

ANALYSIS OF SHORE PILE FOR DEEP EXCAVATIONS

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ABSTRACT

Deep excavations are essential for underground construction, but they also alter the ground conditions and induce ground movements which might cause risks to adjacent infrastructure. In this paper, a parametric study is carried out for the analysis of shore piles both in supported and unsupported conditions in cohesionless type of soil strata with theoretical approaches and developing models in ETABS based on Winkler spring model or subgrade reaction approach of modeling soil behavior. The study reveals the significant effect of modulus of subgrade reaction of soil and embedded length of shore pile in both unsupported and supported conditions. For different soil profiles based on modulus of subgrade reaction, comparisons are made for the variation of moments and lateral displacements with length of shore pile for a given depth of excavation and embedded length of pile in unsupported and supported conditions. Again, with varying embedded lengths of pile, variations of moments and lateral displacements are also observed for fixed values of modulus of subgrade reaction. The results obtained from the developed models are quite closer to that of theoretical approaches and thus the models work effectively in predicting results which can be improved by further studies to study more complicated cases.

Keywords: Deep excavation; shore pile; subgrade reaction; ETABS

INTRODUCTION

With economic development and urbanization, excavations go deeper and become larger in scale and structures in the immediate vicinity of excavations, dense traffic scenario, presence of underground obstructions and utilities have made excavations a difficult task to execute. In this context, analysis and design of proper deep excavations and their supporting systems are essential. When the excavation depth exceeds about 5 to 6 m, then steel sheet pile or rows of concrete piles are used around the boundary of the excavation. Diameter and spacing of the piles is decided based on soil type, ground water level and magnitude of design pressures. Very often, in order to reduce the lateral displacement and depth of embedment of piles, lateral supports or struts are provided. For different soil profiles and layers, theoretical analysis and design of shore piles and struts by conventional approach is a bit tedious process. Therefore, in this study, some models are successfully developed in ETABS for detail and quicker analysis of shore piles to compare the values of moments and lateral displacements with length of pile for different soil parameters below dredge line such as loose, medium and dense sand classified on the basis of modulus of subgrade reaction values in unsupported and supported state. This study also shows that after providing supports, lateral displacements and the depth of embedment of piles is also reduced. Once the analysis is complete, then design of the overall support system can also be readily done using the software and thus saving time.

DATA COLLECTION

In this study, data obtained from a soil report in construction site in Dhanmondi, Dhaka are used in analysis and building models in ETABS. In Table 2, the granular soils are classified into dense, medium and loose sand based on the values of unit weight of soil and friction angle according to the

values of Table 1 proposed by Terzaghi (Teng, 1988). Using these values, with the help of active and passive pressure distribution diagrams, plane of zero shear is found and thus maximum moment is calculated by conventional approach. (Murthy, 2003)

Table 1: Unit Weights of Granular Soil and Coefficient of Active Earth Pressure

Type of soil	Unit wt. of moist soil, γ (lb/ft ³)	Submerged unit wt, γ' (lb/ft ³)	Coefficient of active earth pressure, K_a			
			For backfill	For soils in place	Friction angles	
					ϕ	δ
Dense sand	110-140	65-78	0.35	0.2	38	25
Medium sand	110-130	60-68		0.25	34	23
Loose sand	90-125	56-63		0.3	30	20

After Terzaghi, 1954.

Table 2: Soil Parameters Used for the Analysis.

Soil type above dredge line	Below dredge line
Sand $\gamma = 100 \text{ pcf}$ $\gamma' = 65 \text{ pcf}$ $k_a = 0.35$, $k_p = 2.86$ $\Phi = 30^\circ$	Dense sand $\gamma = 115 \text{ pcf}$, $\gamma' = 70 \text{ pcf}$ $k_a = 0.2$, $k_p = 5$, $\Phi = 38^\circ$
	Medium Sand $\gamma = 105 \text{ pcf}$, $\gamma' = 65 \text{ pcf}$ $k_a = 0.25$, $k_p = 4$, $\Phi = 34^\circ$
	Loose sand $\gamma = 100 \text{ pcf}$, $\gamma' = 60 \text{ pcf}$ $k_a = 0.3$, $k_p = 3.33$, $\Phi = 30^\circ$

Following data are also used to make models in ETABS.

Width of excavation = 30ft, Depth of excavation = 25ft, Pile diameter= 2ft Pile face to face distance= 30 inch, Support is provided at 12.5 ft from top. Location of Ground water = 4ft from top.

Embedded pile length, $L_1 = 20 \text{ ft}$ Embedded pile length, $L_2 = 15 \text{ ft}$ Embedded pile length, $L_3 = 25 \text{ ft}$ MODELS IN ETABS

In ETABS, models are developed based on Winkler's subgrade reaction approach in which soil is modeled as a set of independent elastic springs. The spring coefficients of these springs reflect the material properties of soil and are known as coefficient of subgrade reaction. In ETABS, concrete shore piles are driven to the pre-determined depth. After setting the given parameters, the lateral pressure distribution above the dredge line is formed by using the equation proposed by Peck (Murthy, 2003). The expression is

$$P_a = 0.65\gamma H K_a \quad (1)$$

The pressure p_a is uniform with respect to depth. Fig. (1) gives the apparent pressure distribution diagrams as proposed by Peck.

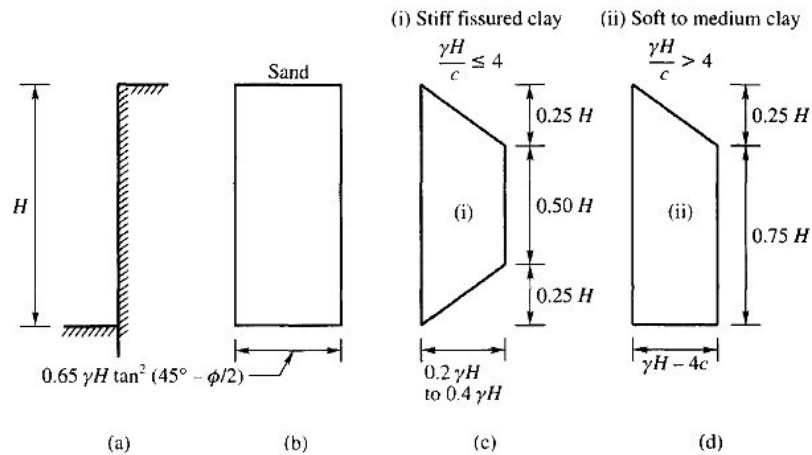


Fig. 1: Earth Pressure Distribution Diagrams for Braced Cuts (Peck, 1974)

Below the dredge line, Winkler's subgrade reaction concept is used. Springs are placed at one feet depth down to the depth of embedment. For sandy soil the coefficient of horizontal subgrade reaction is computed from $k = n_h$

(2)

Where n_h = coefficient of horizontal subgrade reaction for a one feet wide pile at one feet depth. Z = depth in ft, B = width of pile in ft.

The values of n_h are used from a Table 2 given by Terzaghi. (Bowles, 1997)

Table 2: Values of Coefficient of Horizontal Subgrade Reaction (lb/in^3) for a one Feet Wide Pile at one Feet Depth Given By Terzaghi

	Loose sand	Medium sand	Dense sand
Dry or moist	8	24	65
Submerged	4	16	40

The values of coefficient of horizontal subgrade reaction thus computed are put in each feet depth down to the bottom. For each n_h values, separate models are developed and analysis is run on ETABS and thus maximum moments and corresponding deflections for a particular soil profile and loading conditions are obtained before and after providing supports. Analysis is also carried out in a similar way by changing the depth of embedment of pile.

LOAD CALCULATION

$$P_a = 0.65 \gamma H K_a = 0.65 * 0.35 * 70.6 * 25 = 0.4 \text{ksf}$$

Considering each pile takes load from each side.

$$\text{Load per ft of depth} = 0.40 * (\text{pile diameter} + \text{pile face to face distance})$$

$$= 0.40 * (2 + 0.5) = 1 \text{k/ft}$$

This load and corresponding moments and lateral displacements are for 2.5 ft width. Coefficient of subgrade reaction, $k_s = n_h z / B * 1 \text{ft} * \text{pile diameter}$ (k/ft)

This values obtained are placed after 1ft depth successively. RESULTS AND DISCUSSIONS

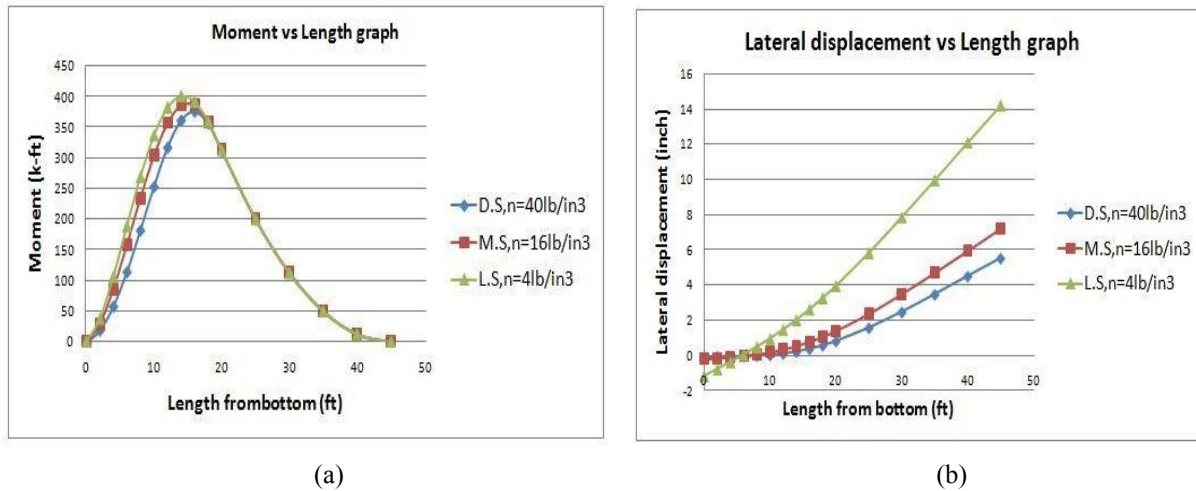


Fig. 2: (a) Moment vs Length graph (b) Lateral Displacement vs Length graph in unsupported state for different n values

In this research, variations of moments and lateral displacements with length of pile for different n values are observed. In unsupported state, for a fixed embedded length of pile, from Fig.2 (a), the values of maximum moment are found to be 376.4 k-ft, 386.2 k-ft and 401.09 k-ft respectively and maximum lateral displacements are found to be 5.5 inch, 7.19 inch and 14.2 inch respectively from Fig.2 (b) for corresponding modulus of subgrade reaction values of 40lb/in³, 16lb/in³ and 4 lb/in³ as proposed by Terzaghi (Teng, 1998). As can be seen from figure, up to dredge line the values of moment are same for different n values but after dredge line the curve splits as per n value. For lower n value moments are larger. As modulus of subgrade reaction represents the stiffness of the soils, greater values of it will yield comparatively less moment and deflection. Moreover, moment values are larger for loose sand, then for medium sand followed by dense sand in unsupported condition which is satisfactory. Moment values are also close to each other. In unsupported condition, deflection increases with length and becomes maximum at the top of the pile. The lateral displacement is quite higher for loose sand in comparison with medium and dense sand.

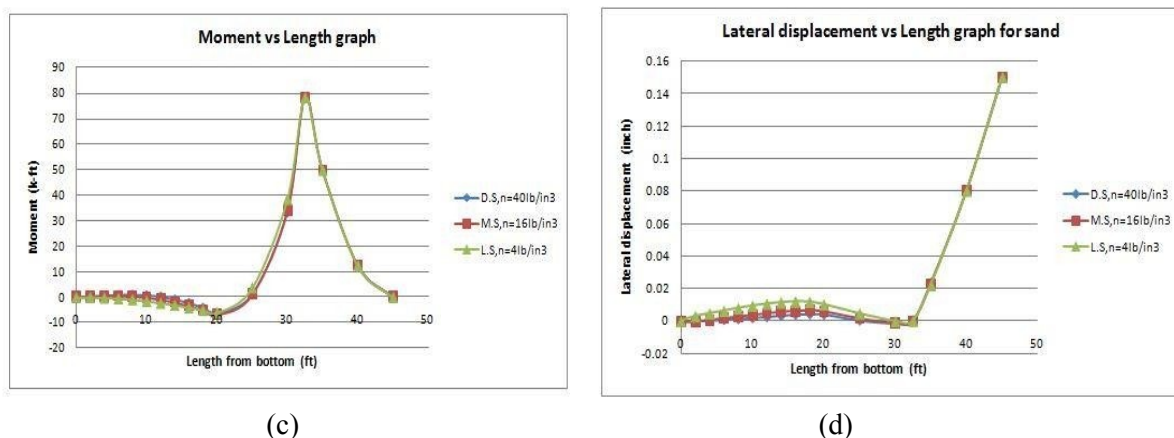


Fig. 3: (c) Moment vs Length graph (d) Lateral Displacement vs Length graph in supported state for different n values

Afterwards, a support is provided at 12.5 ft from top and in this state, for subgrade reaction values 40lb/in³, 16lb/in³ and 4 lb/in³, values of maximum moment are observed as 78.12 k-ft, 78.13 k-ft, 78.13 k-ft in Fig. 3(c) and maximum lateral deflections are reduced and found as 0.15 inch for each type of soil in Fig. 3(d). It is clear that after providing support lateral displacements and moments are reduced and assume very close values for dense, medium and loose sand as per n values.

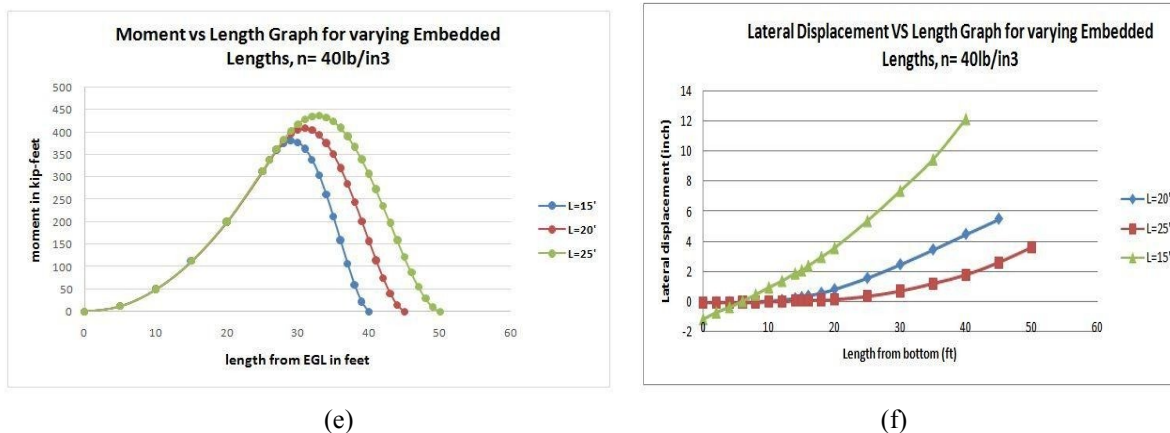


Fig. 4: (e) Moment vs Length graph (f) Lateral Displacement vs Length graph for varying embedded lengths

Again, for a fixed n value embedded length is changed (15ft, 20ft and 25ft) and the variations in moments and lateral displacements are also observed. Figures above are drawn for the same n value 40lb/in^3 and it is seen that the more the embedded length of pile is, the more the resisting moment is and also larger embedded length results in lower value of lateral displacement. For other n values, similar types of results are obtained.

These signs and magnitudes of the parameters are according to expectations.

CONCLUSION

This research was conducted to study the variations in moments and lateral displacements of shore pile with varying embedded lengths in supported and unsupported conditions using Subgrade Reaction approach of modeling soil behavior. From the developed models, one can readily find out the moments and lateral displacements of each point on the shore pile for the given loading conditions and soil profiles and thus providing lateral support at a suitable position, entire lateral support system can be designed by ETABS.

For different soil profiles, lateral displacements due to earth pressure can be reduced by providing supports or by increasing the embedded pile length. Lateral supports also reduce the embedded pile length. However, the models are developed only for granular soils which can be extended further to study the cohesive and layered type of soils as well.

REFERENCES

- Teng, WC. 1988. *Foundation Design*. London: Prentice Hall International. 356p.
- Bowles, JE. 1996. *Foundation Analysis and Design*. New York: McGraw-Hill, 505p & pp. 791-800.
- Murthy, VNS. 2003. *Principles and Practices of Soil Mechanics and Foundation Engineering*. New York: Marcel Dekker, 906-913.
- Macnab, A. 2002. *Earth Retention Systems Handbook*. New York: McGraw-Hill, pp. 319-322.
- Broms, BB. 1964b. Lateral Resistance of Piles in Cohesionless Soils. *Journal of the Soil Mechanics and Foundation Division*, American Society of Civil Engineers, 90(SM3):123-156.