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Analysis for Performance of Anchored Pile Wall Subjected To Variation of Water Table on the Displacement and Bending Moment

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ABSTRACT : *Thisinvestigation discuss about the stability of slope supported by shore pile with tie back anchor subjected to water table at different elevation from the ground level. Under this condition there may be the potential for a circular sliding surface to propagate outside the anchor bond zone and reduction in the shear strength of soil due to increase in pore water pressure. In this study an attempt has been made to analyze the deflection and bending moment of the anchored pile wall with the depth is described. The stability of slope has been studied for the effect of water table from displacement versus depth and bending moment versus depth considerations.*

KEYWORDS –*Anchors,Bending moment, Shoreretentionpile, Lateral displacement*

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I. INTRODUCTION

In the growing urbanization era, constructions in major metros like Bangalore has got great significance. Horizontal growth is restricted,instead; vertical growth is gaining importance.It is mandatory for most of the development to go for 2 to 3 basements.The excavation for basement is very difficult in urban areas due to adjacent tall structures around the developed areas. Any excavation more than 4.5m depth in soil or rock is termed as deep excavation. In this scenario retention of deep excavation requires careful design and planning especially when constructed in Urban areas. Adopting the shoring system in the shallow ground water table areas is more significant decision where deep excavation in small sites is involved. The selection of suitable shoring system in deep excavation can have a significant impact on time, cost and performance of the structure.

Major concern during the planning and execution of deep excavation is the impact of construction related to ground movements on the adjacent properties and utilities. During excavation, the state of stress in the ground mass around the excavation changes. The stability of deep excavations can be achieved with various methods based on the offset available for the excavation, slope of excavation and depth of excavation. In case of depth of excavation is vertical, the most commonly and effectively used system is anchored pile wall system. Usually this system shall have a micro pile or Reinforced cement concrete pile anchored using tie back passive/ground anchor system and is temporary in nature. Hence factor of safety is adopted between 1.5 to 2 in this study.

In the cantilever pile shoring system for deep excavation, as the cross-sectional area and rigidity of the pile increases, the resistance to deformation also increases.Thus, the pile deformations are smaller. At different pile spacing, smaller the distance between piles, smaller is the deformation(Liu, Yun-si et al., 2011) [1]. Studies on the effect of anchor installation on settlement of nearby structures in soft soils (Kempfert et al.,2000) [2]. The main reason for the settlement in the adjacent area is based on the drilling mechanism. The percussion drilling mechanism should not be used in the sensitive ground conditions. The passive earth pressures decrease with the hydraulic head loss. The reduction is more significant for lower friction angles. The passive earth pressures decrease with a decrease in the dilation angle ψ for large ø values(Benmebarek et al., 2006) [3]. Bending moment has a significant role in restraining the lateral displacement of the wall during the excavation process. The nail bending stiffness has a significant effect as deformation progresses. Soil-nail lateral resistance is dependent not only on the relative stiffness and yield strengths of the soil and nail, but also on the local lateral displacement across the shear zone (Cheang et al.,2010) [4]. The anchor failure may occur due to the steel tendon failure or due to the shear failure at the tendon-grout interface (Kim, Hyun-Ki et al., 2012) [5].

II. MATERIAL AND METHODS

2.1 Materials

2.1.1 Soil

The soil used for the analysis are collected from one of the site from North Bangalore where deep excavation is proposed for the two basement constructions. The soil properties are shown in Table1.

Table: 1 Properties of foundation soil

Properties	Unit	Values
Dry unit weight	γ_{dry}	18kN/m^3
Bulkunit weight	γ_{wet}	20kN/m^3
Permeability in horizontal Direction	k_x	1m/day
Permeability in vertical Direction	k_y	1m/day
Young's modulus	E_{ref}	20000kN/m^2
Cohesion	C_{ref}	30(kN/m^2)
Friction angle	ϕ^o	34

2.1.2 Shore Piling

The shore piling used in the present investigation is 500mm diameter RCC pile of 13m depth. The grade of concrete used is M_{25} grade and steel reinforcement as 16mmdiameter Thermo Mechanical Treated bars main reinforcement and 8mm distribution steel at 225mm spacing. The pipe to pile spacing is 1m.

2.1.3 Passive anchor

The tie back anchor system used is passive anchor system. The inclination of the anchor is 30^0 and the diameter of the anchor is 150mm. The anchor rod is 32mm diameterThermo Mechanical Treated bars and grade of steel is Fe500. The length of the anchor is 12m long and spacing of the anchor is 1.50m center to center.

2.2 Method adopted

2.2.1. Numericalanalysis

The numerical analysis study has been carried out for the stabilization of vertical cut using passive anchors and shore piling has been modeled by analytical method and pile design as per IS 2911 [6]. CYPE software has been used to analyze the variation of bending moment and displacement of pile. The numerical analysis was carried out in plane strain condition. The numerical model consists of 300mm diameter concrete pile and placed 1000mm center to center. Four layers of Passive Anchors are placed at 1.5m depth from the ground level, having 2.0m spacing in both horizontal and vertical direction and provided with the length of 9.0m. The shore piles are embedded in the soil to a depth of 5.0m from the excavation level (-8.0m). The above said condition is obtained against the factor of safety 1.5 as optimum condition.

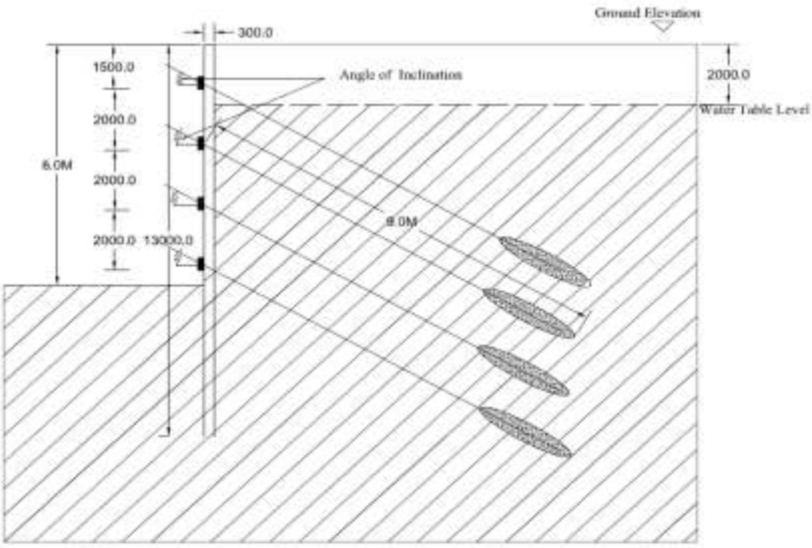

Fig. 1 Model of anchored Pile wall for stabilization of vertical excavation.

III. RESULTS AND DISCUSSION

The study on the effect of water table on the performance of passive ground anchors in the retention of deep excavations has been carried out for the stabilization of vertical cut using passive anchors and shore piling using numerical method.In this study, initially optimum factor of safety is arrived for the optimum inclination of the passive anchor by varying the inclination of the anchor in both saturated and unsaturated condition. Then displacement and bending momentbehavior of the anchored wall with the depth of excavation is analyzed by lowering water table from 2.0m to 10.0m depth from existing ground level in increments of 2m for the optimum inclination of the passive anchor.

3.1 Effect of water table on the factor of safety for various inclination of passive anchor

The performances of passive anchors are studied in saturated and unsaturated conditions for different inclinations against the stability number of vertical cut. Initially unsaturated condition is studied by considering various inclination of anchor with fixed length is analyzed for factor of safety. Then same anchor inclinations are compared with saturated condition and graphs are plotted for angle of inclination versus Factor of safety. The results of vertical cut subjected to various inclinations of anchors in unsaturated and saturated conditions are briefly elaborated in the Table 1.0 and Fig 2.0.

Table 1 Comparison of factor of safety between unsaturated and saturated conditions for various inclinations of passive anchors.

Angle of inclination of passive anchorwith respect to Horizontal (in degree)	Factor of safety	
	Unsaturated Condition	Saturated Condition
60	1.14	0.87
50	1.47	1.11
40	1.75	1.33
30	1.98	1.50
20	2.15	1.63
10	2.25	1.71
0	2.29	1.73

When the vertical cut is stabilized by passive anchor at different inclinations, the strength of vertical cut increases as the angle of inclination decreases. Analysis and results show that, when the passive anchors inclined at $60^0$with the horizontal, the factor of safety is having the value of 1.14. Whereas the passive anchors inclined at $10^0$with respect to horizontal, the factor of safety is having the value of 2.25. This is mainly due to the anchor which goes deeper beyond the active zone and increase the stability. As the passive anchor islonger beyond the failure wedge, the resisting force will increase. Hence factor of safety will also increase. As seen in Fig. 2.0, it is clearly observed that 50^0inclinationsare optimum for factor of safety of 1.5 under unsaturated condition.

For saturated conditions, similar trend is observed, whereas for the passive anchors inclined at $60^0$with respect to horizontal, the factor of safety is 0.87 and for the passive anchors inclined at 10^0 with respect to horizontal, the factor of safety observed is 1.71. This is mainly due to the loss of shear resistance between the saturated soil and grouted anchors. As the shear resistance reduces, the bond strength between the grout and soil will reduce. Hence the factor of safety also reduces. From the Fig. 2.0, it is clearly observed that 30^0inclinationsare optimum for factor of safety of 1.5 under saturated condition.

In general, the grip length decreases in the passive zone as the inclination of the anchor increases for a fixed length of anchor. Hence it can be concluded that factor of safety decreases with the increase in inclination of the anchor for a fixed length.

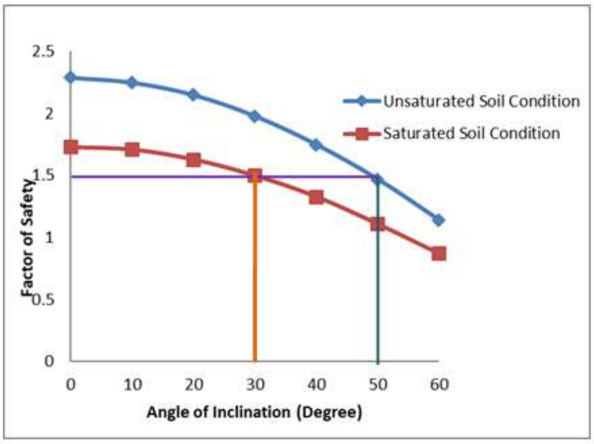

Fig. 2 Variation of factor of safety with angle of inclination of the anchor for saturated and unsaturated conditions

3.2 Effect of water table on the displacement of anchored Pile wall

The water table variation on the passive anchored wall for the optimum inclination of the anchor is studied by lowering water table in increments of 2.0m from the natural ground level to 2.0m below the founding level of the proposed excavation.

Fig.3 shows the variation of displacement of anchored wall with the depth of excavation by lowering water table from 2.0m to 10.0m depth from existing ground level in increments of 2m. It clearly shows that by lowering the water table,increases the lateral displacement byfrom 12mm to 270mm around the excavation line. Hence, the displacement increases about 22 times more than the actual displacement when water table encounters within the excavation line. Initially, the stability of the anchored wall is checked with water table at the depth of 2.0 m from the ground level. The stability check is the ratio between "total passive pressure in fill to the real pressure mobilized in fill" is obtained as less than 1.0 at the final excavation level (that is 8.0m depth), which is not acceptable. However, stabilization of this deep excavation using anchored wall under no water table is evaluated as 1.59, which is more than the minimum acceptable limit of 1.5. Hence the elevation of water table plays a very important role in the stability of the slope and water table should be lowered below the excavation depth by at least 2.0m to get the permissible displacement.

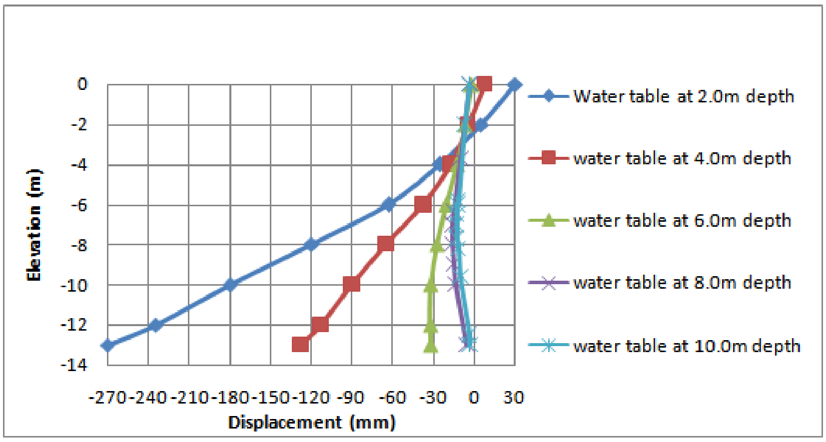

Fig. 3 Variation of displacement with depth at different water table conditions

3.3 Effect of Water Table on the Bending Moments of the anchored Pile Wall

Bending moments is an important criterion for the determining the capacity of the anchors in the anchored Pile wall design. The behavior of bending moments in the anchored wall by lowering the water table is studied and permissible limit of bending moment in the anchored pile wall on optimum lowering of the water table is analyzed.

Fig.4 shows the variation of bending moment with the depth of excavation by lowering water table from 2.0m to 10.0m from existing ground level with increments of 2m. The bending moment will increase with the presence of water table within the influence zone of passive anchor. The maximum bending moment of 750kN-m/m is observed when the water table is high (that is., 2.0m below the ground level) and it gradually decreases as the water table is lowered (that is., -4.0m depth is 390kN-m/m, -6.0m depth is -170kN-m/m, - 8.0m depth is -180 kN-m/m and at – 10.0m depth is -140 kN-m/m). These values from the graph show that, the rise in the water table will increase the bending moment due to increase in the unit weight of the soil beyond the anchored wall. The Stability check is obtained as by taking the ratio between "moment originated by the passive pressures in the infill and the moment originated by the active pressures in the backfill" for the water table at -2.0m, -4.0m, -6.0m, & -8.0m depth is obtained as less than 2.0, which is not acceptable. However, the stability check for the water table at -10.0m depth is observed to be more than 2 (that is., 4.06). This is within the permissible limit. Hence, it can be concluded that the water table should be always lower than the excavation line by at least 2.0m depth.

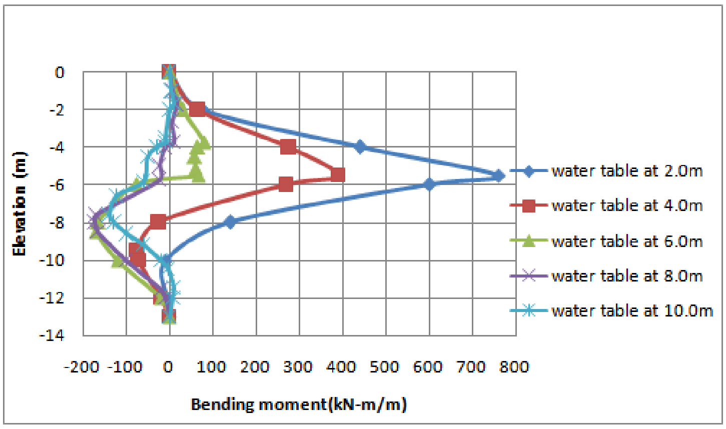

Fig. 4 Variation of Bending moment with depth at different water table conditions.

IV. CONCLUSION

Based on the investigation, the effect of water table on the displacement and bending moment of the anchored pile wall for the optimum inclination of the anchors, the following conclusions are drawn,

- With increase in water table within zone of the influence of passive anchor, both the lateral displacement and bending moment increases in the anchored wall due to increase in lateral pressure. The lateral pressure increase is due to saturated condition of the soil.
- The stability check number is within the permissible limit when the water table is lowered to a minimum of 2.0m below the excavation line. The performance of the anchored wall in the submerged condition is not effective until permanent proper designed dewatering system is installed.
- The analysis and results obtained from this research work shows that, as the angle of inclination of the passive anchor decreases, the factor of safety increases. This is due to the increase in the bond length beyond the failure envelope. The optimum inclination of the anchor for the saturated and unsaturated condition is 30^0against the factor of safety of 1.5.

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