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The Effect of Soil-Pile Interaction on Behavior of Platform to Lateral Impact Load Is Investigated By Using Finite Element Simulation

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ABSTRACT: *Seaward stage structure can oppose wave stacking, wind stacking, activity stacking, and transport crash, in this manner, it is critical to research the auxiliary conduct of stage contemplating soil-structure-heap association when the stage is exposed to deliver sway at an alternate area on deck section. The current investigation manages stage bolstered by heap establishment. The impact of soil-heap communication on conduct of stage to parallel effect load is examined by utilizing limited component recreation which is performed by ABAQUS programming. From the outcomes acquired, clearly the boat impact position on stage will be thought about extreme limit of structure so the structure will experience to free extreme limit because of harm that happens from the boat crash. This examination contains examination of heap horizontal removal, heap turn edge, heap shear power circulation, heap twisting second dispersion and deck chunk relocation. It likewise explains that the heap relocation has been considered heap basic length. The contort point of the heap is progressively delicate to soil type and stacking condition. It is appears that the shear power dist ribution and twisting second appropriation are influenced by stacking condition and soil type. At long last this examination shows that the reaction of deck chunk relies upon soil type, soil-heap collaboration and stacking condition.*
Keywords*: Ship Impact; Offshore Platform; Clay Soil; Loading Condition.*

I. INTRODUCTION

Offshore platforms are normally used for berthing of oil tankers. So the design of these platforms must be considered as the resistance to heavy impacts from ships in addition to the environmental loads [1]. Fenders can be described as absorption energy device whose fundamental target is to transform severe impact load into a reaction that both the structure and the ship can safely sustain [2]. The popular method which is used in fender systems design is the kinetic energy method [3]. Several researches have dealt with the problem of offshore structure to the collision of the ship. In 1983 Edvardsen et al. worked on the resistance of offshore structures against the impact loading from vessels and dropped objects [4]. In 1983 Amdahl investigated the circular tube deformation to lateral impact. The lateral force was applied parallel to the axis of the tube by using rigid plate [5]. In 1988 Wierzbicki and Suh investigated the circular tube deformation to the lateral impact. The load was applied by a line impact onto one section of the tube [6] In 2000 Al-Jasim investigated the berthing dolphin of Khor-Al-Amaya terminal number 8 to impact load from an oil tanker of 330000 DWT at 60% cargo [7]. In 2003 Hussein studied the dynamic response of three-dimensional offshore structure to couple load which consists of ship impact and wave loading [8].

In 2012 Kadim studied the dynamic response of dolphin of Khor-Al-Amaya berth No.8 to ship berthing impact [9]. In 2014 Travanca and Hao investigated the dynamic behavior of offshore platform to impact with high energy from vessel. This study included a procedure to improve equivalent systems [10]. In 2016, Hasan analyzed the Um-Qaser dolphin structure, He also investigated the influence of pile dimensions and soil characteristics on structural behavior to impact loading in which the soil was considered as elastic-plastic soil. Hasan concluded that the response of structure will be decrease as pile diameter and length increased and the applied load will also increase. Also, he found that the variation in soil properties will be reflected on the response of the structure. He found as compression and swelling index increases the response of structure will increase while the increase in soil density and undrained soil strength lead to decrease in response of structure [11]. Liu et al. (2017) investigated the behaviour of a steel square plate under the lateral impact force. Their investigation included finite element simulations and carried out experiments, they also evaluated the plastic response till failure in a quasi-static and dynamic manner [12]. Ali et al (2017) evaluated the cylindrical rubber fender behavior due to applied impact force from a mooring ship with a capacity which is equal 330000 DWT [13]. Liu et al (2018) implemented numerical studies and experimental series to investigate the behavior of tubular components and T-joint under the action of transverse impact forcing. They obtained a good agreement between simulation and tests [14]. Daliri and Naimi (2018) investigated the simplification of construction procedures and how to increase the offshore jacket structure serviceability life. This paper adopted ANSYS program. The transient dynamic load which was applied on offshore jacket composed of extreme wave loading and impact load of vessel [15]. In 2019, Li et al. investigated the relationship between the energy dissipation owing to lateral impact and the residual ultimate strength of circular damaged tube by the impact load. The effect of several variables is considered in this investigation such as diameter, thickness and length of the circular tube and the energy of impact. Also the software LS-DYNA is adopted to achieve nonlinear numerical simulations [16].

This paper was based on numerical simulation which was performed by using ABAQUS program to investigate the response of offshore structure under the impact dynamic load. The applied lateral impact dynamic load have a vital role in evaluating the serviceability life of offshore structure under the different levels of applied force which lead to reduce the ultimate capacity of structure and/or extensive damage. The soil is modelled as elastic – plastic material during the investigation of the current problem taking into consideration the different loading conditions. Also this study adopts three clay soils (soft, medium and stiff) characterized by different physical properties. The present study adopts three different loading condition of ship impact. The first case indicates the load which is applied at mid-span of deck while the second the load indicates the one which is applied at the corner of deck span and third case is represented by the impact of two ships located in opposite direction to produce torsion. In conclusion the structure must be designed to resist reasonable impact load.

II. RESEARCH METHODOLOGY

The aim of this work is based on investigating the behavior of an offshore platform to ship collision load. The model is achieved by adopting ABAQUS software to find the influence of several factors on platform behavior in connection to soil-structure interaction. The following elements are used to represent the frame – soil system
Beam element B32 (Timoshenko beam): It refers to beam with three nodes and material that has linear elastic properties. Brick element C3D20R: It refers to solid with 20-nodes that has nonlinear properties and is utilized to model soil. Mohr-Coulomb model is used to model nonlinear behavior. The coulomb criteria of failure can be written as Naylor et al. (1981) [17]:

$$|\,| \leq \tan \emptyset + \qquad (1)$$

Where;: shear stress;:normal effective stress; c: cohesion ; $\emptyset$: internal angle of shearing friction.
Figure 1 shows the whole platform structure, Figure 2 shows the side view of offshore platform, Figure 3 shows the top view of offshore platform and Figure 4 shows the whole system.
Table 1 comprises all structure elements with its dimensions, Table 2 comprises all the material properties that are used in the analysis of the present problem and Table 3 includes all the details of applied impact load of the ship at the time of application.
Boundary condition: It refers to all soil domains that it is considered fixed except the top which is considered free. The distance from piles to the edges of soil boundary is equal to 8D (D: pile diameter) whereas the distance from the ends of piles to bottom of soil boundary equals to 8D.
Full bond is used to represent the linkage between soil and piles. The value of the damping ratio which is used in the analysis of the present study equal to (0.05).
The clay soils modulus of elasticity can be considered as a constant value through the depth of soil [18], It is also regarded proportional with the cohesion of soil according to the following equation [19, 20]:

Loading condition: It shows that firstly the ship impact load is applied at mid-span of the deck (point A), secondly the ship impact load is applied at the corner of the deck, and finally the ship impact load is applied in opposite direction at points B and C to produce torsion in the offshore platform. At this time, it is required to evaluate the behavior of offshore platform considering soil-structure interaction. The investigation includes displacement of piles and deck, rotation of piles, shear force and bending moment that are developed along with the pile's depth.

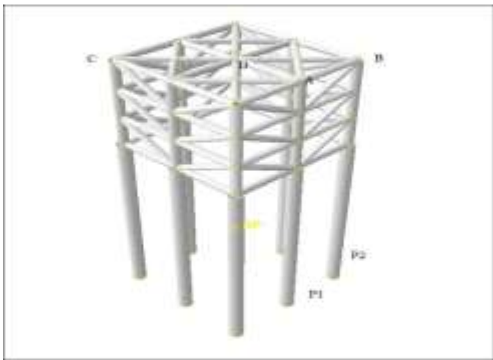


Figure 1. Offshore platform structure

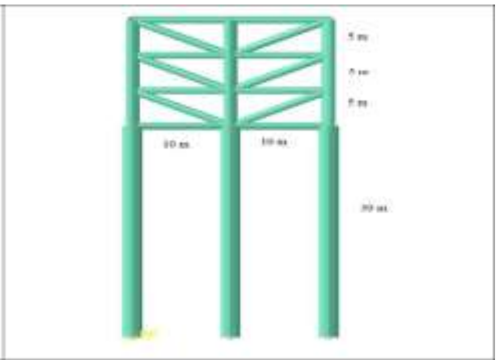


Figure 2. Side view of the offshore platform

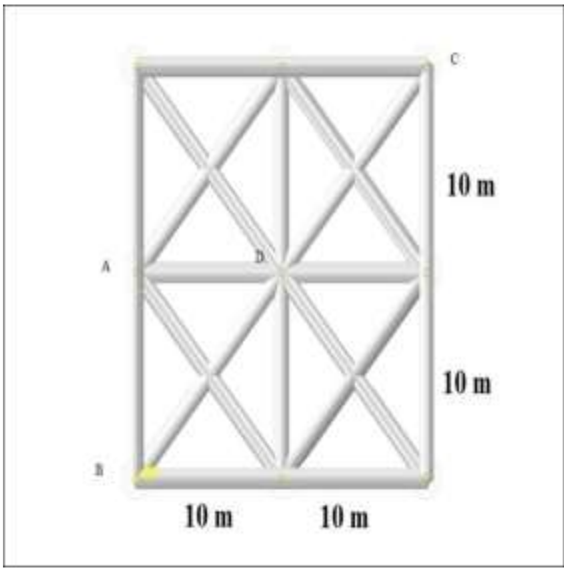


Figure 3. Top view of the offshore platform

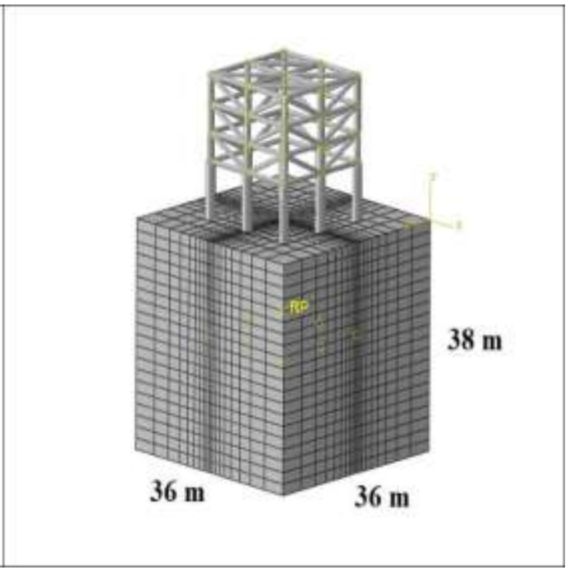


Figure 4. Whole system

Table 1. Details of the offshore platform structure

Element	**Diameter (mm)**	**Thickness (mm)**
Piles	1200	25
Beams	700	12.7
Brace	500	12.7
Deck	600	12.7

Table 2. Details of whole system material

Material	**Elastic modulus (MPa)**	**Poisson´s ratio**	**Cohesion (kPa)**	**Density (kg/m^3)**
Soft clay soil	12	0.4	24	1800
Medium clay soil	24	0.4	48	2000
Stiff clay soil	48	0.4	96	2100
Steel	200000	0.3		

Table 3. Details of ship collision load with time

Time (sec)	**Load (KN)**
0	0
2	2500
13	2300
15	0

III. RESULTS AND DISCUSSION

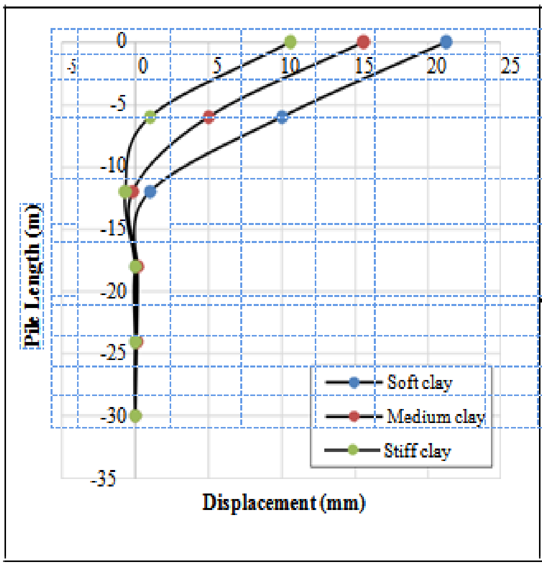
Figure 5 illustrates the lateral deformation of the pile embedded in different clay soils for ship collision loading at mid-span of the deck. The pile starts to deform near the ground surface with decreases in deformation as pile depth is increasing. The rise in lateral deformation of the pile which embedded in soft clay soil is higher as compared with other soil types of the same applied loading condition. It is clear from the figure that the increase in pile head deformation has significant influence that on which can be considered as an important when the soil type changes. Pile critical length has relevant relationship with pile deformation. It is evident from the figure that the critical length of pile in soft clay soil equal to zero while the critical length of pile in medium clay is considered higher as compared with the pile in stiff clay. Figure 6 shows the lateral deformation of the pile embedded in different clay soils for the ship collision loading at the corner of the deck span. The pile starts to deform near the ground surface with decreases in deformation as pile depth is increasing. The rise in lateral deformation of pile which is embedded in soft clay soil is higher as compared with other soil types of the same applied loading condition. It is clear from the figure that the increase in pile head deformation has significant influence and can be considered important as the soil type changes. Pile critical length has relevant relationship with pile deformation. It is evident from the figure that the critical length of the pile in soft clay soil is higher as compare with pile embedded in medium clay soil and stiff clay soil. Figure 7 illustrates the lateral deformation of the pile embedded in different clay soil for the ship collision loading in the opposite direction to cause torsion of deck span. The pile starts to deform near the ground surface with decreases in deformation as pile depth is increasing. The rise in the lateral deformation of pile which is embedded in stiff clay soil is higher as compared with other soil types of the same applied loading condition. It is clear from figure that the increase in pile head deformation has significant influence and can be considered important as the soil type changes. Pile critical length has relevant relationship with pile deformation.

It is evident from figure that the critical length of the pile in stiff clay soil is higher as compare with pile embedded in medium clay soil and soft clay soil. Figures 5, 6 and 7 clarify dramatically the change in lateral behavior which is reflected on pile critical length. It is clearly show that there is a moderate pile behavior for both lateral displacement and critical pile length when the pile embedded in medium clay soil. Pile head displacement can be considered sensitive parameter. It is clear from figure that the higher pile head displacement occurs when the pile is embedded in soft clay soil (loading condition at mid and corner) while in the torsion condition the maximum pile head displacement occurs when the pile is embedded in stiff clay soil. Also, the dramatic increase in critical pile length is especial when the pile is embedded in stiff clay soil for torsion loading condition as compare with other loading conditions for the same soil type. It is obvious from figures that the soil type and loading condition have majority control to describe the pile behavior. Figure 8 shows the lateral behavior of pile embedded in soft clay soil for different loading conditions (mid, corner and torsion). It is clear from figure that the pile head displacement is approximately equal to the first and second loading conditions respectively while there is a significant reduction shown in pile head displacement for the torsion condition. Figure 9 shows the lateral behavior of pile embedded in medium clay soil for different loading conditions (mid, corner and torsion). It is clear from figure that the pile head displacement is approximately equal to the first and second loading conditions respectively while there is a significant reduction shown in pile head displacement for the torsion condition.

Figure 10 shows the lateral behavior of pile embedded in stiff clay soil for different loading condition (mid, corner and torsion). It is clear from figure that the pile head displacement is approximately equal to all loading conditions. Also, Figure 8 shows the modest change in critical pile length while the dramatic variation appears in critical pile length when piling is embedded in medium clay soil and stiff clay soil. Figure 11 illustrates the lateral deformation of the pile embedded in different clay soils for ship collision loading at mid-span of the deck. The pile starts to deform near the ground surface with decreases in deformation as pile depth is increasing. The rise in lateral deformation of the pile which is embedded in soft clay soil is higher as compared with other soil types of the same applied loading condition. It is clear from the figure that the increase in pile head deformation has significant influence and can be considered important as the soil type change. Pile critical length has a relevant relationship with pile deformation. It is evident from the figure that the critical length of the pile in soft clay soil equals to zero while the critical length of the pile in medium clay is considered higher as compare with pile in stiff clay. Figure 12 illustrates the lateral deformation of the pile embedded in different clay soils for the ship collision loading at the corner of the deck span. The pile starts to deform near the ground surface with decreases in deformation as pile depth increasing. The rise in lateral deformation of the pile which is embedded in soft clay soil is higher as compared with other soil types of the same applied loading condition. It is clear from the figure that the increase in pile head deformation has significant influence and can be considered important as the soil type changes. Pile critical length has relevant relationship with pile deformation. It is evident from the figure that the critical length of the pile in soft clay soil is higher as compare with pile embedded in medium clay soil and stiff clay soil. Figure 13 illustrates the lateral deformation of the pile embedded in different clay soil for the ship collision loading in the opposite direction to cause torsion of deck span. The pile starts to deform near the ground surface with decreases in deformation as pile depth increasing. The rise in lateral deformation of the pile which is embedded in soft clay soil is higher as compared with other soil types of the same applied loading condition.

It is clear from the figure that the increase in pile head deformation has significant influence and can be considered important as the soil type changes. Pile critical length has relevant relationship with pile deformation. It is evident from the figure that the critical length of the pile in stiff clay soil and medium clay soil are higher as compare with pile embedded in soft clay soil. Figures 11, 12 and 13 clarify dramatically the change in lateral behavior which is reflected on pile critical length. There is a moderate pile behavior for both lateral displacement and critical pile length when the pile embedded in medium clay soil. Pile head displacement can be considered sensitive parameter. It is clear from figure that higher pile head displacement occurs when the pile is embedded in soft clay soil (loading condition at mid, corner and torsion condition). Also, the dramatic increase in critical pile length is especial when the pile is embedded in stiff clay soil for the torsion loading condition as compare with other loading conditions for the same soil type. It is obvious from figures that the soil type and loading condition have majority control to describe the pile behavior. Figure 14 shows the lateral behavior of the pile embedded in soft clay soil for different loading conditions (mid, corner and torsion). It is clear from figure that the pile head displacement is approximately equal to second and third loading condition respectively while there is a significant reduction in pile head displacement for the loading condition at mid-span of the deck. Figure 15 shows the lateral behavior of pile embedded in medium clay soil for different loading conditions (mid, corner and torsion). It is clear from figure that the pile head displacement is higher for the second and third loading condition respectively as compare with first loading condition. A significant reduction in pile head displacement for loading condition at mid-span of the deck can be seen.

Figure 16 shows the lateral behavior of pile embedded in stiff clay soil for different loading conditions (mid, corner and torsion). It is clear from the figure that the pile head displacement is higher for the second and third loading condition respectively as compare with the first loading condition. A significant reduction in pile head displacement for loading condition at mid-span of the deck is also shown. Also, Figure 4 it is shown that there is equality in critical pile length for first loading condition and second loading condition as compared with third loading condition when the pile is embedded in soft clay soil. From Figure 15 it is shown that there is equality in critical pile length for first loading condition and third loading condition as compared with second loading condition when the pile is embedded in medium clay soil. Figure 16 shows an equality in critical pile length for the first loading condition and second loading condition as compared with third loading condition when the pile is embedded in stiff clay soil.



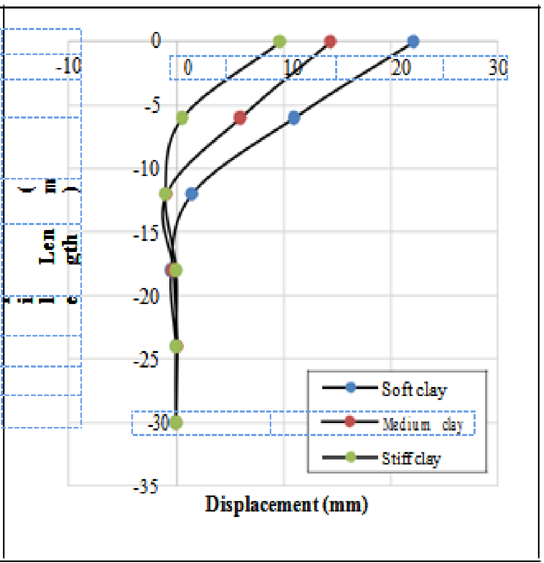


Figure 5. Pile P1 under Load case 1 for different soils

Figure 6. Pile P1 under load case 2 for different soils

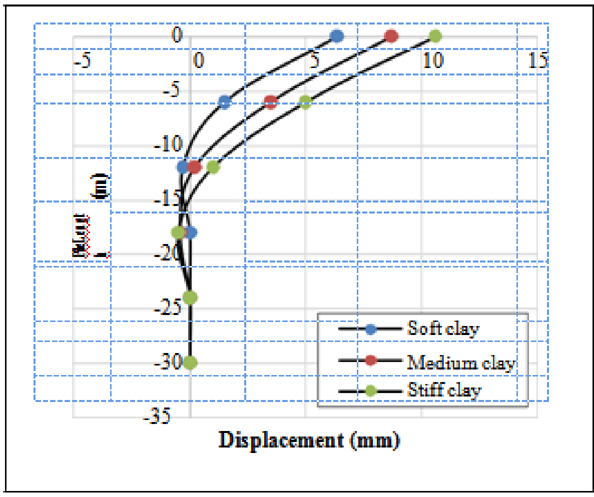


Figure 7. Pile P1 under load case 3 for different soils

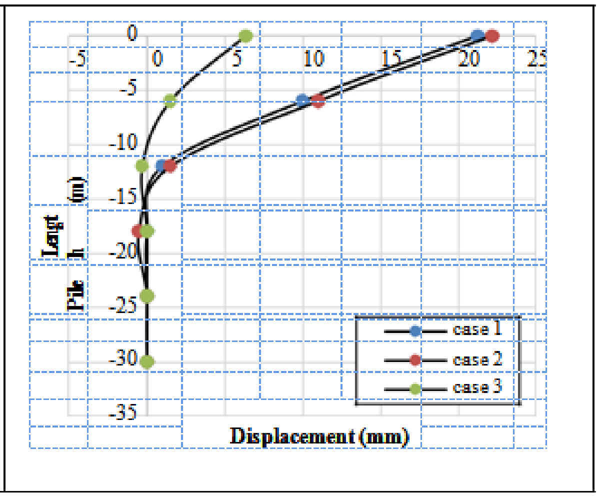


Figure 8. Pile P1 in soft clay under different load cases

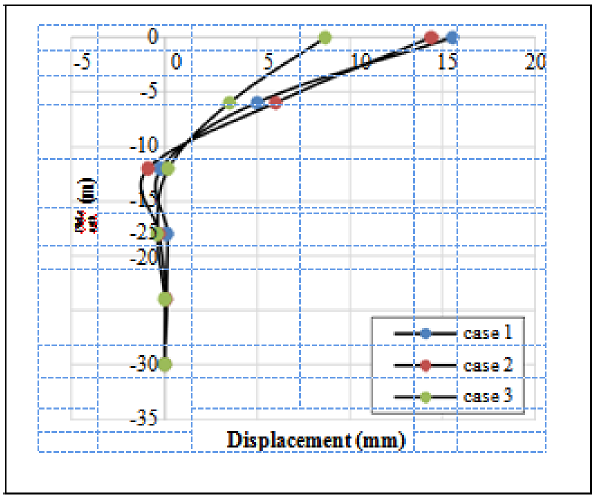


Figure 9. Pile P1 in medium clay under different load cases

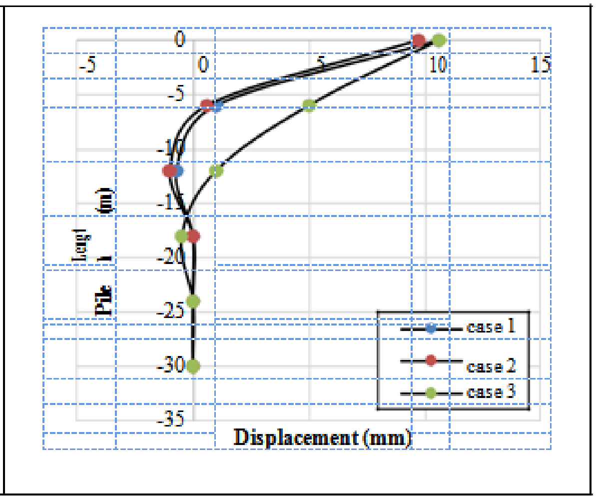


Figure 10. Pile P1 in Stiff clay under different load cases

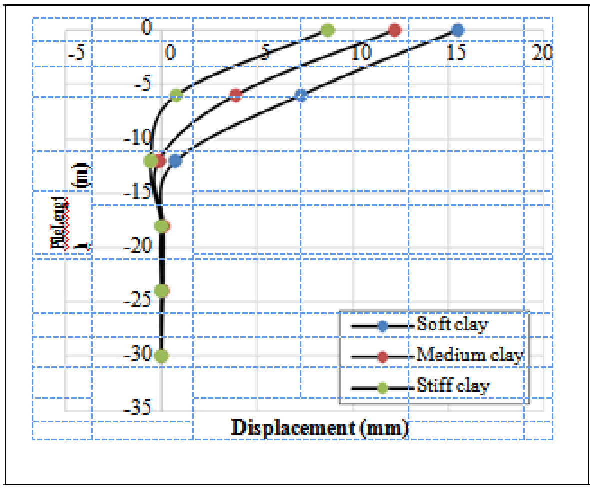


Figure 11. Pile P2 under Load case 1 for different soils

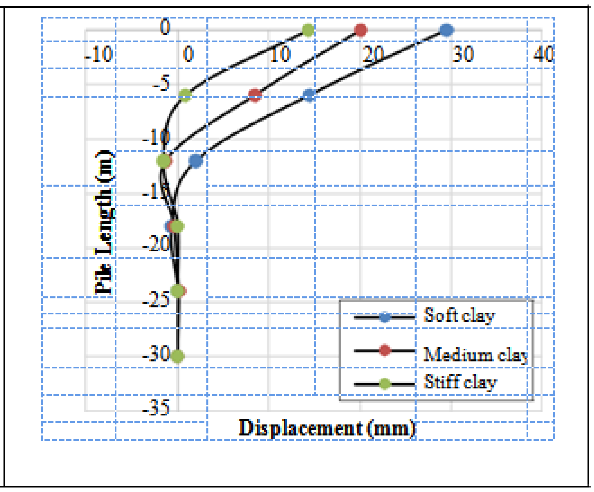


Figure 12. Pile P2 under load case 2 for different soils

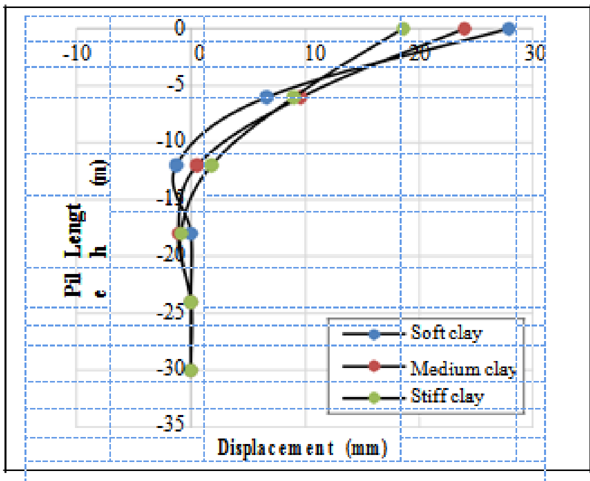


Figure 13. Pile P2 under load case 3 for different soils

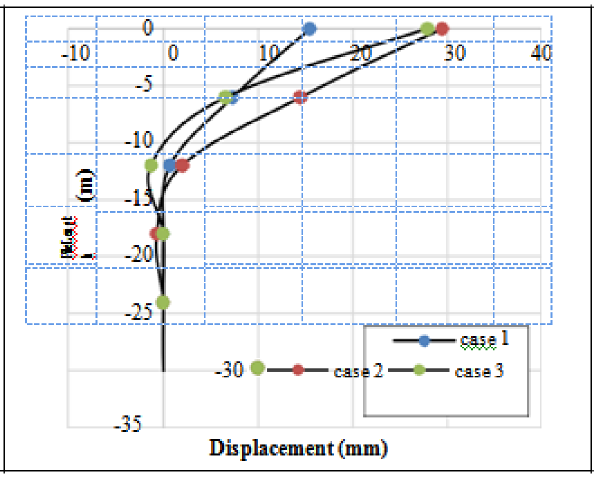


Figure 14. Pile P2 in soft clay under different load cases

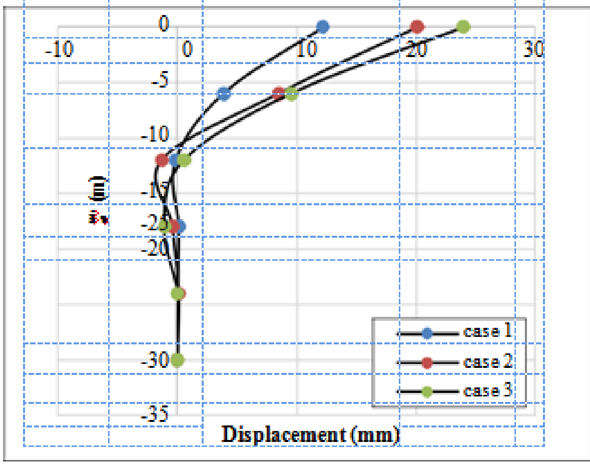


Figure 15. Pile P2 in medium clay under different load cases

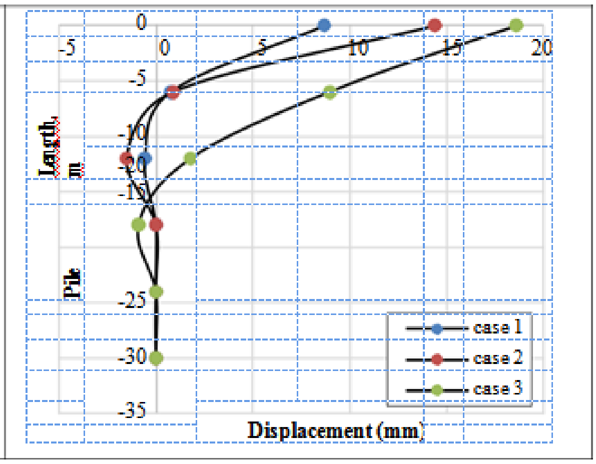


Figure 16. Pile P2 in Stiff clay under different load cases

Figure 17 illustrates the twist angle of the pile embedded in different clay soils for the ship collision loading at mid-span of the deck. The pile starts to rotate near the ground surface with decreases in rotation as pile depth increasing. The rise in twist angle of the pile which is embedded in stiff clay soil is higher as compared with other soil types of the same applied loading condition. It is clear from the figure that the increase in pile head rotation has significant influence and can be considered important as the soil type changes. Figure 18 illustrates the twist angle of the pile embedded in different clay soils for the ship collision loading at the corner of the deck span. The pile starts to rotate near the ground surface with decreases in rotation as pile depth increasing. The rise in twist angle of the pile which is embedded in stiff clay soil is higher as compared with other soil types of the same applied loading condition. It is clear from the figure that the increase in pile head rotation has significant influence and can be considered important as the soil type changes.

Figure 19 illustrates the twist angle of the pile embedded in different clay soils for the ship collision loading in the opposite direction to cause torsion of deck span. The pile starts to rotate near the ground surface with decreases in rotation as pile depth increasing. The rise in the rotation of pile which is embedded in stiff clay soil is higher as compared with other soil types of the same applied loading condition. It is clear from the figure that the increase in pile head rotation has significant influence and can be considered important as the soil type change. Figures 17, 18 and 19 clarify dramatically a change in twist angle behavior which reflects on pile deformation. It is obvious from figures the soil type and loading condition have majority control to describe the pile twist angle behavior. Figure 20 shows the twist angle behavior of pile embedded in soft clay soil for different loading conditions (mid, corner and torsion). It is clear from the figure that the pile head rotation is approximately equal for first and second loading condition respectively while there is a significant increase in pile head rotation for the torsion condition. Figure 21 shows the twist angle behavior of the pile embedded in medium clay soil for the different loading conditions (mid, corner and torsion). It is clear from the figure that the pile head rotation is approximately equal for first and second loading condition respectively while there is a significant increase in pile head rotation for the torsion condition. Figure 22 shows the twist angle behavior of pile embedded in stiff clay soil for different loading condition (mid, corner and torsion). It is clear from the figure that the pile head rotation is approximately equal for first and second loading condition respectively while there is a significant increase in pile head rotation for the torsion condition.

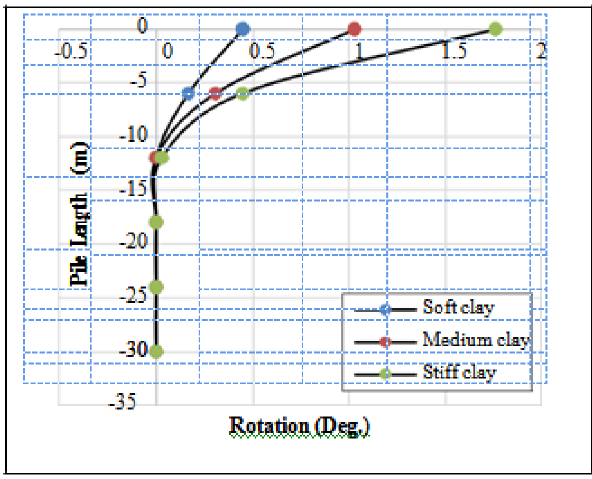


Figure 17. Pile P1 under Load case 1 for different soils

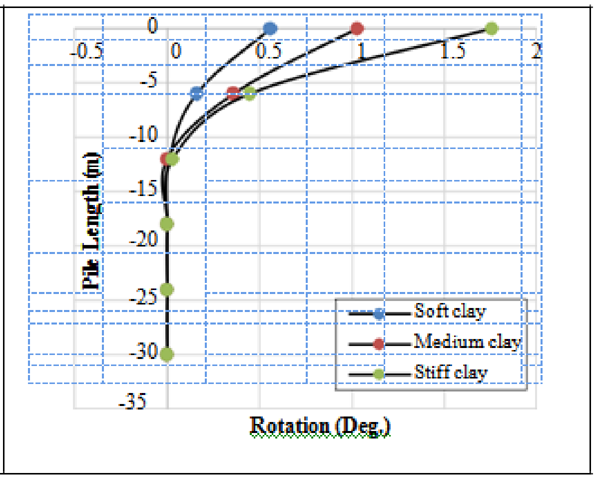


Figure18. Pile P1 under load case 2 for different soils

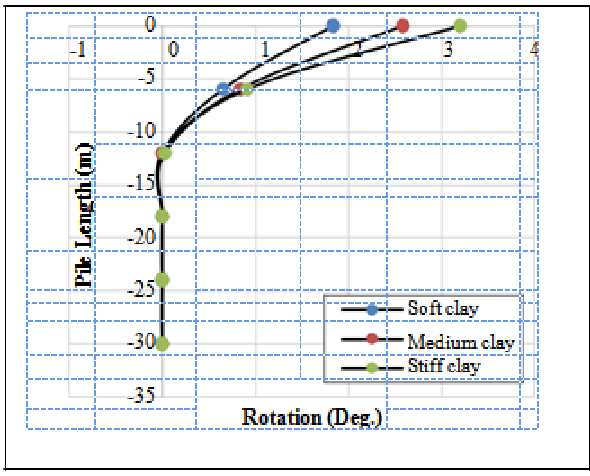


Figure 19. Pile P1 under load case 3 for different soils

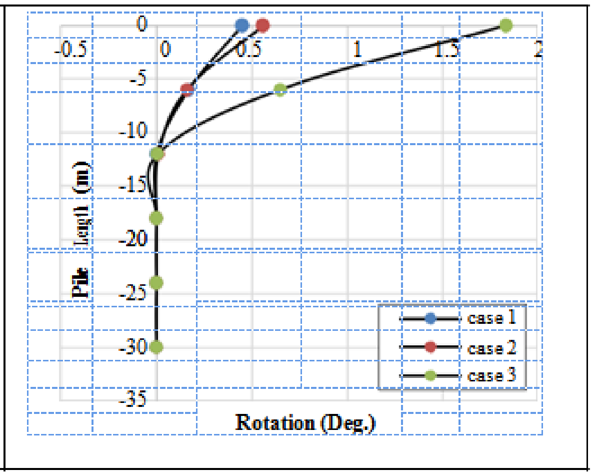


Figure 20. Pile P1 in soft clay under different load cases

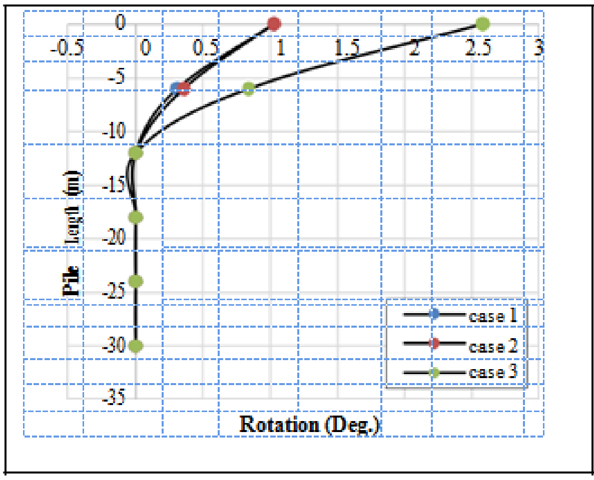


Figure 21. Pile P1 in medium clay under different load cases

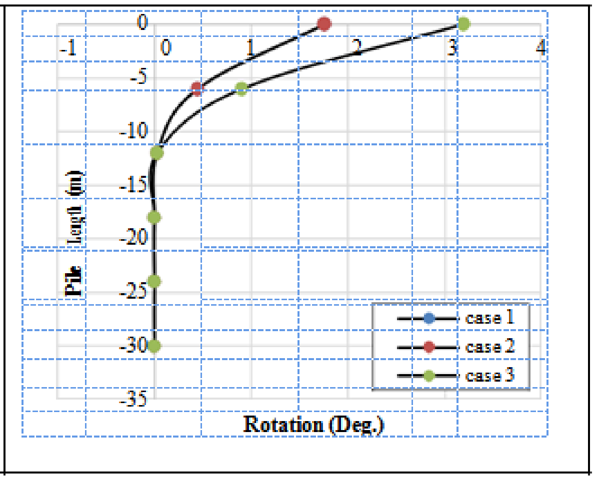


Figure 22. Pile P1 in Stiff clay under different load cases

Figure 23 illustrates the twist angle of the pile embedded in different clay soils for the ship collision loading at mid-span of the deck. The pile starts to rotate near the ground surface with decreases in rotation as pile depth increasing. The rise in twist angle of the pile which is embedded in stiff clay soil is higher as compared with other soil types of the same applied loading condition. It is clear from the figure that the increase in pile head rotation has a significant influence and can be considered important as the soil type change. Figure 24 illustrates the twist angle of the pile embedded in different clay soils for the ship collision loading at the corner of the deck span. The pile starts to rotate near the ground surface with decreases in rotation as pile depth increasing. The rise in twist angle of the pile which is embedded in stiff clay soil is higher as compared with other soil types of the same applied loading condition. It is clear from the figure that the increase in pile head rotation has a significant influence and can be considered important as the soil type change. Figure 25 illustrates the twist angle of the pile embedded in different clay soils for the ship collision loading in the opposite direction to cause torsion of deck span. The pile starts to rotate near the ground surface with decreases in rotation as pile depth increasing.

The rise in the rotation of pile which is embedded in stiff clay soil is higher as compared with other soil types of the same applied loading condition. It is clear from the figure that the increase in pile head rotation has a significant influence and can be considered important as the soil type change. Figures 23, 24 and 25 clarify dramatically change in twist angle behavior which is reflected on pile deformation. It is obvious from figures that the soil type and loading condition has majority control to describe the pile twist angle behavior. Figure 26 shows the twist angle behavior of pile embedded in soft clay soil for different loading conditions (mid, corner and torsion). It is clear from figure that the pile head rotation is higher in the case of torsion load as compare with remain loading condition. Figure 27 shows the twist angle behavior of pile embedded in medium clay soil for different loading conditions (mid, corner and torsion). It is clear from figure that the pile head rotation is higher in the case of torsion load as compare with remain loading condition. Figure 28 shows the twist angle behavior of pile embedded in stiff clay soil for different loading conditions (mid, corner and torsion). It is clear from figure that the pile head rotation is higher in the case of torsion load as compare with remain loading condition. In general, based on this study, pile has a higher twist angle along with its depth when it is embedded in stiff clay soil as compare with remain soils.

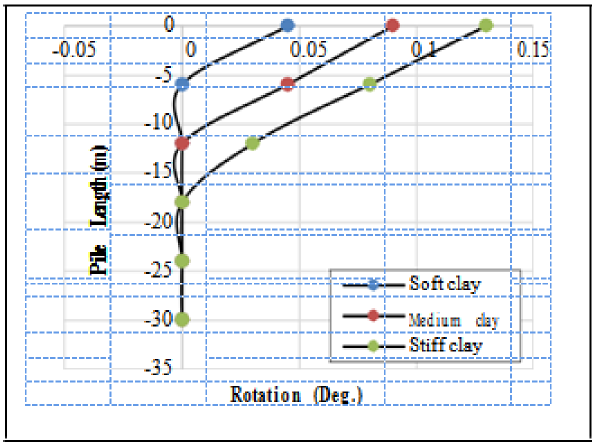


Figure 23. Pile P2 under Load case 1 for different soils

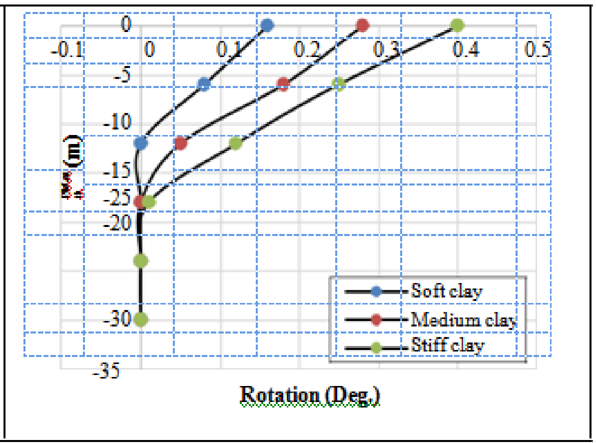


Figure 24. Pile P2 under load case 2 for different soils

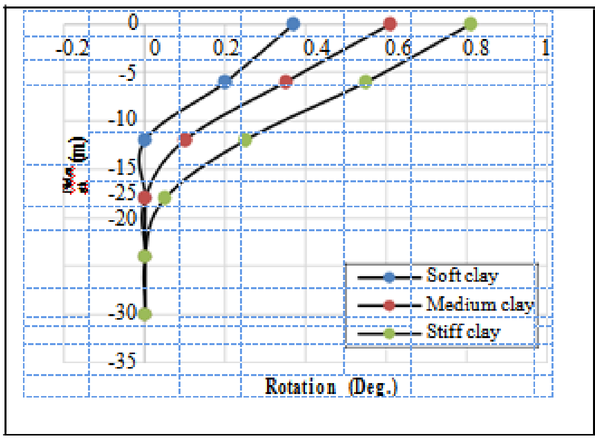


Figure 25. Pile P2 under load case 3 for different soils

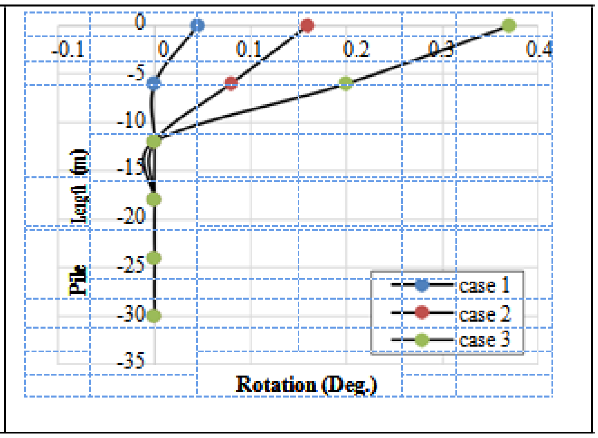


Figure 26. Pile P2 in soft clay under different load cases

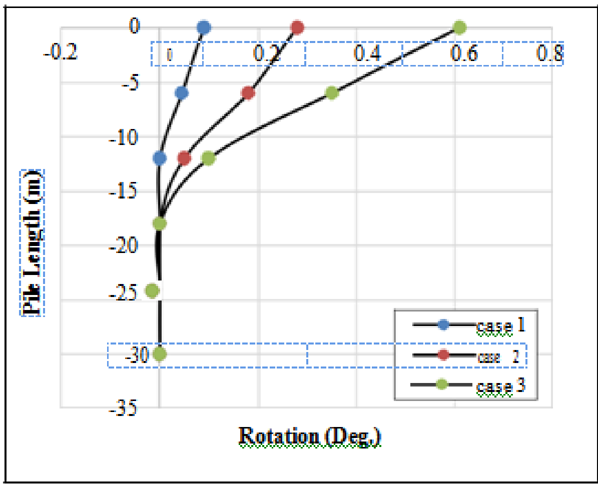


Figure 27. Pile P2 in medium clay under different load cases

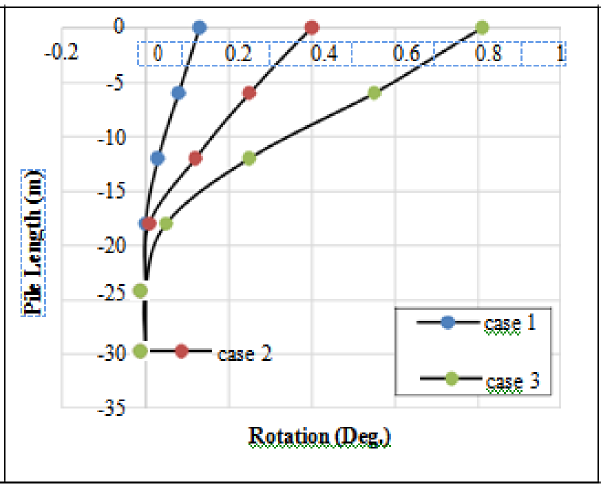


Figure 28. Pile P2 in Stiff clay under different load cases

Figures 29, 30 and 31 shows the distribution of shear force along with a pile embedded in different clay soils (soft, medium and stiff) with various loading conditions. Figure 29 shows the behavior of pile when the load is applied at mid-span of the deck, Figure 30 shows the behavior of pile when the load is applied at the corner of deck and figure

(31) shows the behavior of pile when the loading condition is torsion. It is evident from figures that the maximum value of shear force occurs when the pile is embedded in stiff clay soil for different load conditions but the value of maximum shear force occurs when the load at mid-span is higher than the values when the load at corner of deck and torsion condition. Figure 32 shows the distribution of shear force along with a pile embedded in soft clay soil for the three different loading conditions. Figure 33 shows the distribution of shear force along with a pile embedded in medium clay soil for the three different loading conditions. Figure 34 shows the distribution of shear force along with a pile embedded in stiff clay soil for the three different loading conditions. In all Figures 32, 33 and 34, the maximum shear force occur in first loading condition as compare with remains loading condition. Figures 35, 36 and 37 show the distribution of shear force along with a pile embedded in different clay soil (soft, medium and stiff) with various loading conditions. Figure 35 shows the behavior of pile when the load is applied at mid-span of the deck while Figure 36 shows the behavior of pile when the load is applied at the corner of deck and Figure 37 shows the behavior of pile when the loading condition is torsion. It is evident from figures that the maximum value of shear force occurs when the pile is embedded in stiff clay soil for the first loading condition and the third loading condition but the value of maximum shear force occurs when the pile is embedded in soft clay soil for second loading condition. Figure 38 shows the distribution of shear force along with a pile embedded in soft clay soil for the three different loading conditions. Figure 39 shows the distribution of shear force along with a pile embedded in medium clay soil for the three different loading conditions. Figure 40 shows the distribution of shear force along with a pile embedded in stiff clay soil for the three different loading conditions. In all Figures 39 and 40 the maximum shear force occur in first loading condition as compare with remains loading condition while in Figure 38 the maximum shear force occurs in second loading condition.

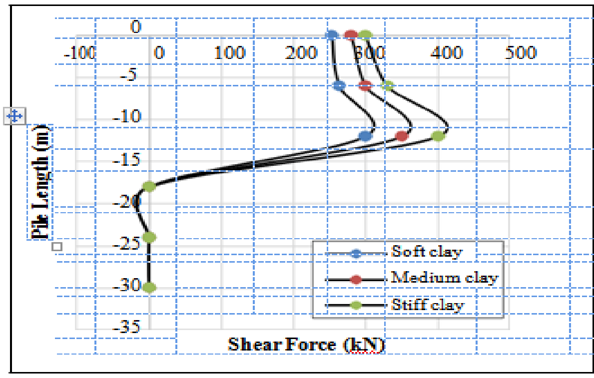


Figure 29. Pile P1 under Load case 1 for different soils

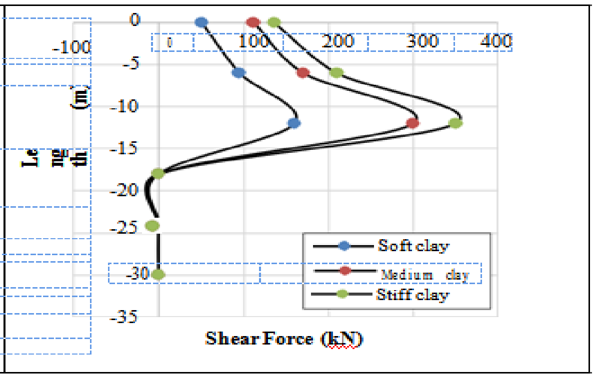


Figure 30. Pile P1 under load case 2 for different soils

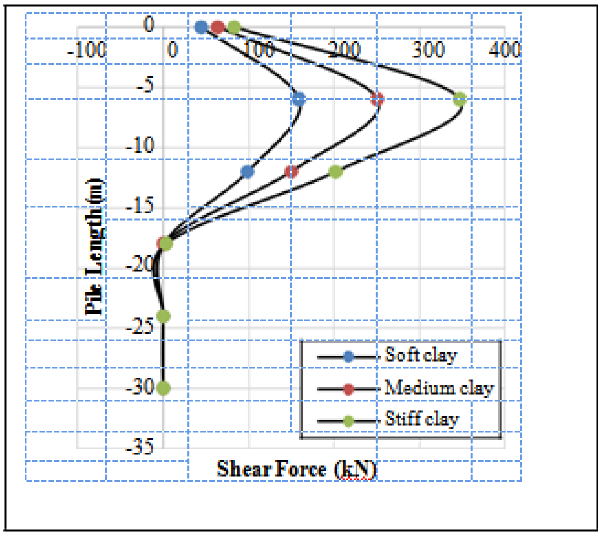


Figure 31. Pile P1 under load case 3 for different soils

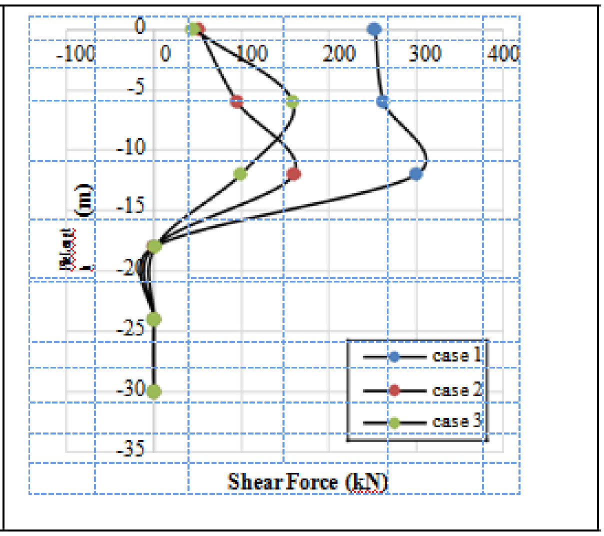


Figure 32. Pile P1 in soft clay under different load cases

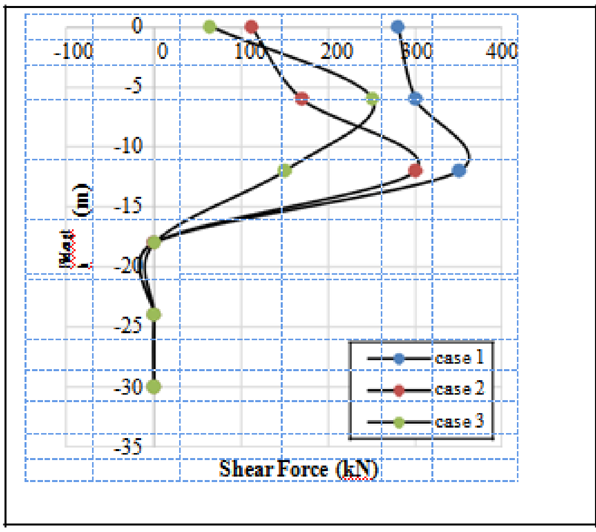


Figure 33. Pile P1 in medium clay under different load cases

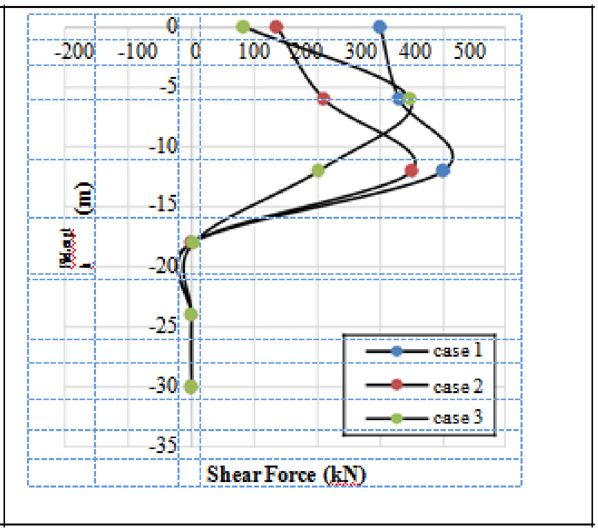


Figure 34. Pile P1 in Stiff clay under different load cases

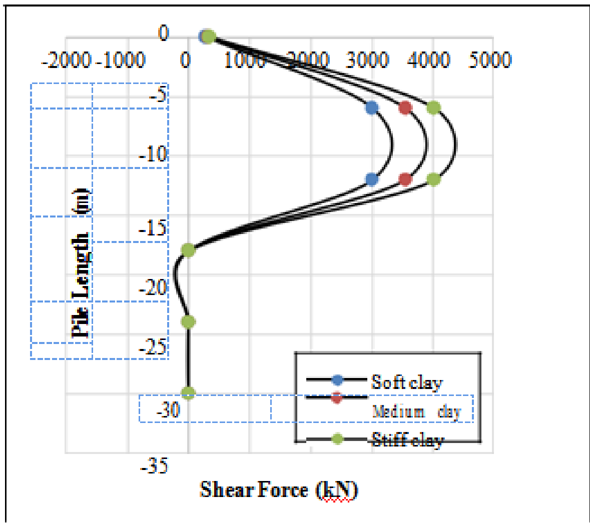


Figure 35. Pile P2 under Load case 1 for different soils

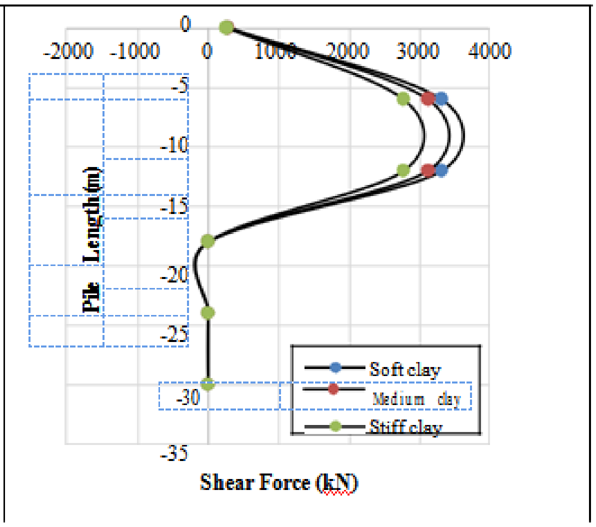


Figure 36. Pile P2 under load case 2 for different soils

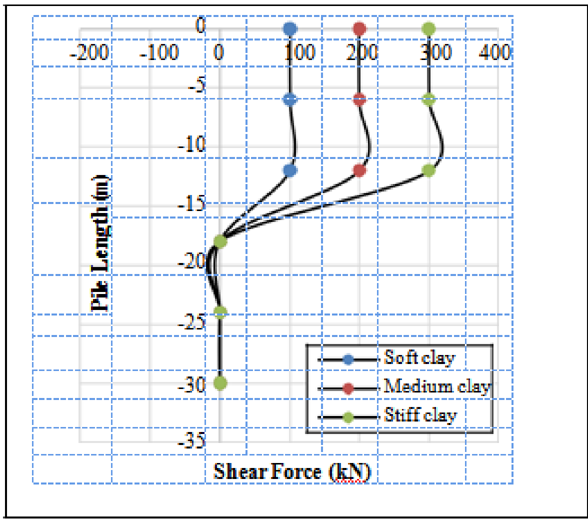


Figure 37. Pile P2 under load case 3 for different soils

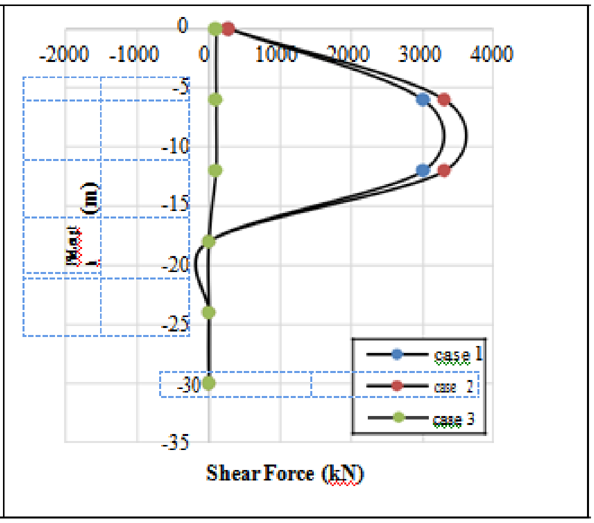


Figure 38. Pile P2 in soft clay under different load cases

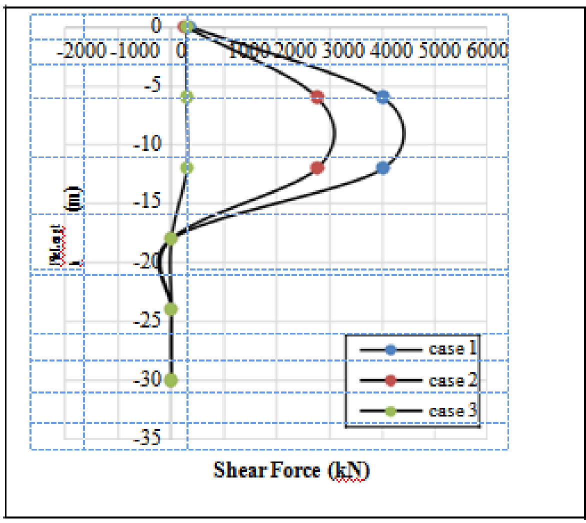


Figure 39. Pile P2 in medium clay under different load cases

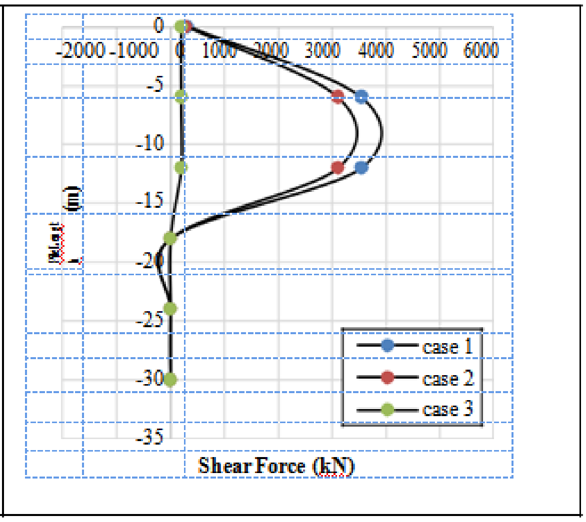


Figure 40. Pile P2 in Stiff clay under different load cases

The bending moment variations along with the embedment depth of the pile are shown in Figures 41, 42 and 43. The difference in distribution and values in bending moment appears clearly in figures. Figures show always the maximum bending moment value reach when the pile is embedded in stiff clay soil. Figures show dramatic behavior for bending moment distribution when the pile is embedded in stiff clay soil while there is a moderate behavior shown when the pile is embedded in medium clay soil and simple behavior when the pile embedded in soft clay soil. Figure 44 shows the distribution of a bending moment along with a pile embedded in soft clay soil for the three different loading conditions. Figure 45 shows the distribution of a bending moment along with a pile embedded in medium clay soil for the three different loading conditions. Figure 46 shows the distribution of a bending moment along with a pile embedded in stiff clay soil for the three different loading conditions. In all Figures 44, 45 and 46 the maximum bending moment occurs in first loading condition as compare with remains loading condition. The bending moment variations along with the embedment depth of the pile are shown in Figures 47, 48 and 49. The difference in distribution and values in bending moment appear clearly in figures. Figures show always the maximum bending moment value reach when the pile is embedded in stiff clay soil. Figures show dramatic behavior for bending moment distribution when the pile is embedded in stiff clay soil while there is a moderate behavior shown when the pile is embedded in medium clay soil and simple behavior when the pile is embedded in soft clay soil. Figure 50 shows the distribution of a bending moment along with a pile embedded in soft clay soil for the three different loading conditions. Figure 51 shows the distribution of a bending moment along with a pile embedded in medium clay soil for the three different loading conditions. Figure 52 shows the distribution of a bending moment along with a pile embedded in stiff clay soil for the three different loading conditions. In all Figures 50, 51 and 52 the maximum bending moment occurs in third loading condition as compare with remains loading condition.

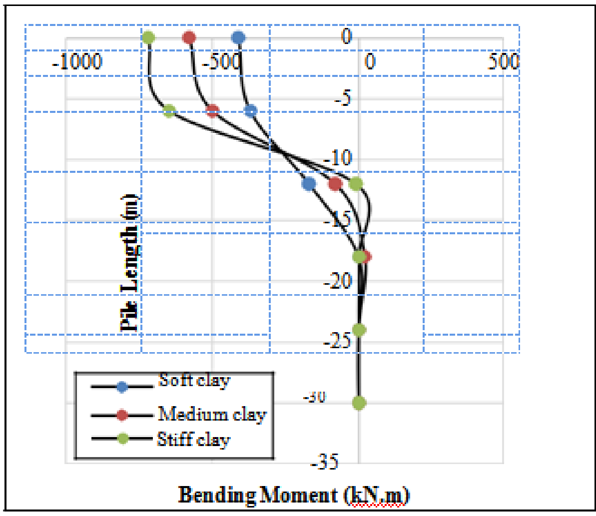


Figure 41. Pile P1 under Load case 1 for different soils

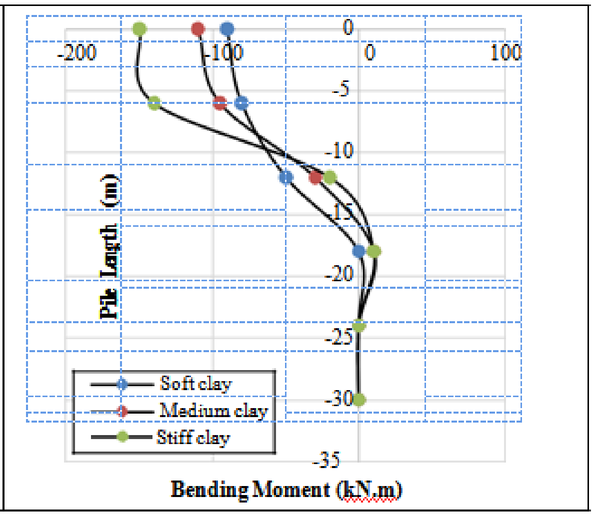


Figure 42. Pile P1 under load case 2 for different soils

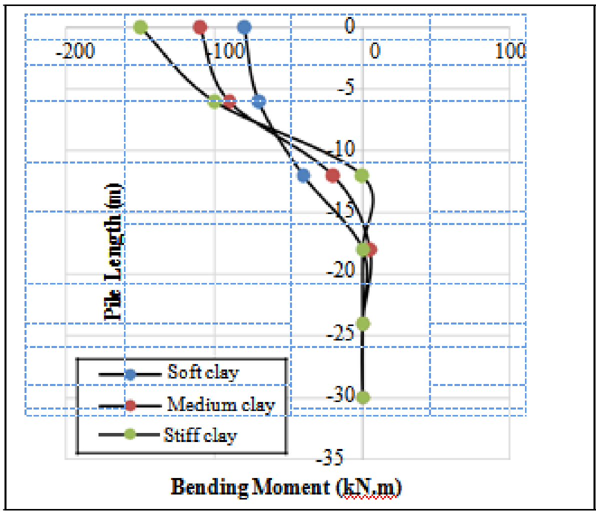


Figure 43. Pile P1 under load case 3 for different soils

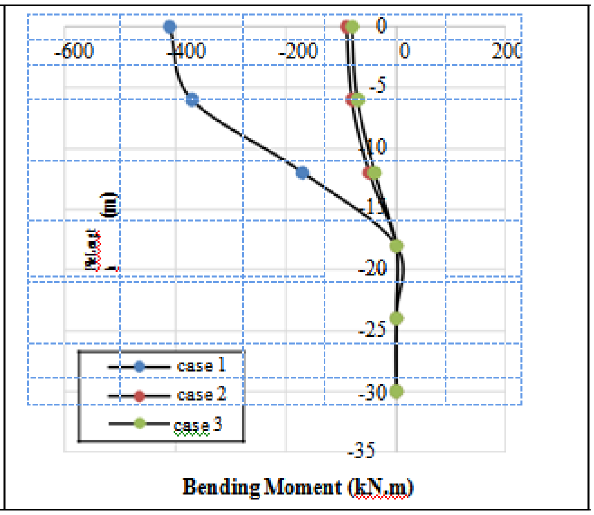


Figure 44. Pile P1 in soft clay under different load cases

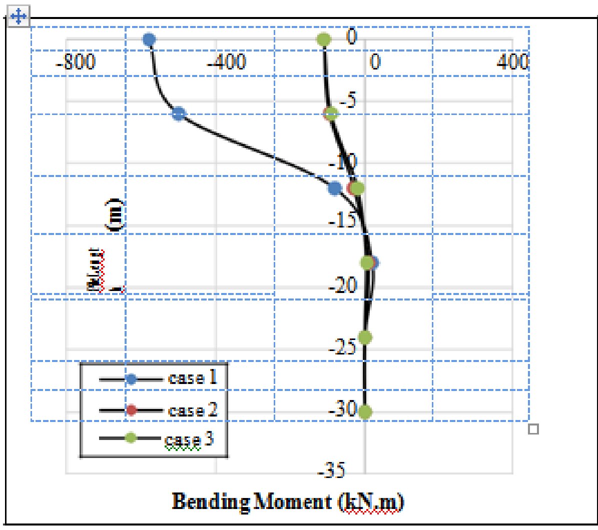


Figure 45. Pile P1 in medium clay under different load cases

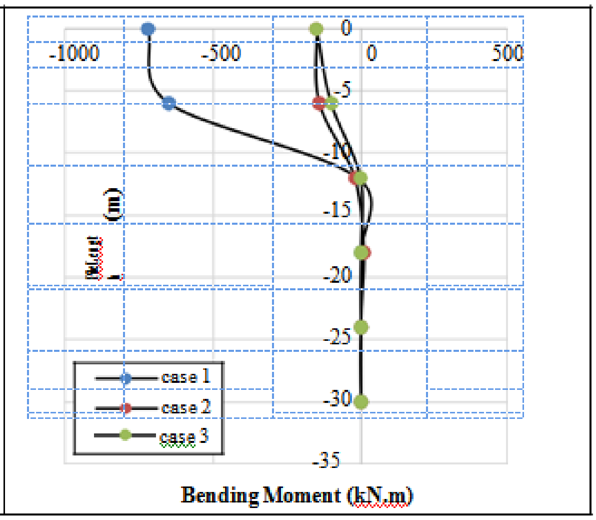


Figure 46. Pile P1 in Stiff clay under different load cases

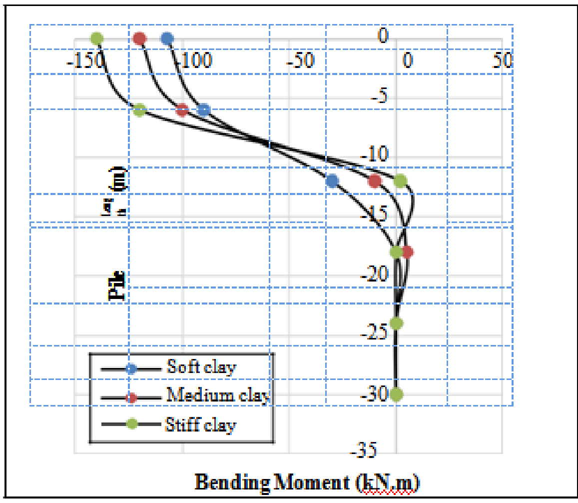


Figure 47. Pile P2 under Load case 1 for different soils

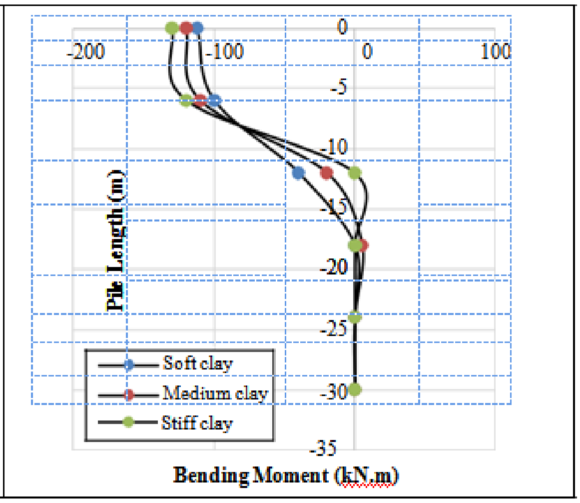


Figure 48. Pile P2 under load case 2 for different soils

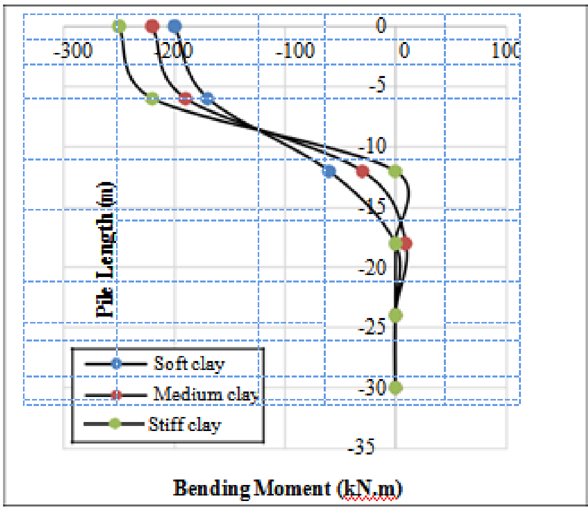


Figure 49. Pile P2 under load case 3 for different soils

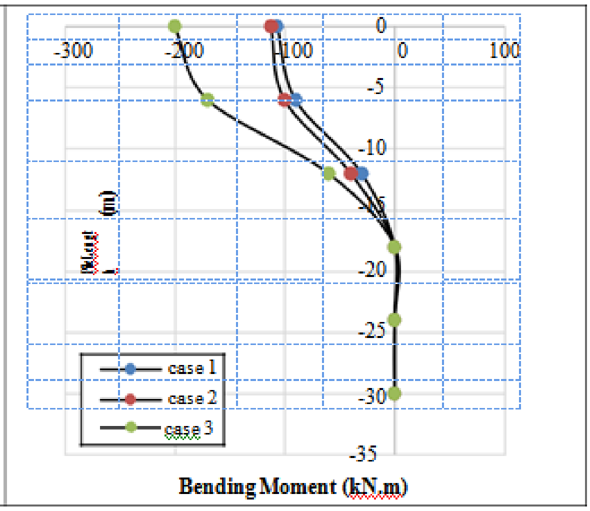


Figure 50. Pile P2 in soft clay under different load cases

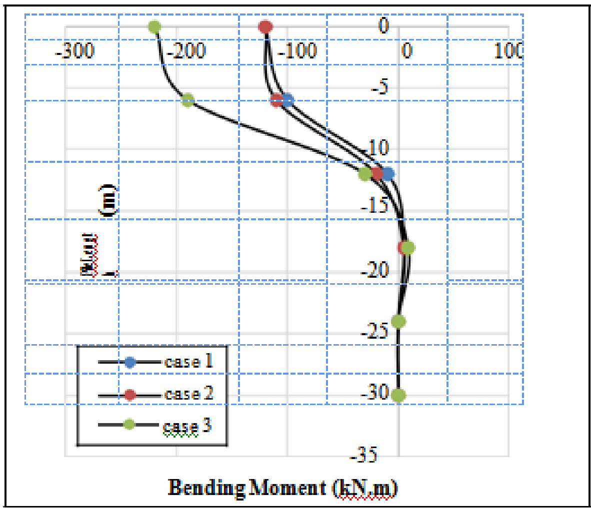


Figure 51. Pile P2 in medium clay under different load cases

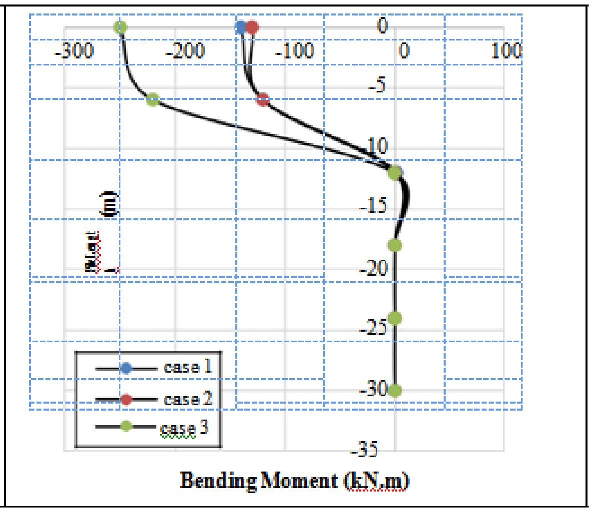


Figure 52. Pile P2 in Stiff clay under different load cases

The deck displacement (point D) variations are shown in Figures 53, 54 and 55. The difference in distribution and values in deck displacement appear clearly in figures. Figures show always the maximum deck displacement value reaches when the pile is embedded in soft clay soil for different loading conditions. Figure

56 shows the distribution of deck displacement when the pile is embedded in soft clay soil for the three different loading conditions. Figure 57 shows the distribution of deck displacement when the pile is embedded in medium clay soil for the three different loading conditions. Figure 58 shows the distribution of deck displacement when the pile is embedded in stiff clay soil for the three different loading conditions. In all Figures 56, 57 and 58 the maximum deck displacement occurs in first loading condition as compare with remains loading condition.

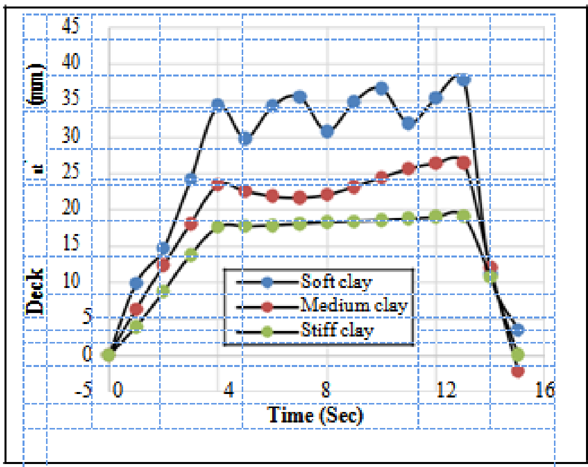


Figure 53. Deck Displacement Load case 1 for different soils

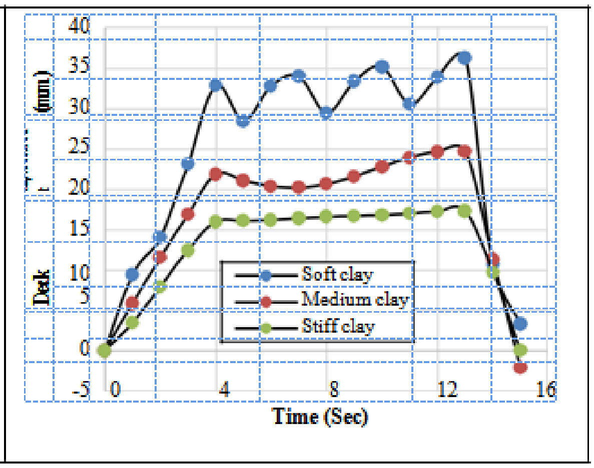


Figure 54. Deck Displacement under load case 2 for different soils

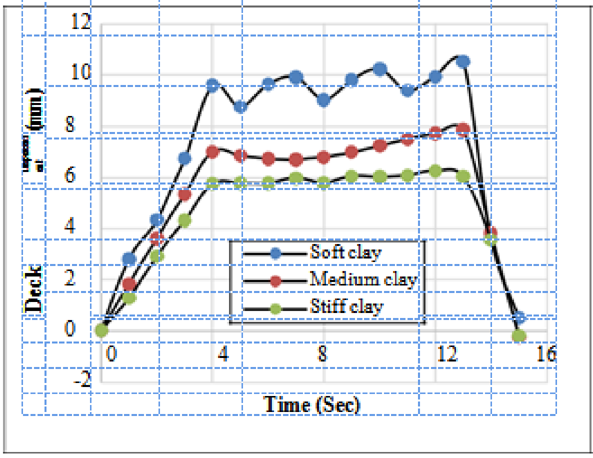


Figure 55. Deck Displacement under load case 3 for different soils

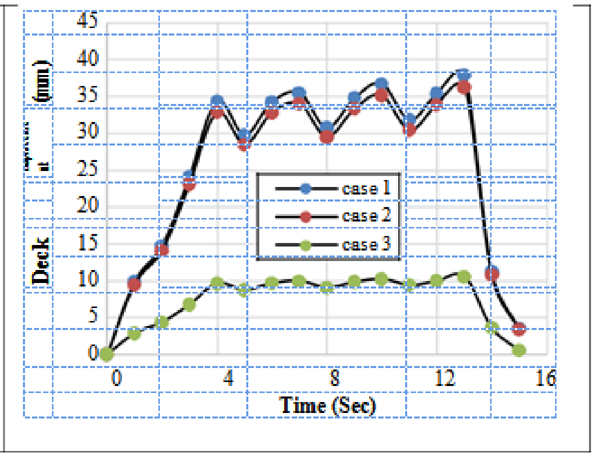


Figure 56. Deck Displacement in soft clay under different load cases

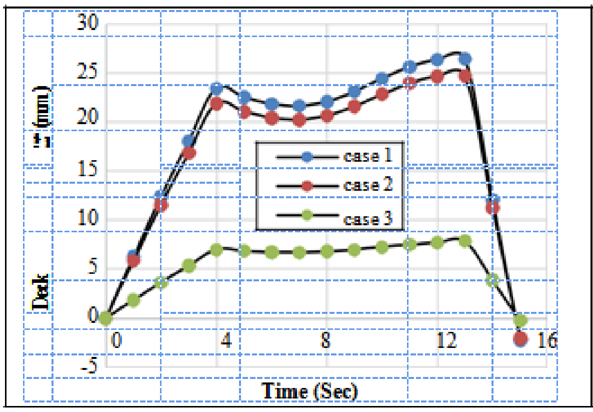


Figure 57. Deck Displacement in medium clay under different load

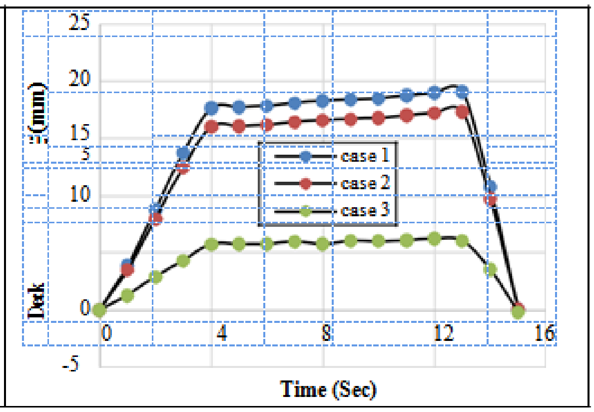


Figure 58. Deck Displacement in Stiff clay under different load cases

IV. CONCLUSIONS

The following points can be obtained from the present paper

- Displacement and critical pile length have a significant influence on evaluating the structural behavior of pile based on majority factors such as soil type and loading condition.

- Twist angle has a vital role in assessing the behavior of pile head under different loading conditions considering the various variables such as different types of soil. It is found that the twist angle is more sensitive to type of soil.
- Shear force and bending moment describe the real behavior of pile under different loading condition and should be considered in the design of pile embedded in the soil.
- Deck displacement reflects the structural behavior of the deck under different loading condition.
- Soil types have major effects on the structural behavior of pile and deck of the platform.
- Different loading conditions, especially torsion, reveal the real behavior of the platform to encounter the risk of different load during serviceability life.

Conflicts of Interest

The authors declare no conflict of interest.

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