Visakhapatnam Chapter

Proceedings of Indian Geotechnical Conference 2020
December 17-19, 2020, Andhra University, Visakhapatnam

Study of Pullout Behaviour of Bell-Shaped Anchor without and with Tie in Clayey Medium

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Abstract. The present work describes the behaviour of bell-shaped anchor with and without geotextile ties embedded into the clayey medium with different density. Kaolinite soil has been used as embedded medium. Both numerical and experimental studies have been performed to analyse the response of anchor as well as the geotextile tie. One typical model of bell-anchor has been chosen whose bell diameter is 0.125 m. Length and layers of ties as well as density of the soil medium have been varied in the current study. For numerical simulation ABAQUS, a FEM software has been used as numerical tool to analyse the model. The model has been analysed as axisymmetric plane strain model. Both of the analysis showed that increasing the embedment depth and density of the embedded medium, improves the uplift capacity of the anchor. Uplift capacity of the anchor also increased with increasing tie length and number of tie layer, but after a certain limit the uplift capacity got almost constant. From the experiment the failure response also was analysed. It was found that the anchor with tie form greater diameter bulge around the anchor compare to anchor without tie, during the failure, which is an indication of greater dispersion of the uplift force to a greater area. The numerical analysis showed that stress generated in the soil for anchor with tie is less than stress produced in soil for anchor without tie. The optimum no of layer of geotextile tie was found to be 2.

Keywords: Bell-shaped anchor; Pullout capacity; geotextile tie; FEM; Kaolinite Soil;

1 Introduction

In the field of geotechnical engineering a tensile member is a very essential structure in certain scenario. For this purpose anchor foundation plays a very important role. Anchors have been used in different types of structures, such as transmission towers chimneys, offshore oil-platforms etc. anchors can resist the uplift or pullout force subjected to the structures. As soil can’t bear any tensile force anchor plays an essential part for stabilizing the structure. Uplift capacity of the anchor consists of dead weight of the soil in the failure zone, shear force along the failure zone and self weight of the anchor. Study of the anchor behaviour is an important part of the geotechnical engineering. Many researchers have investigated and studied different types of anchor in different conditions with different parameters. Das [1] carried out model tests for uplift resistivity of square and rectangular shaped foundation in clayey medium and found that the breakout factor F_c is dependent on ϕ, and increased with embedment depth. With increasing depth of embedment, the failure zone occurred locally above the foundation. They incorporated the effect of pore water pressure and neglected the suction force. In case of shallow foundation they found the critical embedment depth as 6. Stewart [2] investigated the behaviour of circular plate anchor within cohesive medium with cohesion less overlay found that increasing the depth of cohesion less overlay medium increases the uplift capacity of the anchor. Shin et.al [3] Performed an experimental instigation to evaluate the ultimate uplift capacity of rigid metal piles embedded in compacted near –saturated clay by varying the length to diameter ratio and inclination angle for applying load from 10-15 and 0^0-50^0 respectively. They found that the undrained cohesion as well as adhesion was dependent on vertical stress. Krishnaswamy and Parashar [4] investigated the behaviour of the plate anchors with and without geosynthetic reinforcement installed in cohesive soil. They found that the inclusion of reinforcement increases the uplift capacity of the anchors and also the displacement required for achieving the ultimate value is much higher than that of the unreinforced anchor. Merifield. et.al [5] performed three-dimensional numerical limit analysis procedure based on a finite-element formulation of the lower bound theorem of limit analysis. To study the effect of anchor shape on the uplift capacity of horizontal anchors in undrained clayey soil. They found that the break-out factors for square anchors in weightless soil were found to be always greater than those obtained for strip anchors at corresponding embedment ratios. They also found that the ultimate anchor capacity increased linearly with overburden pressure up to a limiting value which reflected the transition from shallow to deep behaviour. For circular anchor the break-out factor for circular anchor was found to be increased steeply before reaching a constant value of approximately 12.56 at H/D= 7. They also found that the ultimate capacity of the anchor increased linearly with overburden pressure up to a limiting value which reflected the transition from shallow to deep anchor behaviour. For square as well as circular anchor the effect of anchor roughness on the break-out factor was found to be minimal. Song et al. [6] studied the behaviour of strip anchors and circular plate anchors during continuous vertical uplift within uniform and normally consolidated clays with help of the small strain and large deformation finite-element analyses and found that for small strain analysis, the distribution of existing data was mostly due to the consequence of soil stiffness whereas for large deformation analysis, when soil and anchor base were attached with suction, the pullout capacity factor developed a unique curve independent of the parameter such as effective unit weight of the soil mass, soil strength (s_u), , and anchor size (B, width of strip anchor and D, diameter of circular anchor). Khatri and Kumar [7] investigated the characteristics of horizontal circular plate anchors in a clayey stratum whose cohesion increases proportionally with depth, with the help of the axisymmetric static limit analysis formulation in combination with finite elements. They also studied the failure patterns and the effect of the roughness of the anchor plate. They found that the value of the uplift factor (F_c) increased continuously with an increase in the value of H/B up to a certain value of embedment ratio (H_{cr}/B) beyond which F_c becomes almost constant. Merifield [8] has studied the behaviour of the multi-plate helical anchors within the clayey soil by using numerical modelling technique. He found that capacity of the shallowest anchor (near to the ground surface) is independent of embedment depth of the anchor. From the above research works it can be found that most of the research works have been done to study the behaviour of anchor within soil mass without the tie attachment. Hence in this study an attempt has been made to study the characteristics of anchor with geotextile ties within clayey soil.

2 Statement of the Problem

In the following paper an experimental study have been performed to investigate the influence of geotextile ties on uplift capacity of the bell- shaped anchor within clayey soil. One typical model anchor anchors with diameter of 0.125m and varying the parameter of the geotextile ties, the investigation have been performed. To study the effect of the geotextile tie length of the tie, number of the geotextile layer has been varied.

2.1 Anchor: The model of the belled anchor has been made of concrete with bell diameter 0.125m. the diameter of the shaft is 0.125m. height of the bell is 0.025m . angle at the joint of shaft and bell is 45^0.

2.2. Soil: For the current investigation kaolinite soil has been chosen as embedded medium. For the current study soil mass has been compacted to standard density. From the laboratory experiment the density of the soil was 14.3 kN/m^3, ϕ =4.03^0, c=21 kN/m^2.

2.3. Geotextile tie: In the present study woven geotextile made of polypropylene has been used. The geotextile has been cut into required diameter of circular sheet with proper care and the geotextile ties are clamped with the anchor with help of circular rings. For multilayer geotextile tie spacing between each layer was kept about 65 mm.

3 Experimental Procedure

For the current study a container of dimension 70 mm x 70mm x 50 mm has been used. Three sides of the container are made of plexi-glass and one side is made of steel. Above the container a steel frame has been constructed to set up the load application mechanism. Here a mechanical wheel has been attached with the frame a tie rod is connected to the wheel through a rotating mechanism, so that the uplift displacement can be controlled with the mechanical wheel. First the soil has been mixed with required water content and a layer of 5mm thickness had been placed, after that the anchor attached with geotextile tie has been placed. Then the soil has been placed in three layers with proper compaction so that standard density can be maintained in each layer. The density of the soil achieved was 14.3 kN/m^3.

The soil was placed up to required depth depending upon embedment ratio of the anchor. A filter paper was placed between the anchor and soil to avoid any suction .The anchor was attached to the tie rod through a proving ring to determine the uplift capacity. Two dial gauges were attached with the anchor top surface to measure the upward displacement.

3.1 Failure Mechanism of the experiment

From the results acquired from the experiment performed in the laboratory, the effect of the geotextile tile on uplift capacity of the bell-shaped anchor can be analysed. After occurring of the failure during the uplift the anchor has been pulled till it comes out of the soil for the purpose of studying the failure pattern. During the uplift pull the top surface around the anchor was bulging. The outer diameter of the overall bulged area was found to be approximately double of the anchor diameter. As suction force was absent, soil at the bottom of the anchor was plane. From the observation it can be stated, that the failure occurred was local failure, because of present of sudden failure pattern. For more precise idea of the failure plane further study will be performed.

4 Plan of work

In the present study, to investigate the effect of geotextile ties on uplift capacity of the bell-shaped anchor a plan of work has been drawn. To study the effect of the length of the geotextile tie, number of layer, these parameters have been varied. The details of the plan have been depicted in table 1. Series E1 is performed to analyse the effect of length of geotextile for single layer of geotextile tie. Series E2 was performed to study the behaviour with multilayer geotextile tie attached with bell-shaped anchor and its effect on the uplift capacity for different length of geotextile tie.

Table 1. Plan of experimental study

Series	Anchor Diameter (m)	H/D ratio	L_g/D Ratio	No. of layers (N)
E1	0.125	0.5,1,2,3	2,3,4	1
E2	0.125	0.5,1,2,3	2,3	1,2,3

Fig.1 bell-shaped anchor with geo-textile tie

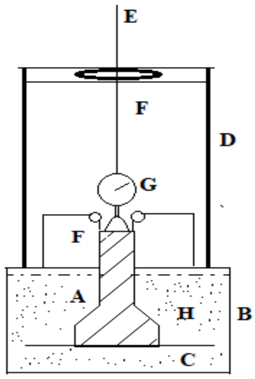

Fig 2. Experimental setup

5 Results and Discussion

Fig.4 represents load versus displacement curve for bell-shaped anchor with and without geo-textile ties of single layer where $L_g/D = 3$. Fig .5 represents uplift capacity of anchor for a single layered geotextile with varying the length of the geotextile. Fig 6 shows the uplift capacity for varying layer of geotextile ties with $L_g/D = 2$. Fig.7 represents the breakout factors for anchor with single layered tie with varying the length of the geotextile ties.

Fig. 3. Positioning of anchor before placing the soil mass

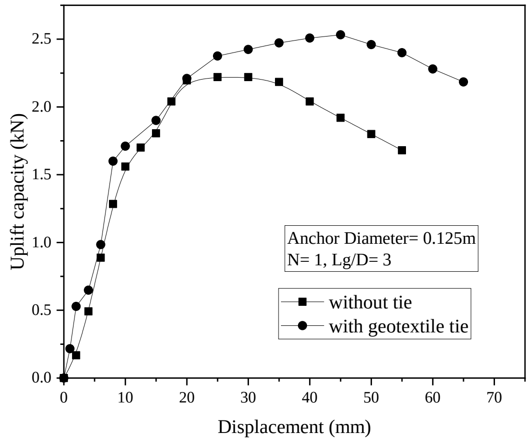

Fig. 4. Uplift capacity versus displacement curves for anchor with and without geotextile ties.

5.1 Effect of the length of the geotextile ties

From fig 4 it has been observed that inclusion of geotextile tie with the anchor improved the uplift capacity of the bell-shaped anchor. From fig. 5 it has been found that at ratio of L_g/D =2 (Diameter of geotextile ties to Diameter of the anchor) uplift capacity of the anchor achieves a critical value. After this there isn't much improvement due to inclusion of geotextile tie. It has also been found that the stress in the soil gets dispersered due to addition of tie to the anchor, because the failure zone was comparatively spreaded than anchor without geotextile tie.

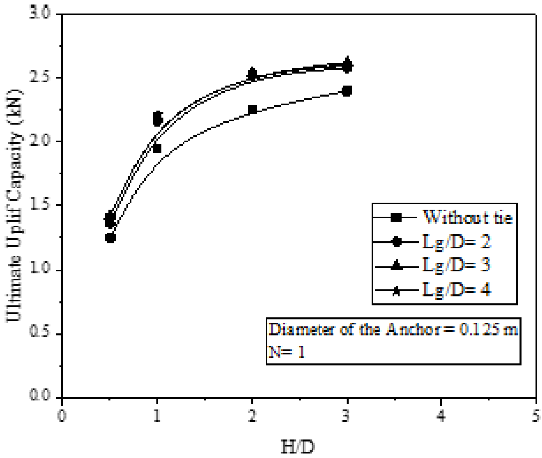

Fig.5. Uplift capacity of the anchors with geo-textile ties varying the length of the ties for single layered ties.

5.2 Effect of number of layers of the geotextile ties on uplift capacity

In the present analysis the influence of the geotextile tie on the uplift capacity of the bell-shaped anchor has been studied. From fig.6 it can be observed that increasing the number of the layer of the geotextile ties improves the uplift capacity. But after a certain number of layers the uplift capacity does not improve much. In this particular case the critical number of layer has been found as 2.

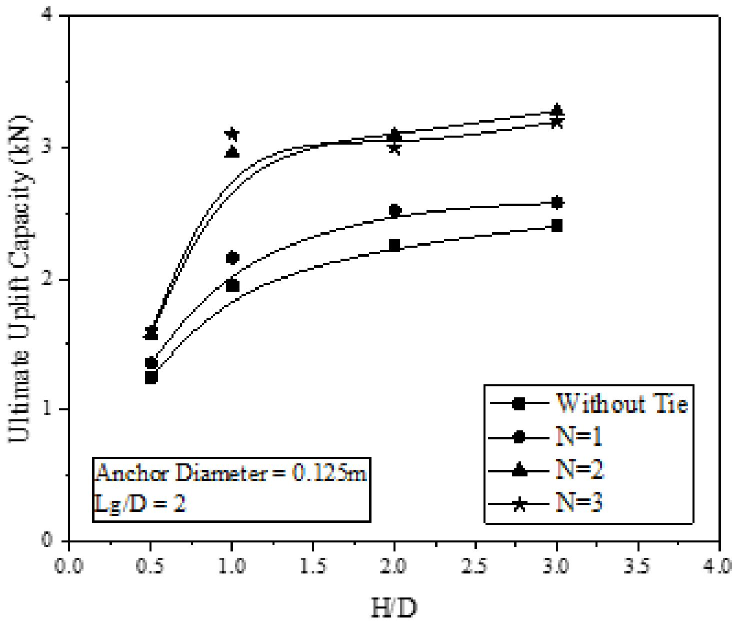

Fig.6. Uplift capacity of the anchors with geo-textile ties for multiple layer for Lg/D = 2

5.3 Breakout Factor of the anchor

In the present study breakout factors for the bell-shaped anchor with geotextile ties has been evaluated. From the analysis it has been observed that with increasing the H/D ratio of the anchor the value of the breakout factor increases, but after achieving a certain value it gets constant. Fig .7 represent the curves for breakout factor for two layered bell shaped anchor (bell diameter = 0.125 m) with varying the length of the geotextile. The maximum breakout factor found from the analysis is 11.

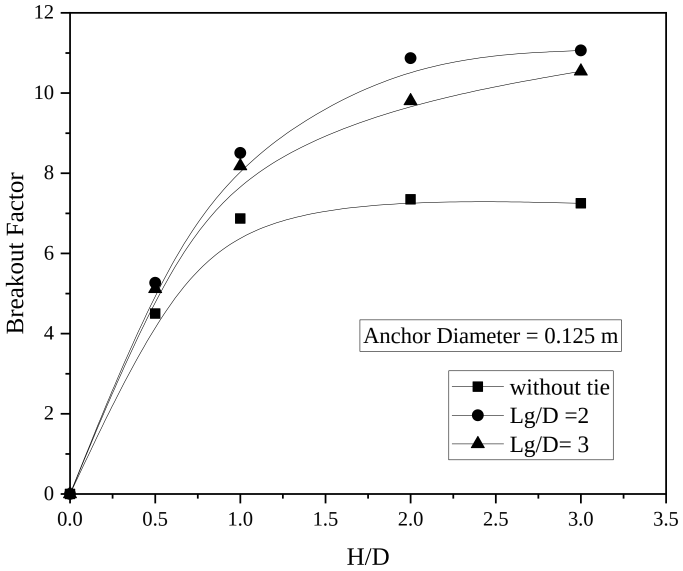

Fig .7. Breakout Factor of the anchor for single layer geotextile tie with varying the geo-textile length

6 Conclusions

An experimental investigation has been performed to study the behaviour of bell-shaped anchor with geotextile tie on uplift capacity of the anchor by varying different parameters of the geotextile tie. Following conclusions can be drawn from the analysis of the acquired results.

1. Inclusion of the geotextile ties definitely improves the uplift capacity of the bell-shaped anchor.
2 The optimum length of the geotextile tie has been found as 2 and optimum layer of the geotextile has been found as 2.
3. Breakout factor is found to be increased with H/D ratio and after reaching a certain point the breakout factor gets more or less constant value.
4. The failure of the soil mass during the uplift is considered to be local failure.
5. Stress in the soil mass is comparatively lesser for Anchor with geotextile ties.

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