Effects of Soil Properties on the Sheet Pile Retaining Wall Deflections

A. R. Maddi, C. Vipulanandan, Ph.D., P.E.
Texas Hurricane Center for Innovative Technology (THC-IT)
Department of Civil and Environmental Engineering
University of Houston, Houston, Texas 77204-4003
E-mail:srmaddi@uh.edu, cvipulanandan@uh.edu Phone: (713) 743-4278

Abstract: In this study, impact of soil cohesion and internal angle of friction on sheet pile wall deflections were investigated. The value of soil cohesion was varied from 70 to 280 kN/m^2 and soil friction angle from 0 to 40°. A sheet pile of thickness 27.6 mm was used in this study. The sheet pile wall is used for excavation of upto 40 ft. The depth of the sheet pile wall embedded in the soil was 60 ft in the soil. The finite element method was used to perform numerical modeling and analyses to evaluate the structural response and behavior of the walls. The results show that increasing the value of cohesion reduced the deflection values and increasing friction angle increased the deflection values. Maximum value of deflection of 284.4 mm was observed for cohesion of 70 kN/m^2 and friction angle of 40°.

1. Introduction:

Sheet pile walls are one of the earth retention systems utilized in construction projects especially during excavation. They consist of continuously interlocked sheet pile segments embedded in soils to resist horizontal pressures. Sheet pile walls are used for various purposes; such as large and waterfront structures, cofferdams, cut-off walls under dams, erosion protection, stabilizing ground slopes, excavation support system, and floodwalls. The movement of flexible walls is important because it may cause damages to adjacent structures. Sheet pile walls have relatively much lower system stiffness compared to other in-situ walls such as slurry walls (Clough and O'Rourke 1990). Due to their lower system stiffness, sheet pile walls experience relatively larger deformations. Steel is the most common material used for sheet pile walls due to its resistance to high driving stresses, relatively lightweight, and long service life. This type can be used either above or under water if it is provided with modest protection. Steel sheet piles walls are suitable for structures that require deep penetration or large water depths. They are available in various cross-section shapes with the allowable stress ranged from 170 to 210 MPa (25 – 30 ksi). The PZ- type piles based on American Society for Testing and Materials International (ASTM) A328 or A572,Grade 50 are the most common ones that are used in retaining and floodwall applications. The deformations of sheet pile walls, either cantilever or anchored walls, are very important, especially when soft cohesive soils are present at the site. The total deformation of the wall can be due to unloading caused by the excavation area, elastic deformation of the wall, shear deformations of the earth body, and the soil movement below the wall. For the cantilever sheet pile wall; the bottom of the wall is assumed not to displace, whereas the top of the wall at the ground assumed to have enough movement to allow the active and passive earth pressure to be generated (Han et al., 2017).

PLAXIS, 2-D finite element analysis software package, was used for the parametric study in this research. PLAXIS program is a special purpose finite element program used to perform deformation and stability analysis for various types of geotechnical applications such as excavation, foundations, embankments and tunnels. Geotechnical projects require advanced constitutive models for the simulation of the nonlinear, time dependent and anisotropic behavior of soils and rock. PLAXIS can be used to model different element types; such as different retaining wall types as sheet pile walls and diaphragm walls, anchors to support the retaining wall, various types of loads behind the wall, and the interface elements between the anchored sheet pile walls and the soil. PLAXIS, 2-D program consists of three main parts which are Model, Calculation and Output mode.

Objective: The objective of the study was to investigate the steel sheet pile wall behaviour in terms of deformations and bending moments by varying soil properties.

2. Problem:

A parametric study was performed to investigate the effect of various soil properties on sheet pile walls behaviour. The width and depth of each model boundaries were fixed and were not changed. Size of the numerical model is shown in Figure 1.

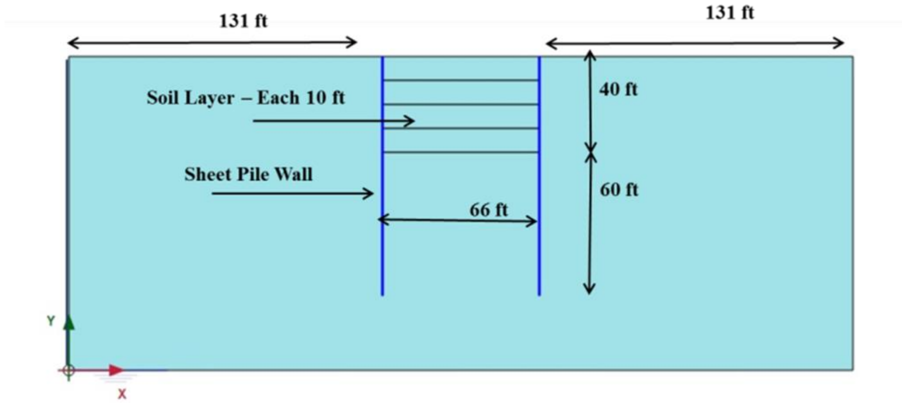

Figure 1: Plaxis 2D model for sheet pile analysis.

3. Results and Discussion

Case 1:

The value of maximum deflection increased with increase in depth of exaction linearly for all values of internal angle of friction. (Figure 2)

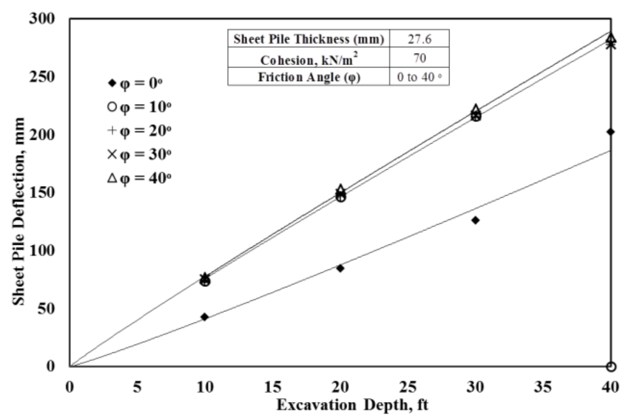

Figure 2: Sheet pile wall deflection in soil with cohesion of 70 kN/m² and varying friction angle from 0 to 40°.

The maximum deflection at excavation depth of 40 ft increased with the value of internal value of friction from 202 mm to 284.4, 41 % increase. (Table 1)

Table 1: Sheet pile wall maximum deflection in soil with cohesion of 70 kN/m² and varying friction angle from 0 to 40° at different depths of excavation.

	Maximum Deflection (mm)				
	Internal Angle of Friction (Deg.)				
Excavation Depth (ft)	**φ = 0°**	**φ = 10°**	**φ = 20°**	**φ = 30°**	**φ = 40°**
10	42.68	73.91	74.31	75.21	76.86
20	84.81	146.6	147.1	149	153
30	125.9	216.2	215	216.8	222.6
40	202.4	Failure	277.5	278.2	284.4

Case 2:

The value of maximum deflection increased with increase in depth of exaction linearly for all values of internal angle of friction. The maximum deflection at excavation depth of 40 ft increased with the value of internal value of friction from 157 mm to 283, 80 % increase. (Figure 3 &Table 2)

Increasing the value of cohesion from 70 to 280 kN/m^2 reduced the defection at 40 ft excavation depth.

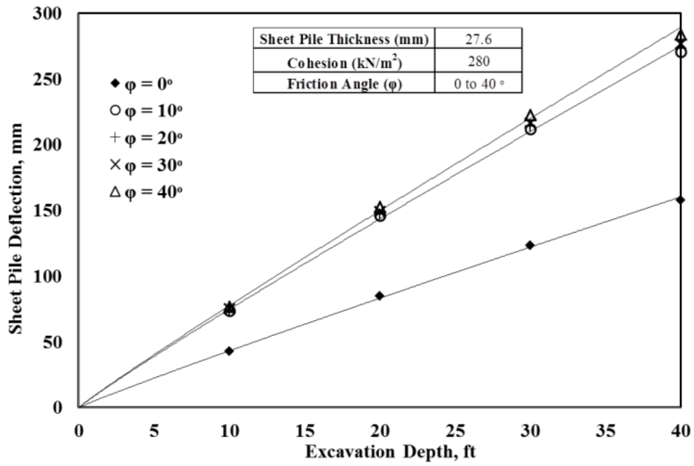

Figure 3: Sheet pile wall deflection in soil with cohesion of 280 kN/m^2 and varying friction angle from 0 to 40°.

The soil with internal angle of friction equal to 0 and cohesion of 280 kN/m^2 had lowest maximum deflection of 157.6 mm.

Table 2: Sheet pile wall maximum deflection in soil with cohesion of 280 kN/m^2 and varying friction angle from 0 to 40° at different depths of excavation.

	Maximum Deflection (mm)				
	Internal Angle of Friction (Deg.)				
Excavation Depth (ft)	**φ = 0°**	**φ = 10°**	**φ = 20°**	**φ = 30°**	**φ = 40°**
10	42.68	73.9	74.3	75.07	76.59
20	84.64	145.9	146.9	149	152.7
30	123.3	212	213.9	216.7	222.4
40	157.6	270.6	273.4	276.6	283.9

5. Conclusion

For soil with cohesion 70 kN/m^2, the maximum deflection at excavation depth of 40 ft increased with the value of internal value of friction from 202 mm to 284.4, 41 % increase. For soil with cohesion of 280 kN/m^2, the maximum deflection at excavation depth of 40 ft increased with the value of internal value of friction from 157 mm to 283, 80 % increase. The soil with internal angle of friction equal to 0 and cohesion of 280 kN/m2 had lowest maximum deflection of 157.6 mm.

6. Acknowledgements

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7. References

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