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EFFECT OF ANCHOR DEPTH ON BEHAVIOR OF SHEET PILE WALLS USING PLAXIS 2D

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Abstract

Sheet pile walls are structures used to retain soil, rock or other materials in a vertical condition. Hence they provide a lateral support to vertical slopes of soil that would otherwise collapse into a more natural shape. They have been used to support excavations for below grade parking structures, basements, pump houses, and foundations, construct cofferdams, and to construct seawalls and bulkheads. In order to have a more efficient usage of construction areas in congested urban areas a vertical development of buildings becomes necessary. Currently we more often face situations where urban buildings need as many parking spaces, so, due to lack of space, that requires the development of several underground floors. The design and execution of deep excavations in congested urban areas is quite a challenge especially in terms of geotechnical engineering and it requires a good knowledge of the soil mechanics and soil interaction with the retaining walls of the excavation. As such, the performance of support systems for deep excavation requires careful consideration of soil-structure interaction. This study involves 2D Finite element model is developed using PLAXIS to investigate the behavior of anchored sheet pile walls by varying different anchor location. The analysis is carried out considering non-linear behavior of soil using Mohr-coulomb failure criteria.

KEY WORDS: Sheet pile walls, support excavations, 2D Finite element, PLAXIS

1. Introduction

Sheet piles walls are widely used as economically and technically effective temporary retaining structures and deep excavation support systems. Sheet pile walls may be cantilever or anchored walls. Cantilever sheet pile walls are usually used with low wall height between 3 - 5 m and sometimes less due to limitations on the availability of certain section modulus and their associated costs (Geotechnical Engineering Bureau 2007). The anchored sheet pile walls are required when the wall height exceeds 5 m or when the lateral wall deflection is limited for design consideration (Eskandari and Kalantari 2011). When the height of sheet pile is less than 6m, it is economical to use sheet pile which is anchored near its top. There are several types of anchors that can be used with sheet pile walls; such as grouted tiebacks and deadman. Temporary supports for the walls can also be provided by struts, braces, and rakers (Geotechnical Engineering Bureau 2007). The selection of suitable type of anchor generally depends on the soil type, groundwater, and cost (Juran and Elias 1991). Grouted tiebacks are suitable for situations requiring one or more levels of anchors whereas tie deadman anchors are typically limited to situations requiring a single level of anchors (California DOT 2004). Anchoring the sheet pile cause less penetration depth and also less moment to the sheet pile. Well constructed anchor walls undergo less lateral deflection than braced walls and so provide a better control of back-slope subsidence. Anchor installation only requires a small excavation to allow equipment access.Anchored walls are always pre stressed which essentially removes the slacks from the system. The anchor will maintain their load through the excavation sequence unless creep occurs. Excavation support systems most frequently use tiebacks to resist the lateral earth pressures. A wall system is designed to resist the lateral earth pressures and water pressures that develop behind the wall. Earth pressures develop primarily as a result of loads induced by weight of the retained soil, earthquake ground motions, and various surcharge loads. For purposes of anchored wall system design, three different lateral earth pressure conditions are considered: (1) active earth pressure; (2) passive earth pressure; and (3) at-rest earth pressure.

2. Numerical Model

The influence of sheet pile wall geometry, grout-ties area, inclination and location, length of grout, dredging depth and backfill soil angle of repose are the most effective parameters in enhancing this type of walls (ElNaggar, 2010). This study is to investigate the behavior of sheet pile walls which are supported with anchor with surcharge load and excavation of one layer constructed in cohesionless soils under varying different location of the anchor and calculated factor of safety. PLAXIS, 2-D finite element analysis software package, was used for the parametric study in this research. Finite element method is relatively a new technique for solution of walls. Full finite element mesh and elements for soil, wall and anchors are described and soil properties and soil models can be input. Soil properties like c’, φ, E and wall characteristics are required. Moment, shear, displacements of wall and anchor reactions are presented and displacement vectors can be observed. Programs automatically solve in stages . Mohr-coulomb model is used to model soil.

2.1. Geometry of Model

The problem can be modeled with a geometry model of 50 m width and 40 m depth. The anchor is modeled as an inclined soil anchor with an inclination of 45^0 with horizontal. The free length is 10m and the fixed length is 5.5.m. To study the effect of the location on the behavior of the wall, four different values of depth were considered (2, 4, 6, and8 m). The other parameters of the model were kept constant. A ground anchor can be modeled by a combination of a node-to-node anchor and a geotextile. The geotextile simulates the grout body whereas the node-to-node anchor simulates the anchor rod. In reality there is a complex three dimensional state of stress around the grout body. Although the precise stress state and interaction with the soil cannot be modeled with this 2D model, it is possible in this way to estimate the stress distribution, the deformations and the stability of the structure on a global level, assuming that the grout body does not slip relative to the soil. With this model it is certainly not possible to evaluate the pull-out force of the ground anchor. The pile wall is modeled as a beam. The interfaces around the beam are used to model soil-structure interaction effects. They are extended under the wall for 1,0 m. Extend inter faces around corners of structures to allow for sufficient freedom of deformation and to obtain amore accurate stress distibution. Interfaces should not be used around the geotextiles that represent the grout body. The excavation is constructed in several excavation stages. The separation between the stages is modeled by geometry lines.The ground water level is placed in 1 m from surface of the earth.

The schematic view of the anlayzed model of the studied section is given in Fig. 1

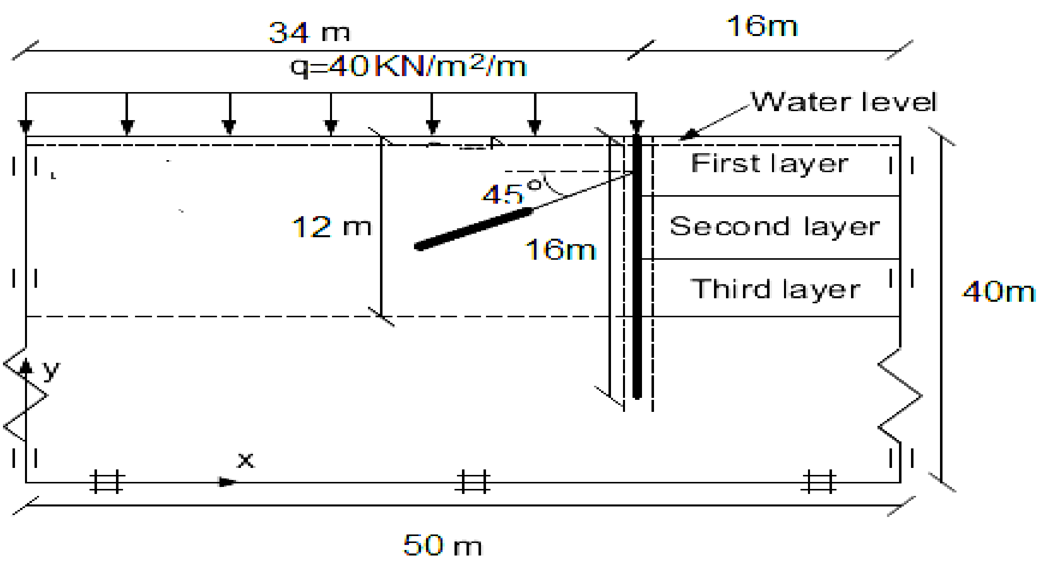


Fig.1 Modeled section

2.2. Material properties of the Model

The soil consists of one distinct layer. The data sets for soil & interfaces with the parameters given in Table 1. The beam elements used to model the walls are, on their own, fully permeable. Therefore, the interfaces around the wall must be used to block the flow through the wall for groundwater calculations and consolidation analyses. This can be achieved by setting the permeability parameter of the interface to Impermeable. In that case a very low (but non zero) value of the interface permeability is used. The properties of the concrete pile are entered in a material set of the beam type. The concrete has a thickness of 1.265 m . The properties are listed in tables1,2,3and4.

Table 1Soil and interface properties

Parameter	Name	Sand	Unit
Material model	*Model*	MC	
Type of material behaviour	*Type*	drained	-
Dry soil weight	γdry	17	kN/m^3
Wet soil weight	γwet	20	kN/m^3
Horizontal permeability	Kx	0.001	m/day
Vertical permeability	Ky	0.001	m/day
Young's modulus	E_{tef}	20000	kN/m^2
Poisson's ratio	ν	0,3	-
Cohesion	*Cref*	13	kN/m^2
Friction angle	ϕ	28.1	^{0}
Dilatancy angle	ψ	0	^{0}
Interface reduction factor	*Rinter*	Rigid	-

Table 2 Properties of the pile

Parameter	Name	Value	Unit
Type of behaviour	*Material type*	Elastoplastic	_
Normal stiffness	*EA*	2,4-10^7	kN/m
Flexural rigidity	*El*	1,28-10^6	kNm/m
Equivalent thickness	*D*	0,80	M
Weight	*W*	19,2	kN/m/m
Poisson's ratio	ν	0,15	-

Table 3 Properties of the anchor rod

Parameter	Name	Value	Unit
Type of behaviour	Material type	Elastoplastic	-
Normal stiffness	EA	$2 \cdot 10^5$	kN
Spacing out of	L_S	2.5	m
Maximum force	$F_{max,\ comp}$	$1.1 \cdot 10^{15}$	KN
	$F_{max,tens}$	$1.1 \cdot 10^{15}$	KN

Table 4 Property of the grout body (geotextile)

Parameter	Name	Value	Unit
Normal stiffness	*EA*	$1\text{-}10^6$	kN/m

3. RESULTS AND ANALYSIS

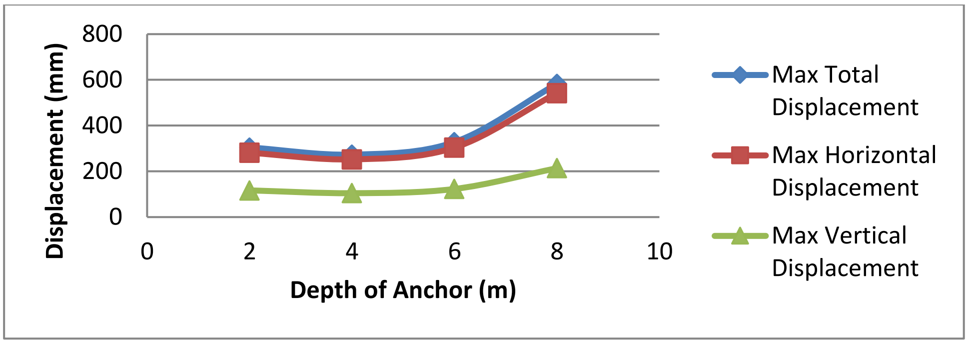
The calculation consists several phases. For the initial phase groundwater condition will be set . Second phase activate sheet pile wall and surcharge load (permanent load of 40 kPa). Excavation to level -4.0 m (-6.0, and -8.0 m for different models) in the third phase . For fourth phase activate grouted anchor at level -2.0 m (-4.0, -6.0 and -8.0 m for different models). Fifth phase excavation to level -12.0 m.

The analysis results in terms of maximum total wall displacements, maximum horizontal displacements,maximum vertical displacements, maximum wall bending moments, anchor forces,and factor of safety with increasing wall anchor depth are given in Table 5,shown in Figures 2through 6, and analysis below.

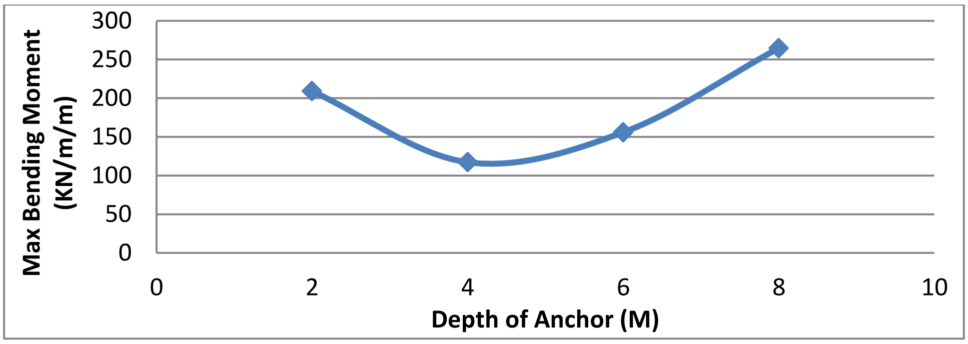
The results show that an increase of anchor depth up to 4m leads to a decrease in the maximum bending moment,total wall displacement, horizontal displacement of wall face and vertical displacement and factor of safety; but an increase in the anchor force. After that by increase of anchor depth leads to an increase in maximum bending moment,total wall displacement, horizontal displacement, vertical displacement and anchor force and factor of safety decrease. Results indicatethat, for this case study, increasing of anchor depth up to 4m inflate the behavior and Increase stability of the wall Therefore, the optimum depth of anchor is 4 m for this case. As an important result of this study, it can be said that the best location for the anchor was at 25% of the wall height below the top of the wall. Similar results were found by Bilgin and Erten (2009).

Table 5 Summary of the effect of anchor depth on sheet pile wall

Depth of Anchor (m)	Total displacent (mm)	Horizontal displacment (mm)	Vertical displacmet (mm)	Bending moment KN/m/m	Anchor force KN/m	Factor of safety
2	304.58	281.30	116.79	209.10	118.20	1.869
4	273.21	252.43	104.51	117.16	141.70	1.873
6	328.01	304.05	123.07	155.86	175.10	1.866
8	582.89	542.28	213.75	264.79	210.00	1.834



Fgure 2 Effect of anchor depth on wall displacement



Figur3 Effect of anchor depth on maximum wall bending moment

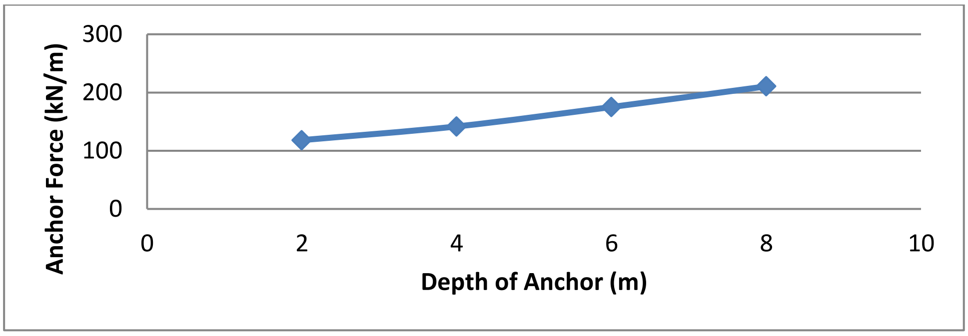


Figure 4 Effect of anchor depth on maximum anchor forces

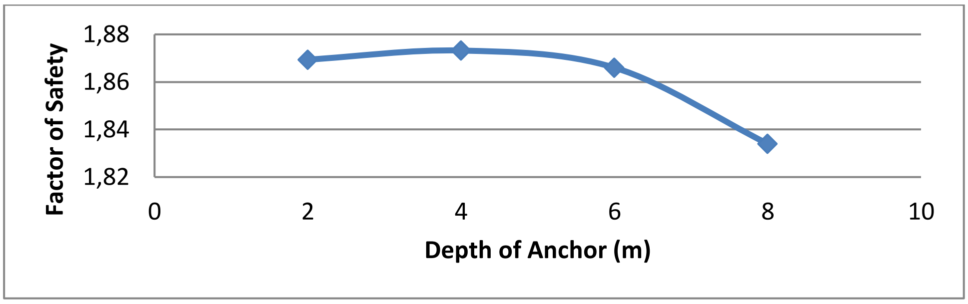


Figure 5 Effect of anchor depth on factor of safety

4. CONCLUSIONS

The wall behavior was investigated through the wall displacements, bending moments, factor of safety and anchor forces. A finite element analysis, using PLAXIS software, were utilized to perform the parametric analyses. According to the numerical analyses the following conclusions are drawn:

1. It was found that finite element software (PLAXIS 2D) is powerful tool for investigating the behaviour of a wall stabilized. .
2. it can be concluded that the best location for the anchor was at 25% of the wall height below the top of the wall
3. it can be noticed that the increase of the depth of the anchor increases the maximum force in anchor.

REFERENCES

1. Ali, m. 2014. Application of Submerged Grouted Anchors in Sheet Pile Quay Walls. Thesis, University Of Trento, Italy.

2. Bilgin, Ö. 2010. Numerical studies of anchored sheet pile wall behavior constructed in cut and fill conditions. Computers and Geotechnics. Vol. 37:399–407.

3. California Department of Transportation (California DOT), 2004. "Retaining walls design." Bridge Design Specifications.

4. El-Naggar, M. 2010. Enhancement of steel sheet-piling quay walls using grouted anchors. Journal of Soil Science and EnvironmentalManagement. Vol. 1(4): 69–76.

5. Eskandari, L. and Kalantari, B. 2011. "Basic Types of Sheet Pile Walls and Their Application in the Construction Industry-a Review." Electronic Journal of Geotechnical Engineering, Volume 16, BundleK.

6. Hetham, A. 2013. Effect of wall penetration depth on the behavior of sheet pile walls. Master of Science thesis, University of Dayton, Ohio.

7. Juran, I. and Elias, V. 1991. "Ground anchors and soil nails in retaining structures." Chapter 26, Foundation Engineering Handbook, 2nd ed., Kluwer Academic Publishers, Boston, MA, P. 868-906.

8. Geotechnical Engineering Bureau 2007. "Geotechnical design procedure for flexible wall systems." State of New York Department of Transportation.

9. Kıvanç, S. 2006. Numerical analysis of anchored concrete pile wall: A case study.Master of Science thesis, Atilim University, Turkey.

10. Plaxis 8.2. (www.plaxis.nl).

11. Iversen, K. M., Nielsen, B. N., & Augustesen, A. H. (2010). Investigation on the Effect of Drained Strength when Designing Sheet Pile Walls. Aalborg: Department of Civil Engineering, Aalborg University. (DCE Technical Reports; No. 93).