eng. and Foundations, Faculty of Engineering, Cairo University; e-mail: husseinelmamlouk@gmail.com

ABSTRACT: This paper discusses the stability and performance of embedded retaining structures supported by leaving a temporary earth berm on the passive side of the wall in a thick clay deposit characterized by weak soil properties. Available literature and design guidelines for discontinuous berms are limited. The objective of this paper is to investigate the ability of berms to enhance the performance of diaphragm walls especially during the removal process of the berm as it's deemed to be the most critical stage during construction. The influence of different parameters on the wall performance was investigated comprising; berm height to excavation height ratio (H_b/H_e), berm crest width to excavation height ratio (W_b/H_e) and soil stiffness to atmospheric pressure ratio (E_{50}/P_a). Deflections and settlements were presented in the form of a ratio from the selected height of excavation. Increasing the berm height is more effective compared to a similar increase in the crest width of berm. Such effectiveness tends to be balanced in case of land-use limitations. Refining the soil properties reflected an overall enhancement in the wall behavior with respect to the berm's geometry parameters.

1 INTRODUCTION

The technique of leaving earth-berms in place against embedded walls during excavation can provide cost-effective short-term stabilization of the wall before the placing of permanent supports (e.g. structural floors). The presence of berms results in an overall increase of the stabilizing passive pressure acting on the wall due to the increase of volume of the passive wedge on the excavation side. Earlier, graphical methods were developed in order to determine the provided earth pressure due the presence of a berm. Empirical methods evolved during 1980s and 1990s (NAVFAC 1986, Williams and Waite 1993) to evaluate the influence of the berm as a passive thrust on the retaining walls. (Potts et al. 1993) performed finite element analysis to evaluate the significance of using berms as a temporary support for retaining walls by using finite element software called "ICFEP". (Powrie et al. 1993, Georgiadis and Anagnostopoulos 1998) used different finite element softwares to capture the behavior of embedded retaining walls supported by an earth berm in a 2-D space, as an approach to quantify the significance of berm geometry as a stabilizing element for retaining walls in cohesion-less soils. Available literature and guidelines for the design of bermed walls existing in very soft substrata are limited. Discontinuity of berms during the removal process was often discounted in research studies. (Gourvenec and Powrie 2000) who first introduced the discontinuous characteristic of a berm during the removal process and its effect on the deflections of walls embedded in thick clay stratum. A 3D finite element program CRISP was constructed against the data obtained from a real surveying for the construction of diaphragm walls on the A4/A46 Batheaston bypass in England. The Lias clay soil was modeled as a stiff over-consolidated linear elastic – perfectly plastic Mohr Coulomb material. One of the main drawbacks encountered while modelling the discontinuous berms that exist in a soft stratum is specifically the adopted three-dimensional software and generally, the processing speed of computers in the time when the study was performed which stood against conducting thorough analyses.

This study highlights the behavior of bermed walls during the berm removal process especially when the wall exists in soft stratums of weak properties. Different opening widths were considered along the study. The effect of berm's geometry was investigated using a three dimensional finite element software (Plaxis 3D, v.2013) considering different heights and crest widths of berm. Alteration in the elastic properties of soil was examined by introducing different stiffness for the soft clay.

2 METHODOLOGY

Plaxis 3D was verified against a monitored case study reported by (Liao and Lin 2009) who reported field-monitoring data of a diaphragm wall supporting a bermed excavation in Taipei City (El-Sherbiny 2016). Various sensitivity analysis was conducted by considering different opening widths in the berm section during removal process for a simplified stratigraphy consisting of a layer of sand followed by deep soft clay, (Fig. 1). An infinitely long bermed excavation of depth (H_e) = 7.5 m was assumed.

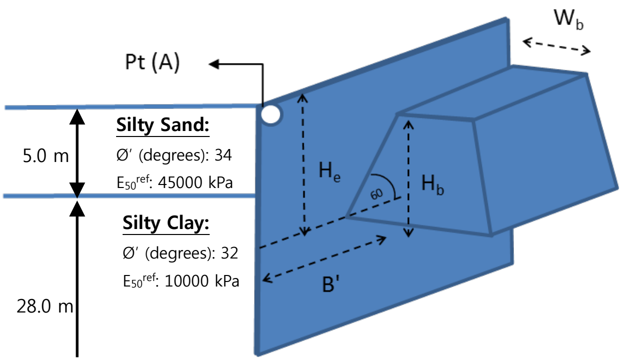

Figure 1. Typical soil model for the bermed excavation used in the parametric analysis

A diaphragm wall having a thickness of 0.7 m and a depth of 19 m supported the excavation. Three basic openings' widths (B') were involved in the recent study (i.e. 0 for intact, 3.5m, 5m & 6m respectively). Wall deflections were estimated at the center of the opening Pt (A). Different heights (H_b), crest widths of berms (W_b) and stiffness of soils (E) were examined against a reference case for the wall berm configuration.

2 RESULTS

Height and width of berm are one of the most effective parameters that affect the behavior of the berm as a stabilizing agent for retaining walls. Hence, three different heights were adopted along the analyses; H_b = 5m, 5.5m and 6m, similarly, three different crest widths were selected for the study; W_b = 1.5m, 3m and 4m. On the other hand, the berm basically consists of a soil in its natural state, not a refilled soil nor compacted one. Thus, the properties of the natural soil act as a very significant parameter that has a major contribution on the behavior of the berm to provide a sufficient support to the retaining wall. Modulus of elasticity of soil is mainly used for the estimation of the soil deformations. Accordingly, three different moduli of stiffness were considered in order to gain a better understanding about the effectiveness of such parameter; E = 8.0, 10.0 and 12.0 MPa. (Fig. 2) illustrates the effect of the different heights of berm on the resulting maximum wall deflections for the different opening widths. Increasing the height of berm led to a linear reduction in the wall deflections especially for a berm existing in an intact condition, on the contrary, wall movements increased significantly for the same wall height in case of introducing bigger openings along the berm's section.

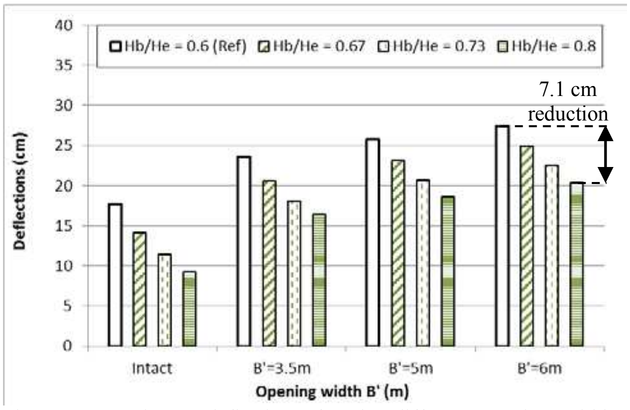

Figure 2. Maximum deflections for the different opening widths considering various heights of berms

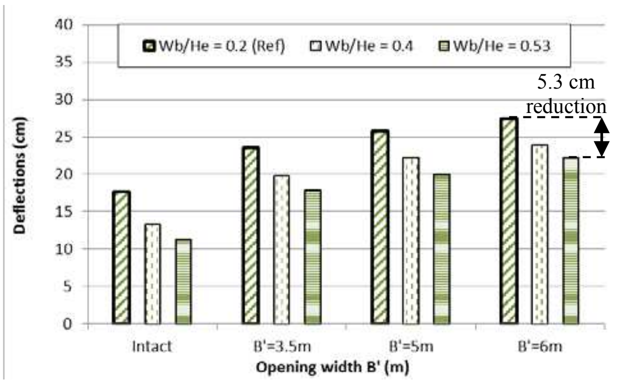

Figure 3. Maximum deflections for the different opening widths considering various heights of berms

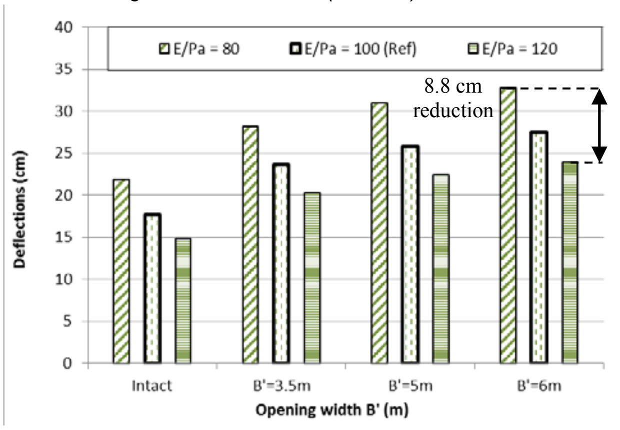

Figure 4. Typical soil model for the bermed excavation used in the parametric analysis

Different crest widths of berm and stiffness of soil reflected a similar linear behavior as shown in (Figs 3 & 4). Yet, higher stiffness of soil showed a better effective impact on reducing the wall movements as shown in (Fig. 4), in turns, it can be defined in other words that further improvement for the natural soil is more efficient in case of using berms in unfavorable lands as a passive resistant (Elsherbiny et al. 2017).

3 CONCLUSION

Bermed excavation systems are usually associated with high lateral movements of the wall especially in lands characterized by weak soil. Deflections at the center of openings are mainly governed by the width of opening (B'), for a unit increase in the opening width, deflections increase correspondingly. Increasing the height of berm is a bit effective in reducing the wall deflections compared to a similar unit of increase in the crest width of berm. Improving the soil properties reflected much more reduction in the wall deflections compared to the reduction caused by any alteration in the geometry of the berm.

4 ACKNOWLEDGEMENTS

The Authors would like to thank Professor Susan Gourvenec for personally sharing her earlier research giving the chance for conducting this thorough study to let it see the light.

5 REFERENCES

El-Sherbiny M. 2016. Numerical analysis of embedded retaining walls supported by discontinuous unimproved and improved berms. MSc. Thesis, Cairo University, Giza.

El-Sherbiny M. M., El-Sherbiny M. R. and El-Mamlouk H. H. 2017. Three-dimensional effect of grouted discontinuous berms for passive support of diaphragm walls, Proceedings of the conference Grouting, Hawaii.

Georgiadis, M. and Anagnostopoulos, C. 1998. Effect of berms on sheet-pile wall behaviour. Geotechnique, 48(4), 569-574.

Gourvenec, S. and Powrie, W. 2000. Three-dimensional finite element analyses of embedded retaining walls supported by discontinuous earth berms. Canadian Geotechnical Journal, 37(5), 1062-1077.

Liao, H. J. and Lin, C. C. 2009. Case studies on berm excavation in Taipei silty soil. Canadian Geotechnical Journal, 46(8), 889-902.

Potts, D. M., Addenbrooke, T. I. and Day, R. A. 1993. The use of soil berms for temporary support of retaining walls. Proceedings of the conference Retaining structures, Cambridge, 440-447.

Powrie, W., Davie, J. N. and Britto, A. M. (1993). "A cantilever retaining wall supported by a berm during temporary works activities". Proceedings of the conference Retaining structures, Cambridge, 418-428.