International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 7, Issue 6, June 2017)

Impact of Sliding Layer Location on Response of Single Pile Induced to the Lateral Soil Movement

Mohammed A. Al-Neami[1], Kais T. Shlash[2], Ahmed Saad Elewi[3]

[1]*Assist. Professor, Building and Construction Engineering Department, University of Technology, Baghdad, Iraq.*
[2]*Professor, Civil Engineering Department, Uruk University - Baghdad, Iraq.*
[3]*Ph. D. Student, University of Technology, Building and Construction Engineering Department, Baghdad, Iraq.*

***Abstract*— Constriction embankment near pile bridge, deep excavation near high-rise structure with deep foundation on soft or weak soil lead to generate a lateral soil movement inducing additional displacement and bending moment on pile. A series of laboratory model tests was undertaken to investigate the responses of piles subjected to lateral soil movement with different location of sliding depth. A manufactured laminar shear box with special structure frame was used to provide different movement rates and designed to move up and down so that various sliding layer depths can be achieved. The variation of vertical and horizontal displacements, bearing capacity and bending moment along pile shaft embedded in dry sand were measured at different location of sliding layer. The major findings in this research that the horizontal and vertical displacements, bending moment and bearing load of pile increase with increasing the rate of lateral soil movement. Higher value of positive bending moment is occurred at the near sliding layer while the negative moment is developed approximately at centre of sliding layer. In addition, the location of sliding layer has a significant effect on shape and value of bending moment, horizontal and vertical displacement and bearing load. The vertical movement increases with increasing the location of sliding depth and approaching to the maximum magnitude for the sliding sand layer location near the pile tip (end of pile)**

***Keywords*—lateral soil movement; passive pile; sliding layer location; sand soil**

I. INTRODUCTION

In the case of piles closing to deep excavations like tunnel operation, pile for slop stabilization, embankments behind piled and bridge abutments in soft or weak soil layer, the load in these cases generates lateral soil movement act on pile. The lateral soil movement leads to developing the horizontal pressure between the pile and soil, with a consequent development of deflection in the pile and bending moment [1]. Figure (1) shows a typical example of pile under lateral soil movement [2].

The slip surface of landslides is substantially weaker (softer) than the materials above or below it. Also in deep excavation, the weaker layer moves toward pile and in embankment near bridge abutment the weaker soil moves regardless the location of this layer. This zone has been referred to as the discrete shear zone [3].

De Beer and Wallays [4] experienced a case of the pile loaded by lateral soil movements caused by an embankment, as in Figure (2). Tschebotarioff [5] assumed that the soil pressure distribution along the pile shaft was of triangular shape as depicted in Figure (3). In addition, another researcher had been conducted the empirical solutions, experimental studies (small-scale model or centrifuge model) and numerical studies for piles under lateral soil movement [6; 7; 8; and 9].

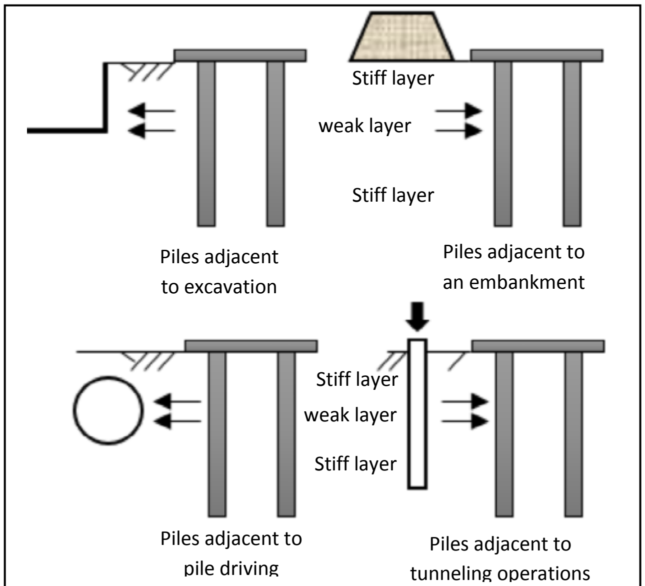

Fig. (1): Typical example of pile under lateral soil movement

International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 7, Issue 6, June 2017)

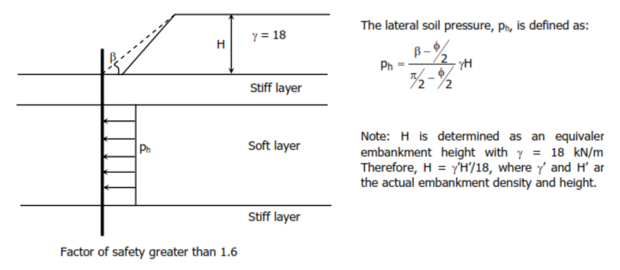

Fig. (2): Method of De Beer and Wallays

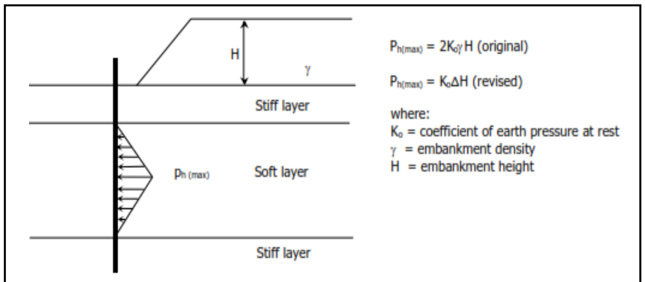

Fig. (3): Tschebotarioff's design method [5]

II. TEST DESCRIPTION

The testing system consists of five main parts, (laminar shear box, the horizontal movement system, the raining technique of sand, piles model and instrumentation with date acquisitions). Related information is introduced herein.

2.1 Laminar shear apparatus and loading system

The laminar shear box apparatus used in this study was manufactured as a physical model to simulate the lateral soil movement and to clarify the variation of vertical and horizontal displacements; bearing capacity and bending moment along pile shaft embedded in dry sand that developed under the lateral soil movement. It consists of lower part of the fix box while the upper part consists of rigid rectangular laminar frames. The lateral movement system encompasses of horizontal hydraulic jack system and loading steel block that exerts a lateral force applied to the upper movable laminar frames at a side of moving soil in shear box. This system provides different movement rates.

The structure of hydraulic jack is designed to move up and down along the steel structure that carries the hydraulic jack, so that various sliding layer depths can be achieved using the same loading block for the same movement layer (the hydraulic jack system can be used for any level or any frame that need to move it by adjusting in all directions, Plate (1). [10] Present more details and dimensions.

2.2 Pile model and sand properties

A hollow cylindrical smooth aluminum pipe of 18 mm in diameter and 570 mm in length, and 1.5 mm thickness with bending stiffness of 0.18×106 kN.mm^2, is used as a pile model. The embedded length of pile is 540 mm. Thus, the embedment depth to diameter ratio (L/D) in this study is equal to 30.

Dry sand brought up from site in middle of Baghdad City at depth of (10-15) m was used in this research to study the effect of lateral soil movement on pile. A summary of the test results with standard specification is presented in Table (1).

Miniature button load cell (nictech-blc-4w-350 series) of 100 kg capacity, 20 mm diameter and 10 mm height is used to measure the load at pile tip. The total horizontal and vertical displacements of the pile cap after applying a horizontal soil movement were measured using LVDT (Linear Variable Differential Transformer).

2.3 Model Preparation and Experimental Procedures

In the beginning of testing, the aluminum pile model is prepared by installing half bridge with 4 couples of strain gages are fixed along two sides of the piles with equally spaced intervals. Sleeve membrane is used to cover the external surface of pile to protect the strain gauge with any damage may be occurred during the testing process. Sand raining technique has been used to prepare and obtain a soil bed with a uniform and homogeneous density. Before the developing the soil movement, all wire sensors (strain gages, displacement transducers and load cell) must ensure connected with their loggers to record the pile response.

III. TEST RESULTS

To investigate the position of sliding layer effect on response of piles model, different locations of sliding layer below the surface are selected.

International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 7, Issue 6, June 2017)

Four sliding locations (Ls1) (0, 100, 200 and 300mm) for single pile are selected. The length to diameter ratio (L/D) equals to 30 and loose sand with relative density of 30% is used.

Eight tests for single pile (4 pile models are tested with movement rate of 12.5 mm/min and other four models are tested with movement rate of 7.5 mm/min) used in this study. For all cases, the thickness of movement layer of (Lm) 100 mm is considered.

Plate (1): Laminar shear box

International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 7, Issue 6, June 2017)

Table (1):
Properties of the sand used.

Property	***Value***
Coefficient of uniformity, Cu	1.70
Coefficient of curvature, Cc	0.96
Classification (USCS)*	SP
Specific gravity, Gs	2.67
Maximum void ratio, e_{max}	0.99
Minimum void ratio, e_{min}	0.74
Initial dry unit weight, γ_d (test)	13.74
Initial relative density, R.D%	30%
Initial void ratio, e (test)	0.922

3.1 Horizontal displacement at pile cap results

Figures (4) and (5) present the variation of total horizontal movement recorded by LVDT touch with pile cap for single pile due to changing the location of sliding layer under two soil movement rates of 12.5 mm/min and 7.5 mm/min.

Evaluating the behaviors of pile shown in figures, leads to the following conclusions:

- Under the same time and with 12.5 mm/min soil moving rate, the peak horizontal movement is developed when the movement is occurred in the layer within the depth of (100-200) mm below the top of pile due to interference between this layer and the layers below and underneath it, which works to reduce the upward movement and thus increasing the total horizontal movement.
- In case of movement soil with depth of (300-400) mm and (0-100mm) sand layer, the lowering horizontal movement is observed. This behavior may be attributed that when the depth of soil movement (0-100) mm most of sliding is transferred to the free vertical movement while in case of (300-400) the movement is constrained due to overburden pressure above it.
- The horizontal movement is proportional with continuing soil movement.
- Changing effect of sliding layer location is more obvious in case of movement rate of 7.5 mm/min. The pile has the same behavior but the values of horizontal movement are lower than those occurred at 12.5 mm/min movement rate and more time is needed to reach peak values because the sand matrix has more time to redistribute its particles

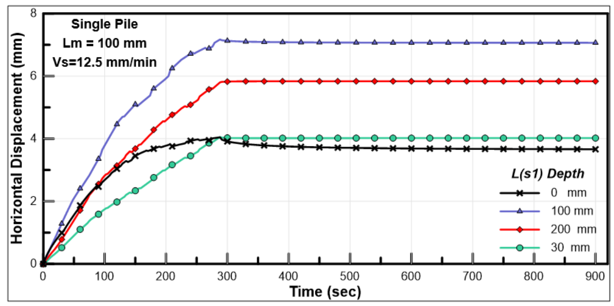

Fig. (4): Variation of horizontal displacement of foundation with time at 12.5 mm/min soil movement

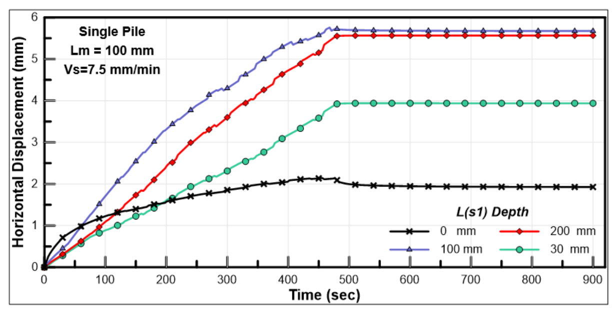

Fig. (5): Variation of horizontal displacement of foundation with time at 7.5 mm/min soil movement

3.2 Vertical displacement at pile cap results

The vertical displacement at pile head with time under two movement rates of (12.5 mm/min and 7.5 mm/min) are presented in Figures (6) and (7) respectively. Generally, for all tests had been investigated, it can be seen that the vertical movement increases (upward) with the increasing of location of sliding depth and approaches to the maximum value for the sliding sand layer location near the pile tip due to confining the area of lateral sliding by the overburden pressure of sand and translated to the vertical movement. Also, the high movement rate (12.5 mm/min) gives a marginally small magnitude more than the rate 7.5 mm/min.

IJETAE
EXPLORING RESEARCH AND INNOVATIONS

International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 7, Issue 6, June 2017)

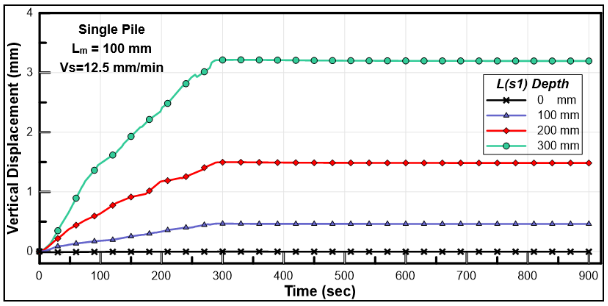

Fig. (6): Variation of vertical displacement of foundation with time at 12.5 mm/min soil movement

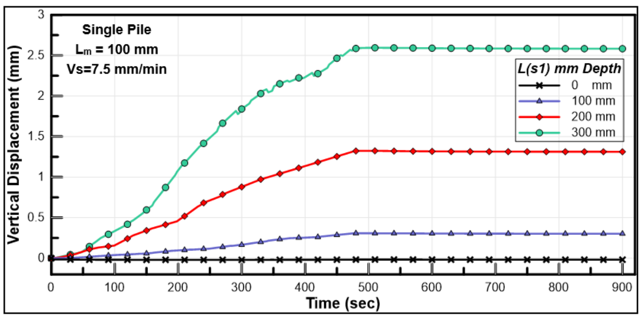

Fig. (7): Variation of vertical displacement of foundation with time at 7.5 mm/min soil movement

3.3 Bearing load at pile tip test

It is important to investigate and explain the end bearing load variation of pile with time for different movement layer locations. Figures (8) and (9) are plotted to explain this target.

The variation of bearing at pile tip shown in figures, attributing to the reduction in bearing that occurred as a result to develop the negative skin friction due to soil movement, which leads to push the pile upward. Therefore, the bearing load at pile tip is close within small time to zero (floating pile). Finally, when the soil movement is stopped, bearing load is returns to increasing due to redistribution of sand particles and the pile sinks gradually.

3.4 Bending moment along Pile results

In the design of pile cross-section, it is important to know the value and position of maximum bending moment developed in the pile.

The variation of bending moment along the single pile was measured using several strain gauges pasted along the sides at certain distances of piles.

Figure (10) and (11) illustrate the variation of bending moment developed along the pile depth for pile with soil movement rates of 12.5 and 7.5 mm/min) respectively.

Each figure depicts bending moment results at various soil movement [(20, 40, 60) mm (stopping moving layer) and end test] respect to the pile depth.

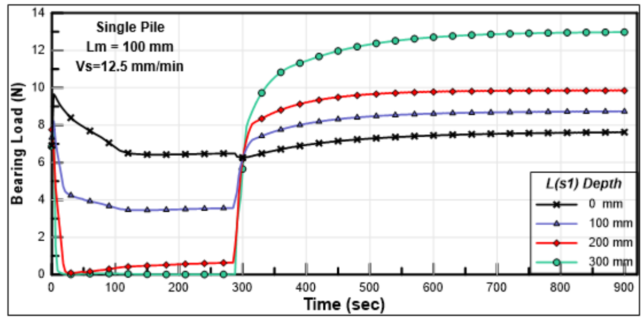

Fig. (8): Variation of bearing load with time at 12.5 mm/min soil movement

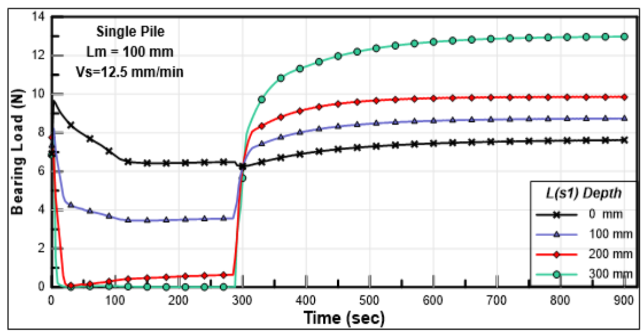

Fig. (9): Variation of bearing load with time at 7.5 mm/min soil movement

It can be concluded that the location of sliding layer has a significant effect on shape and value of bending moment along the pile depth. Nonlinear bending moment is developed and varied with respect to location of applied lateral movement. The shape of bending moment is transferred from positive for the upper sliding layer to a negative bending moment for deeper position near the end of pile. This behavior is occurred due to the change the fixity of pile. The higher value of positive bending moment is occurred at the near sliding layer while the negative moment is developed approximately at center of sliding layer because the friction bonds at these points are the lowest as compared with others points along pile depth. For all piles models, the peak magnitude of bending moment decreases with depth due to resistance mobilize against the movement as a result of increasing the overburden pressure, which causes a loss in lateral loading, occur due to sliding movement.

International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 7, Issue 6, June 2017)

IV. CONCLUSION

The purpose of this research is to study the response of single pile under lateral soil movement in different depth of sliding layer. A major finding from these studies is summarized below:

1. The horizontal displacement, vertical displacement, bending moment and bearing load increase with increasing the rate of lateral soil movement.
2. The movement layer below the surface gave a horizontal displacement higher than the movement layer on the surface.
3. The vertical movement increases with increasing the location of sliding depth and approaching to the maximum magnitude for the sliding sand layer location near the pile tip (end of pile).
4. The location of sliding layer has a significant effect on shape and value of bending moment along the pile depth. Nonlinear bending moment is developed and varied in respect to location changing of applied lateral movement and the higher value of positive bending moment is occurred at the near sliding layer while the negative moment is developed approximately at center of sliding layer.
5. The variation of end bearing load decreases with changing the movement layer location gradually downward and takes larger values when the location of moving layer at 400 mm from soil surface.

REFERENCES

[1] Poulos, H. G., and Davis, E. H., (1980), “Pile Foundation Analysis and Design”, Series in Geotechnical Engineering, John Wiley and Sons.

[2] Bauer, J., Kempfert, H. G., and Reul, O., (2014), “Lateral pressure on piles due to horizontal soil movement – 1g model tests on single piles and pile rows”. In Proceedings of the 8th International Conference on Physical Modelling in Geotechnics, Perth (Gaudin C and White D (eds)). Taylor and Francis, London, UK, vol. 2, pp. 839–845.

[3] Poulos, H.G. (1995), “Design of reinforcing piles to increase slope stability” Canadian Geotechnical Journal, Vol. 32, pp. 808–818.

[4] De Beer, E.E. & Wallays, M., (1972), “Forces induced in piles by unsymmetrical surcharges on the soil around the piles”, Proc. 5th European conference on Soil Mechanics and Foundation Engineering, Marid, Vol. 1, pp. 325-332.

[5] Tschebotarioff, G.P., (1973), “Foundations, Retaining, and Earth Structures”, McGraw - Hill, New York.

[6] Fukuoka, M. (1977), “The effects of horizontal loads on piles due to landslides”, Proc. 10th Spec. Session, 9th Int. Conf. on SMFE, Tokyo, pp. 27-42.

[7] Leung C.F., Chow Y. K., Shen, R. F. (2000), “Behavior of Pile Subject to Excavation-Induced Soil Movement”, Journal of Geotechnical and Geoenvironmental Engineering, ASCE, Vol. 126, No.11, pp. 947-954.

[8] Al-Qaisee, G. S. H., (2015), “Effects of Unsupported excavation on a nearby pile-soil system”, PhD. Thesis, Civil Engineering Department, University of Baghdad, Iraq.

[9] Hmood, M. K. H., (2016), “Behavior of piles subjected to lateral soil movement”, PhD. Thesis, Civil Engineering Department, University of Baghdad, Iraq.

[10] Shlash, K. T., Al-Neami, M. A. and Al- Lami, A. S., (2017), “Behavior of Single Pile Subjected to Lateral Soil Movement in Different Rates”, Journal of Scientific and Engineering Research, Vol. 4, No. 5, pp. 51-58.

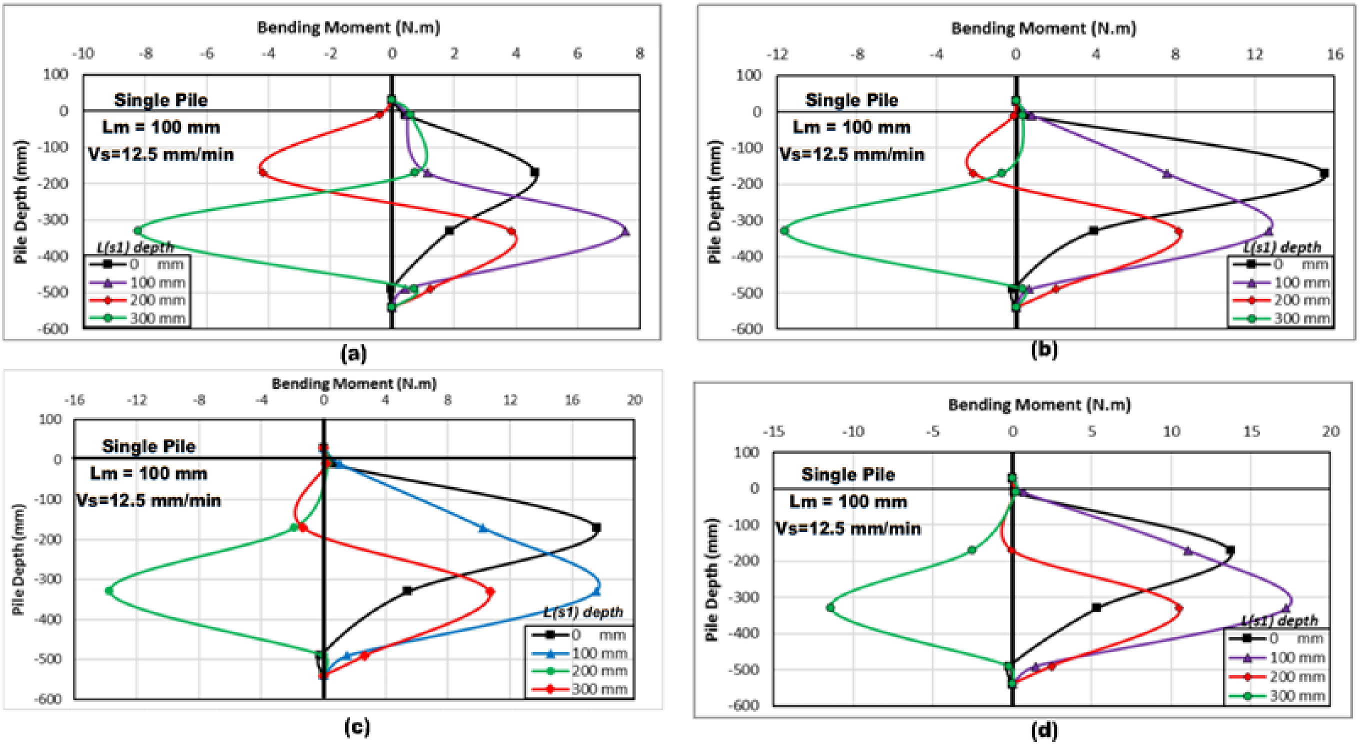

Fig. (10): Variation of bending moment along Pile for different pile depth of sliding layer at soil movement rate 12.5mm/min at (a.) 20 mm soil movement. (b.) 40 mm soil movement. (c.) 60 mm soil movement. (d.) after stop movement at time 900 sec.

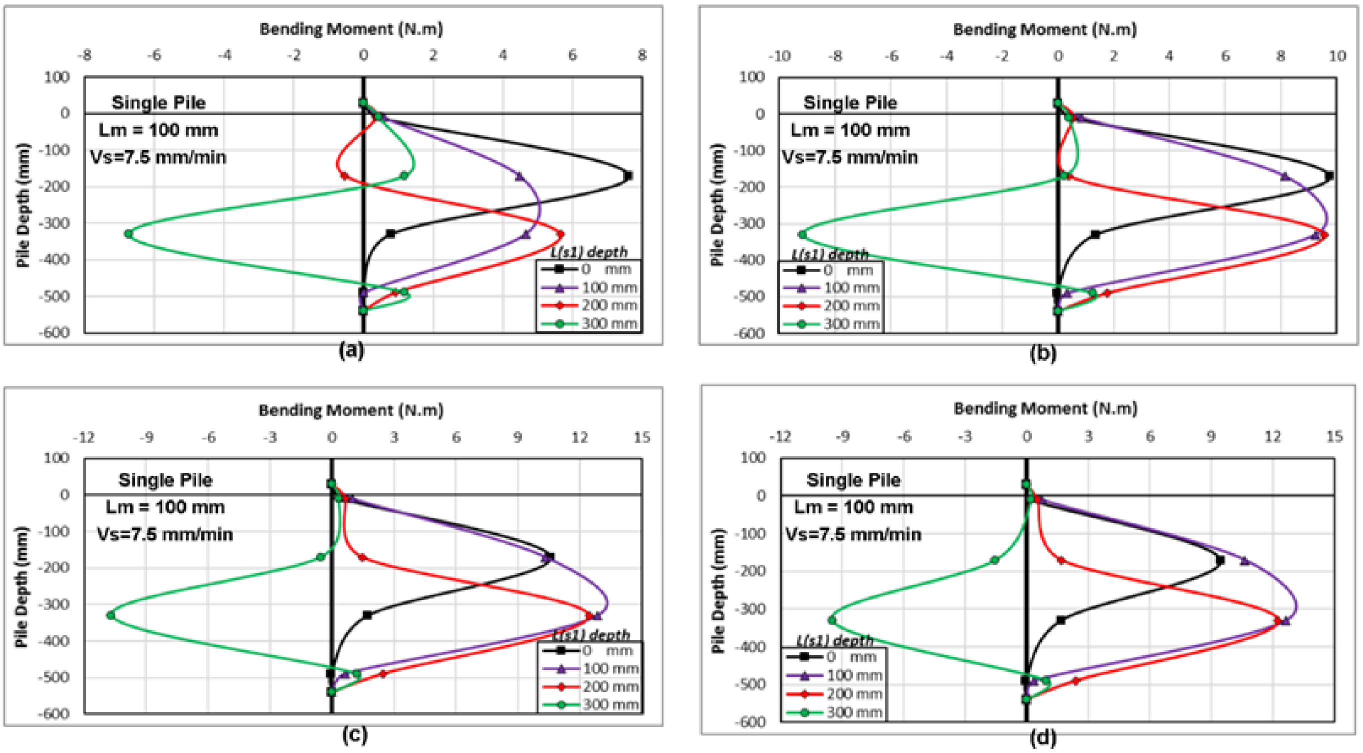

Fig. (11): Variation of bending moment along Pile for different pile depth of sliding layer at soil movement rate 7.5mm/min at (a.) 20 mm soil movement. (b.) 40 mm soil movement. (c.) 60 mm soil movement. (d.) after stop movement at time 900 sec.