13th Australia New Zealand Conference on Geomechanics – Acosta-Martínez & Lehane (Eds.)

Lateral load - deflection profile of cantilever sheet pile wall

Aparna & N. K. Samadhiya
Department of Civil Engineering, Indian Institute of Technology Roorkee,Roorkee,Uttarakhand, India

ABSTRACT: This paper discusses the result of an experimental study conducted for evaluating the effect of depth and distance of adjacent footing on the behavior of cantilever sheet pile wall. Model sheet pile wall tests have been performed in the medium dense sand. The deflection of sheet pile wall and lateral load coming onto the sheet pile wall are observed with the help of dial gauges and Proving rings respectively. The position of footing from the sheet pile wall and depth of footing have been varied in this study. The footing is placed at 20 cm, 40 cm, 60 cm and 80 cm from the wall face at the backfill side with three different depths of footing. The peak lateral load coming onto the sheet pile wall and maximum deflection of the sheet pile wall are observed decreasing with increasing depth of footing and distance of footing from the wall face.

1 INTRODUCTION

Embedded cantilever sheet pile retaining walls are frequently used for temporary and permanent support of excavations up to about 4.5 m height. The embedded cantilever wall obtains its ability to resist the pressure of the retained soil by developing resisting earth pressures on the embedded portion of the wall. Embedded retaining structures sustain overturning moments and horizontal forces, which are caused by backfill soil, groundwater, and surcharge loading. The contact pressures and resistances are distributed over the embedment depth due to the backfill loading so that the entire retaining structure remains in equilibrium. (Stanislav, 2006). They are widely used in excavation support systems, slope stabilization, floodwalls, and waterfront structures.

Rowe (1952) conducted fifteen different tests on flexible retaining wall backfilled with cohesionless soil. The influence of different parameters like surcharge, position of anchors, dredge level, type of soil, flexibility of pile and distribution of soil pressure has been studied. The author showed that all method of sheet pile wall design matches with the experimental results on applying a reduction factor to the bending moments obtained from free earth support method. Milligan (1983) had done experimental studies on anchored sheet pile wall. The deformations in the soil were measured by the radiographic method. The effect of various parameters like the flexibility of wall, surface characteristics and method of construction was analyzed in the study. As expected the magnitude of deflection of the wall with a smooth surface was larger than the wall with a rough surface. Hanna & Khurdi (1974) had conducted experimental studies on anchored flexible retaining walls in sand by considering certain primary factors like anchor geometry, initial design assumption, soil density and initial stress state. A rapid increase in wall deflection was observed as excavation proceeded. Upon movement of the wall, the lateral earth pressure behind the sheet pile wall gets reduced. Clough & Reed (1984) studied the sheet pile wall supported excavation for the culverts. The excavation was 7.6 m wide and 9.2 m deep. Large movements were developed in the sheet pile, which was mainly due to the low strength of the mud at the area. The factor of safety against basal heave was 0.9 to 1.4 which was comparatively low. Different parameters like wall movements, wall settlements, and pore pressures were analyzed in the test. Ohori et al. (1988) studied the behavior of double sheet pile wall structure which is subjected to horizontal force. For this study of the sheet pile wall, an elasto-plastic model has been made for the calculation purpose. The model test is compared with the result obtained from the calculation model. Rajagopal & Sri Hari (1998) had done an experimental study on sheet pile wall with vertical anchors. The effect of the tie rod, length and shape of anchors, density of soil and location of anchors have been studied. Georgiadis & Anagnostopoulos (1998) conducted an experimental study as well as numerical analysis to investigate the influence of surcharge loads on the behavior of the wall. Seok et al. (2001) analyzed a braced excavation which results in the deformation of the ground surface and the settlement of the structure adjacent to the sheet pile wall. The settlement is due to the reduction in the foundation stiffness which was caused due to the deformation of the excavation face. Finno & Roboski (2005) presented a paper on the pattern of ground deformations measured while constructing a tie back excavation of 12.8 m deep in Chicago.

Present study focuses on the change in the behavior of sheet pile wall by changing few parameters around it. Sheet pile wall is placed adjacent to a pre-existing footing where excavation has to be made. The distance between sheet pile wall face and footing has been varied. The footing is placed at different levels so as to vary the depth of footing. The relation between lateral load on the sheet pile wall and its respective deflection along the height of the sheet pile wall has been shown in this study.

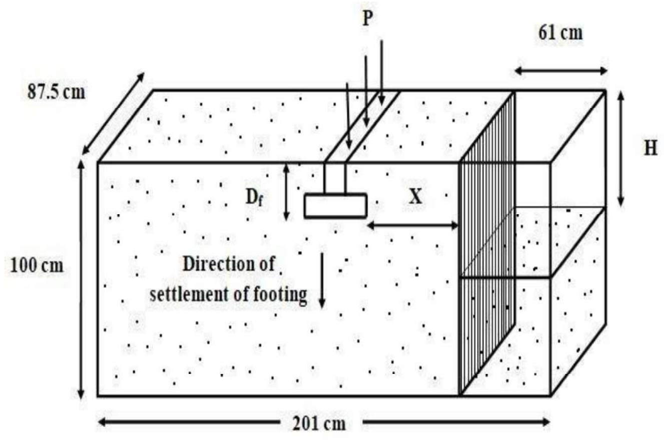

Figure 1. Experimental Setup

2 METHODOLOGY

Model tests are conducted in the laboratory with sand as backfill to understand the significance of various parameters affecting the system of sheet pile wall supported excavation nearby a strip footing. Figure 1 shows the schematic diagram of the testing facility and Figure 2 shows a clear picture of the facility in the laboratory. It comprises of one test tank of dimension 2010×875×1000 mm, one hydraulic jack for applying load on footing, one sheet pile wall of dimension 1000×860×1 mm, footing of dimension 860×150×25 mm and aluminium hollow pipes to connect sheet pile wall to outer arrangement for measuring deflection of sheet pile wall with the help of dial gauges. Four proving rings are used to check the lateral load coming onto the sheet pile wall. Four titanium hollow pipes are used to connect proving rings from outer arrangement to the sheet pile wall.

Figure 2. Test facility in Laboratory

2.1 *Test Procedure*

Dry sand (ϕ = 34°) is poured from a constant height to maintain a uniform density of 15 kN/m^3 throughout the test tank. Medium dense sand has been used to fill the test tank with 55% relative density. Initially, the sheet pile wall made-up of Galvanised iron, is placed 61 cm away from the outer plywood wall inside the tank and it is clamped to both sides of the top of tank to stand vertically then titanium pipes or aluminium pipes (according to the test performed) are connected to it then the whole tank is filled with medium dense sand. After preparing the sand bed, footing is placed over it with loading block on the centre of it. A mechanical jack is used to apply load onto the footing equivalent to a load intensity of 20 kN/m^2. The load has been measured with the help of a proving ring.

Initial readings of all four proving rings (or dial gauges) are taken then the load is applied and corresponding changes in proving ring or dial gauge readings are noted down. Then excavation is made in front of the sheet pile wall. Successive excavation is made having 15 cm sand layers each excavated at a time. After first layer excavation, readings are noted down and like this, till the fourth layer, all readings are noted down. Total 60 cm height of sand has been excavated in four layers. The proving ring readings (load readings) and dial gauge readings (deflection readings) are observed. Sequential excavation is made in four layers. 15 cm, 30 cm, 45 cm, and 60 cm soil height is removed respectively in the first, second, third and fourth layer of excavation. X is varied as 20 cm, 40 cm, 60 cm and 80 cm from the wall face at the backfill side as shown in fig. 1 and depth of footing has been varied as at the surface, at

7.5 cm, at 15 cm below the sand bed level. All experimental findings are presented in the next section.

3 RESULTS AND DISCUSSIONS

Figure 3 shows deflection of sheet pile wall at different levels of excavation without the application of surcharge load. It is observed that sheet pile wall deflects more as the excavation continues (Aparna et al., 2017). The maximum deflection observed is 82 mm at the top of the wall. Figure 4 shows the lateral load coming on the sheet pile wall at different levels of excavation without the application of surcharge load. It is observed that the lateral load coming on the sheet pile increases as the excavation continues. Active pressure condition is developed after deflection of 0.3% of height of wall (Bowles, 1982) and wall experiences higher active pressure on it with each successive excavating layer. The maximum load found is 293 N at 250 mm below the top of the wall. The coming lateral load and corresponding lateral deflection of sheet pile wall were measured and recorded for each successive excavating layer along the height of the sheet pile wall. Figure 5 is showing the relation between the lateral load coming on the sheet pile wall and corresponding deflection of it along its height with each successive layer. It can be seen from the graph that the deflection of the sheet pile wall increases with increasing lateral load on it. For all the cases maximum lateral load is found 250 mm below the top of sheet pile wall because of the manner of load distribution.

Figure 6 shows the peak lateral load top deflection curves of sheet pile wall for footing placed at 400 mm (X = 400 mm) behind the sheet at different depth of footings. It is observed that top deflection advances as lateral load coming on the sheet pile wall increases. It is also observed that the top deflection of the sheet, as well as peak lateral load on the sheet, are recorded maximum for the case when footing is placed at the surface and these are found decreasing as the depth of footing increases. For cases when footing is placed below the top sand bed level (D_f = 75 or 150 mm), load applied on footing causes less deflection at the top of the sheet pile wall as lateral load is distributed from that level of footing. Maximum distributed load on sheet pile wall also shifted downwards and causes less lateral load on proving rings.

Figure 7 shows the graph between peak lateral load coming on sheet pile wall and the top deflection of the sheet when footing is placed 600 mm behind the sheet at different depth of footings.

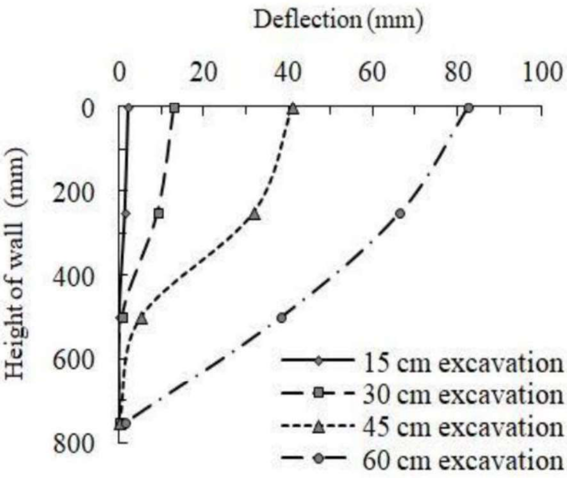

Figure 3. Deflection of Sheet Pile Wall without surcharge load

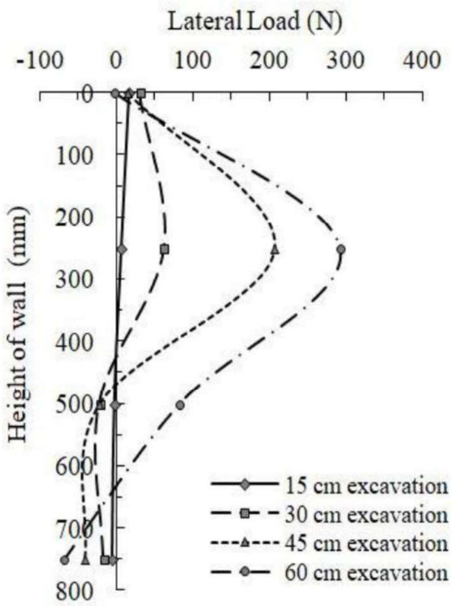

Figure 4. Lateral load on Sheet Pile Wall without surcharge load

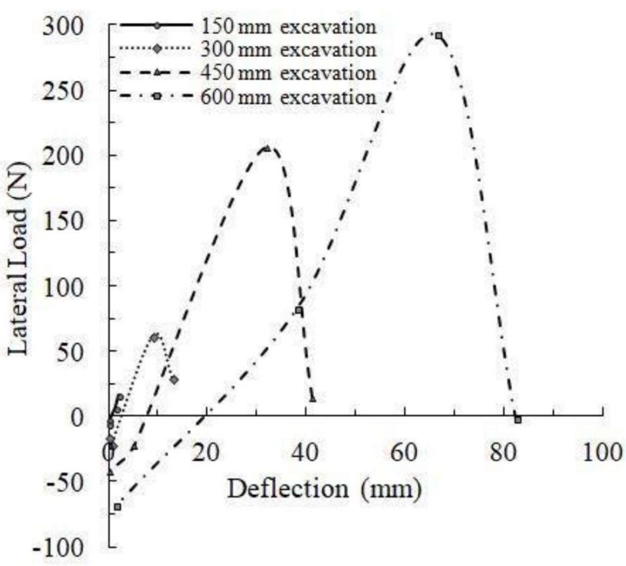

Figure 5 Lateral load - deflection of Sheet Pile Wall

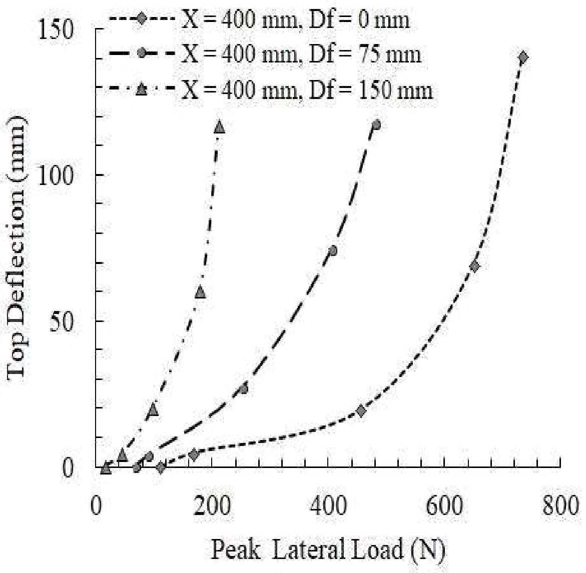

Figure 6. Peak Lateral load – Top deflection of Sheet Pile Wall for X = 400 mm

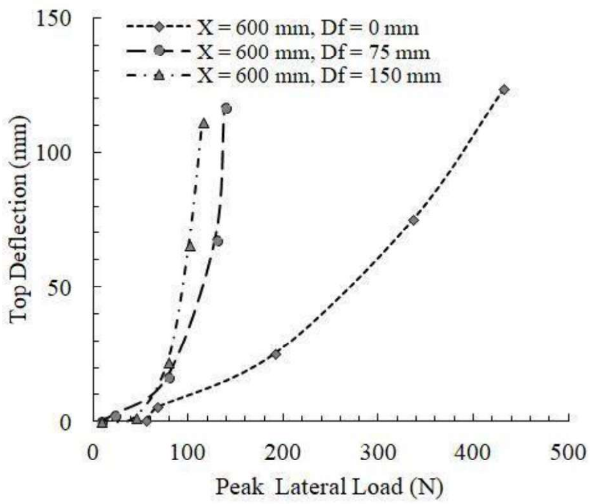

Figure 7. Peak Lateral load – Top deflection of Sheet Pile Wall for X = 600 mm

Figure 8 shows the graph between peak lateral load coming on sheet pile wall and the top deflection of the sheet when footing is placed at the surface and 200 mm, 400 mm, 600 mm and 800 mm behind the sheet pile wall in different cases. It is observed that the top deflection of sheet increases in proportion to the coming lateral load and both of these found decreasing with increase in the distance between the footing and sheet pile wall. The maximum deflection and lateral load are observed for the case when footing is placed just 200 mm away from the sheet pile wall. The influence zone shifts away from the sheet so the observed load and deflection reduce significantly.

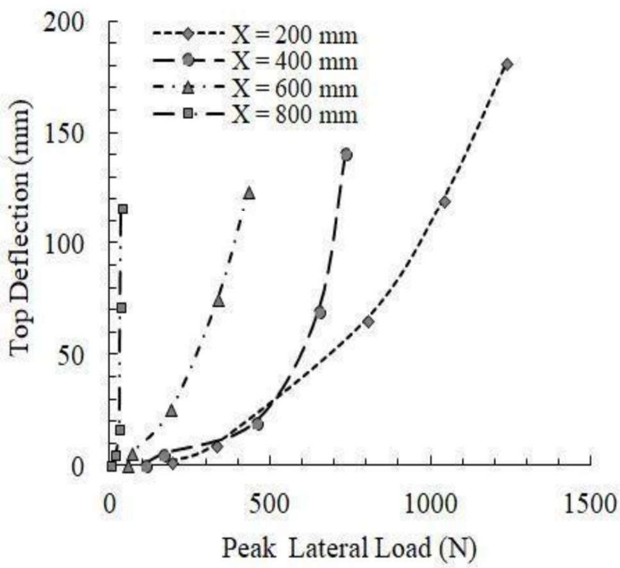

Figure 8. Peak Lateral load – Top deflection of Sheet Pile Wall for D_f = 0

4 CONCLUSIONS

This study shows the relation between the top deflection of the sheet pile wall and the lateral load coming onto it. Laboratory Experiments are conducted and various parameters are varied in this sheet pile wall supported excavation system. The result shows that deflection of sheet increases in proportion to the load coming onto it. The load on the sheet pile wall and its deflection increase with each successive excavating layer. The deflection and load on the sheet pile wall both decreases with increase in the depth of footing and also with increase in distance between footing and the sheet pile wall.

REFERENCES

Aparna, Raj, A. & Samadhiya, N.K. 2017. Effect of Sheet Pile Wall Supported Excavation on Adjacent Structures. *Indian Geotechnical Conference GeoNEst*, IIT Guwahati, India.

Bowles, J.E. 1982. *Foundation Analysis and De-sign, 3rd ed.*. McGraw Hill, New York, NY, USA.

Clough, G.W. & Reed M.R. 1984. Measured Behavior of Braced Wall in very Soft Clay. *Journal of Geotechnical Engineering* 110(1):1-19.

Finno, R. J. & Roboski, J.F. 2005. Three-Dimensional Responses of a Tied-Back Excavation through Clay. J*ournal of Geotechnical and Geoenvironmental engg.*131(3): 273-282.

Georgiadis, M. & Anagnostopoulos, C. 1998. Lateral Pressure on Sheet Pile Walls due to Strip

Load. *Journal of Geotechnical and Geoenvironmental engg.* 124(1): 95-98.
Hanna, T. H. & Kurdi,I. 1974. Studies on Anchored Flexible Retaining Walls in Sand. *Journal of Geotechnical Engginering,* 100(GT10): 1107-1122.
Milligan, G. W. E. 1983. Soil deformation near anchored sheet-pile walls, *Geotechnique* 33 (1): 41-55.
Ohori, K., Takahashi, K., Kawai, Y. & Shiota, K.1988. Static Analysis Model for Double Sheet-pile Wall Structures. *Journal of Geotechnical Engineering* 114(7): 810-825.
Rajagopal K. & Sri Hari V. 1998. Experimental Study on Retaining Walls Supported by Vertical Plate Anchors. *Indian Geotechnical Journal* 28(3): 270 – 296.
Rowe, P.W. 1952. Anchored Sheet-Pile Walls *Instn Civ. Engrs.* Paper No. 5708.
Seok, J. W., Kim, O. Y., Chung, C. K. & Kim, M. M. 2001. Evaluation of Ground and Building Settlement near Braced Excavation Sites by Model Testing *Can. Geotech. J.* (38): 1127-1133.
Stanislav, S. 2006. Interactional Approach of Cantilever Pile Walls Analysis. *ACTA Geotechnica Slovenica*: P 47-59.