Performance of Helical Anchors in Sand

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ABSTRACT

Helical anchor consist of some steel shafts with a series of helical steel plates welded on a pitch. During installation, helical anchor was screwed into the ground by using a standard truck or trailer mounted augering equipment. The equipment will apply a rotating moment to the steel shafts to screw the anchors into ground. The torque resistance of the anchor will be monitoring along the installation. When the torque resistance achieved its designed values, it verified that capacity of anchor achieved. Behavior of helical anchor under uplift load in cohesionless soil has been studied using previous researches. Based on a few number of laboratory model results many investigators reported the uplift loading of helical anchor embedded in cohesionless soil, a review of related last works shows that not much research has been done to define the uplift capacity in cohesionless soil, a problem that is often encountered in field. The paper observed that the ultimate uplift capacity is dependent on the relative undrained/drained shear strength of cohesionless soil, the depth ratio of embedment and soil thickness ratio.

KEYWORDS: Soil anchor, Helical, Screw, Cohesionless soil, Uplift response

INTRODUCTION

The earliest helical anchor created by a blind English brick maker names Alexander Mitchell for designing a foundation support of a lighthouse in 1833. The concept of “screw pile” was very successful in the designing but the development of helical plate foundation was not progress (Chance, 2004). Until 1950’s, a power-installed screw anchor for resisting tension load was found in US and this type of anchor was starting popular and widely used in the construction site. The helical anchor formed by a steel shaft which one or more helical plates welded to the shaft to create a “screw anchor”. Helical anchors are primary designed and constructed to provide the uplift resistance to the foundation of a structure. However, helical anchor system also can provide the compression support to the structure. Generally, helical anchor can be dividing to two types that are single helix anchor and multi helix anchor. Both of types of helical anchor have shown in Figure 1.

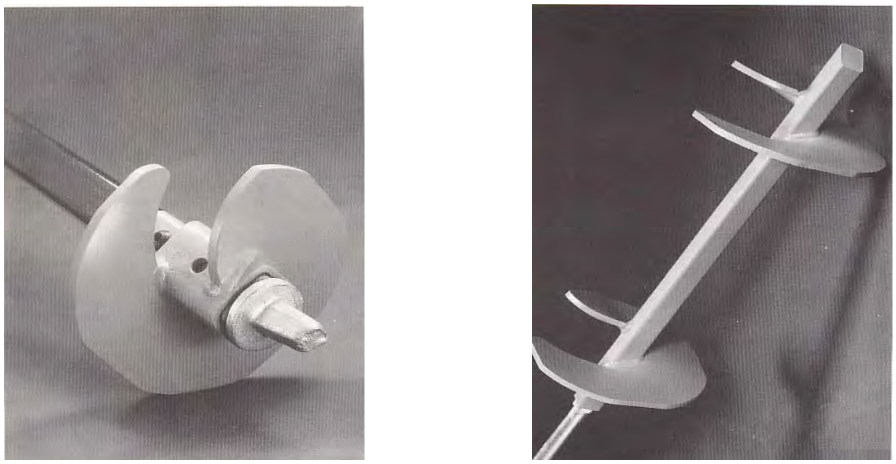

Figure 1: Photo for Single Helix Anchor and Multi Helix Anchor (Braja M Das, 1990)

In the construction site, the helical anchor are installed by applying a rotating and axial forces to the shaft of anchor and screw the anchor into the ground with power augering truck. The helical anchor can be installed rapidly and minimize the soil disturbance in the installation. This anchor system always install to the maximum torque values that recommended by the manufacturers. The helical anchor system is not suitable for the foundation in stiff soil or soil containing gravel because the helixes may be damage in installation process. Therefore, this type of anchor system always applied in the sand, silt and clay.

Selection of Variables

In the dimensional analysis, the most significant and difficult step is select the variables. Since engineers usually wish to keep the problems as simple as possible, a suitable balance between the simplicity and the accuracy of experiment result is very important. Generally in engineering problems, there are three groups of variables are involved which are the geometry, material properties and external effects.

a) <u>Geometry</u>
   The geometric characteristics can describe in length and angles. In most of engineering problems, the geometry variables usually are ready identified before the experiment.

b) <u>Material Properties</u>
   Due to the responses of a material to the applied external effect such as forces and pressure is depend on the material strength and other properties. Therefore, material properties must be included as variables in an experiment.

c) <u>External Effects</u>
   This terminology used to indicate any variable that produces or tend to produce a change in the experiment. For example, in soil mechanic, if forces subjected to the soil, soil will consolidated and soil properties will change. Therefore, the forces need to be considering as variables.

THEORY OF UPLIFT

The helical anchor systems have been widely used in our construction site for resisting the tension load. However, the increasing of using the helical screw anchor system was slow down by the reasons of the lack of techniques to estimate the uplift capacity of helical anchors accurately and consistently. The inaccurate and inconsistent estimating of uplift capacity of these anchors caused by the uncertainties in the failure mechanism and some geometry factors of these anchors. To solve this problem, a number of researches and theories have conducted to estimate the ultimate uplift capacity of anchor in various types of soil during the last twenty years. Therefore, a literature review has carried out to indicate the theories proposed by several researchers to design the helical anchors subjected to pullout forces.

Mitsch and Clemence (1985) proposed a semiempirical solution to predict the ultimate uplift capacity of multi helical anchor in sand. They introduced values for coefficient of lateral earth pressure as a function of H/D ratio and relative density. Their values were 30 to 40% reduction compared with those proposed by Meyerhof and Adams (1968). They indicated that this reduction caused by the shearing disturbance of the soil during anchor installation.

Clemence and Pepe(1984) studied the effect of installation and pullout of multihelix anchors on the lateral stress in the sand layer. The values of lateral earth pressure measured before and after the installation of anchor, at the failure of anchor and continuously during the application of the uplift loads. From the test, they indicated that the installation of helical anchors in dry sand causes an increase in lateral earth pressure around the anchor and the pressure was significantly increase in dense sand. They concluded that the increase of lateral earth pressure was depending on the relative density of sand and the embedment ratio (H/D).

Based on the result from a laboratory test, Ghaly and Hanna (1994) indicated that there are three components mainly contribute to the uplift capacity of shallow anchor, which are the selfweight of anchor, weight of sand within the failure surface and the friction along the failure surface. From the experiment result, a theoretical model developed by using the limit equilibrium technique and Kotter's differential equation. In this model, they assume the failure surface in log-spiral shape. In their model, they have reduce the complexity of model by developing the weight and shear factors for shallow and deep anchors. These factors presented in graph that plotted with the friction angle and embedment depth ratio.

Failure Mechanism

The uncertainty of failure mechanism of anchors always is a problem for the designer to predict the ultimate uplift capacity. Therefore, a number of theories have proposed in this last 20 years to describe the failure mechanism for anchors subjected to uplift forces. Generally, these theories can be categories to three methods that are cone method, friction cylinder method and curved method.

Cone Method

Based on laboratory model tests result, Ghaly et. al, (1991) suggested that for single screw anchors, the rupture surface under the ultimate pullout load is a truncated cone that having an apex angle of $\theta = \frac{2}{3}\phi$ as shown in Figure 2. They proposed that the uplift resistance of anchor is providing by the weight of soil and foundations in the cone shape rupture surface as well as the friction resistance along the failure surface.

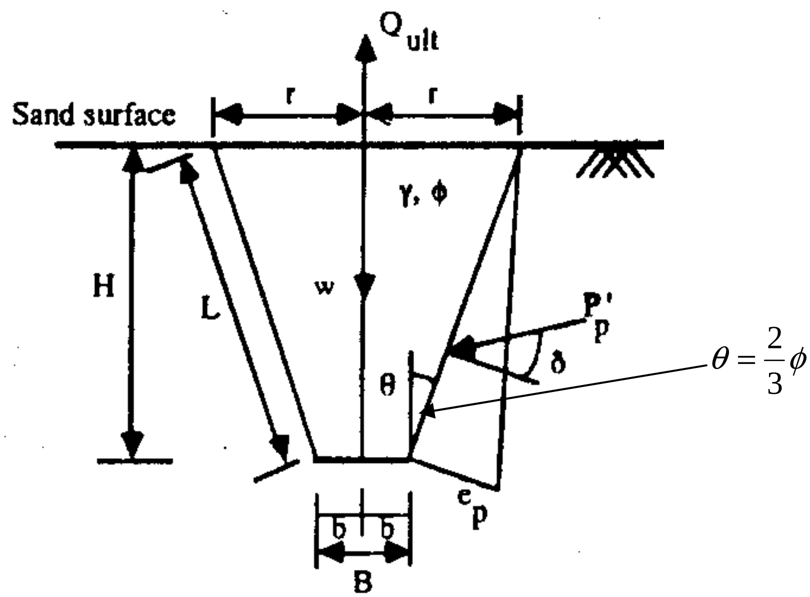

Figure 2: Cone Shape Failure Surface (Ghaly et al., 1991)

They also reported that the angle of inclination of the failure cone θ with respect to the vertical axis does not exceed $\frac{2}{3}\phi$ from the shallow anchor to deep anchor. This proposed failure mechanism method is similar to that observed by the Mitsch and Clemence (1985) in their laboratory test. Based on result of the investigation for shallow multi-helical anchors, they found that the angle of θ is equal to ϕ/2. In their test, the truncated cone failure surface was just occurring at the upper helix and the lower helix will fail in another method.

Frictional Cylinder Method

Mitsch and Clemence (1985) observed that the frictional cylinder failure surface in their laboratory test as shown in Figure 3. They found that sand around the helixes is fail in this form of method that is in a frictional cylinder shape. In this method, net uplift capacity mainly provided by the shearing resistance along the failure surface and the weight of sand within the failure surface. This method can applied to shallow and deep anchors.

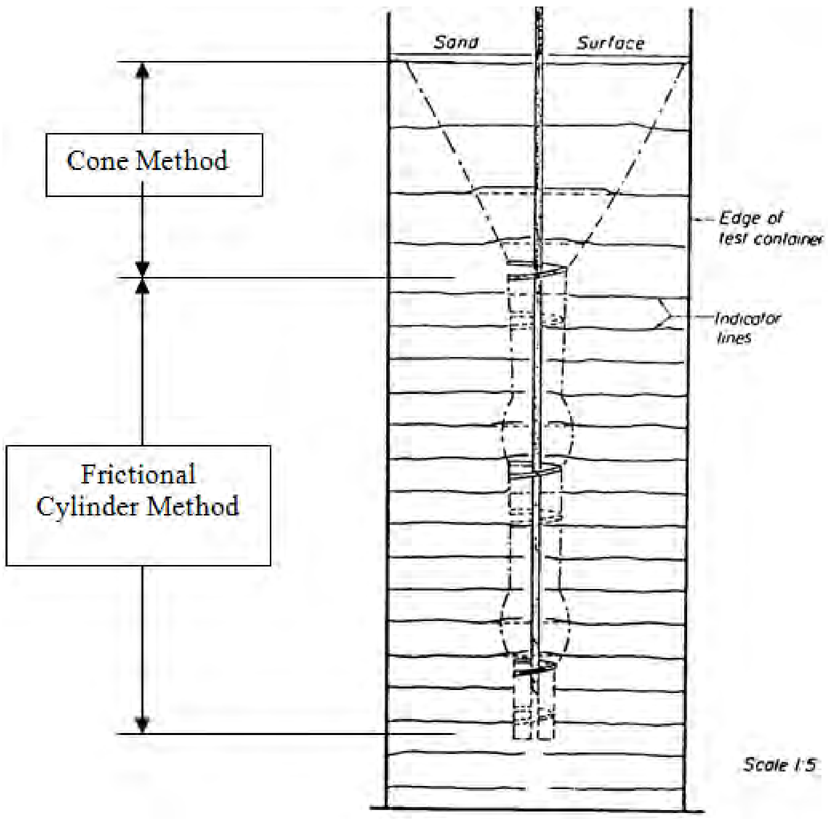

Figure 3: Cone Method and Friction Cylinder Method (Mitsch and Clemence, 1985)

Curved Method

Ghaly and Hanna (1994) have done an investigation into the performance of single vertical screw anchors in sand. They observed that the failure surface can described by curved method. For shallow anchor case, the failure surface is in log spiral shape as shown in Figure 4. However, for the deep anchor case, the failure surface occurs in a form of closed bulk and the surface for this bulk can describe by log spiral shape. The geometry for the log spiral shape of failure surface is significant affected by the friction angle of sand and the embedment depth ratio. For the deep anchor case, the height of the closed bulk increased as friction angle decreased.

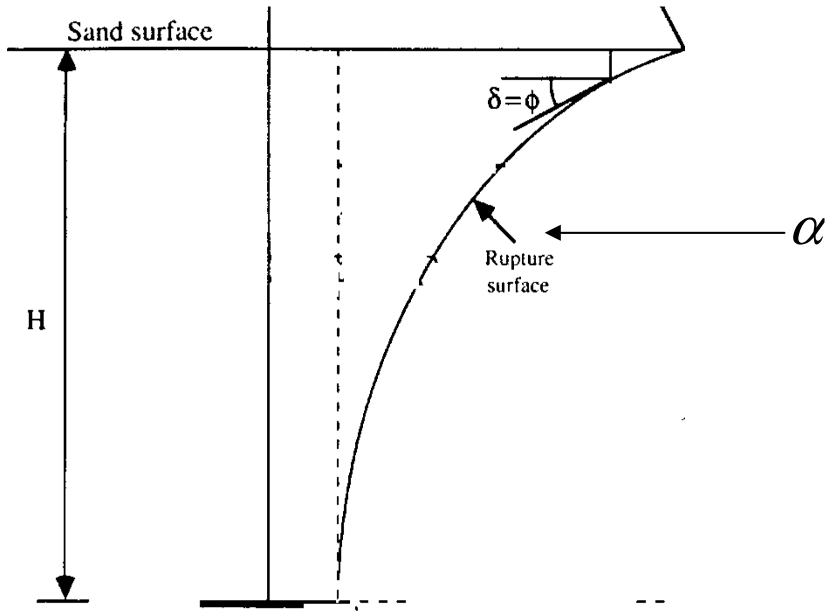

Figure 4: Curved Method (Ghaly and Hanna, 1994)

Relationships between Uplift Resistance and Main Factors

The ultimate uplift capacity of anchor always affected by some geometry factors of anchor and the soil characteristic such as the embedment ratio, soil characteristic/density, diameter of shafts, size of anchor and inclination of pullout load. The embedment ratio and soil relative density are the major factors that affect the uplift resistance and these two factors have been study by several researcher like Clemence, Ghaly and Hanna and others. Due to these factors give a significant effect to the ultimate uplift capacity of helical anchors, the relationship between the uplift capacity and these factors will be discuss in below paragraphs.

Embedment Depth Ratio

During past 20 years, a number of researches have been conduct to explain the relationship between the embedment ratio and uplift resistance of anchors. Embedment ratio (H/D_h) is the ratio that the depth of anchor (H) divided by the diameter of anchor's helix (D_h). Researchers such as Mitsch and Clemence (1985) have indicated that for helical anchors, the breakout factor of anchors will increase with the embedment ratio. The breakout factor increase with by the increase of height and diameter of failure surface. When the diameter and height of failure surface increase, the skin friction along the failure surface will increase and provide a larger uplift resistance to the anchor. Figure 5 show the relationships between the breakout factor and the embedment depth ratio. From observation to Figure 7, it can be seen that the breakout factor will increase slightly when achieve a higher embedment ratio and approximate remain at a value when the embedment depth ratio reach about 10.

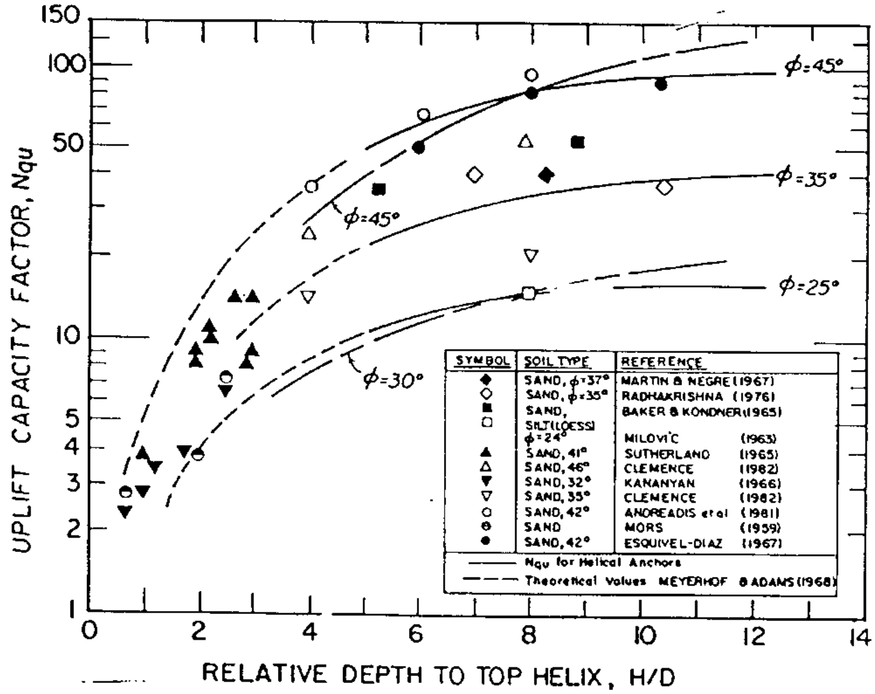

Figure 5: Plot of Breakout Factor with Embedment Depth Ratio (Mitsch and Clemence, 1985)

Friction Angle and Unit Weight of Sand

Based on the laboratory test on single helical anchor in sand Ghaly et al. (1991) have proposed that the performance of a single helical anchor depend on the sand characteristic such as the unit weight and friction angle of sand. When the unit weight and friction angle of sand increased, the uplift capacity of anchor will increase as shown in Figure 6. The uplift capacity increases with the change of the failure surface. Ghaly et al. (1991) observed that the friction angle of sand is the main factor affecting the magnitude of the sand deflection and the extent of this deflection. The changing of failure surface contributes to the friction resistance along the failure surface and the weight of sand within the failure surface will be different.

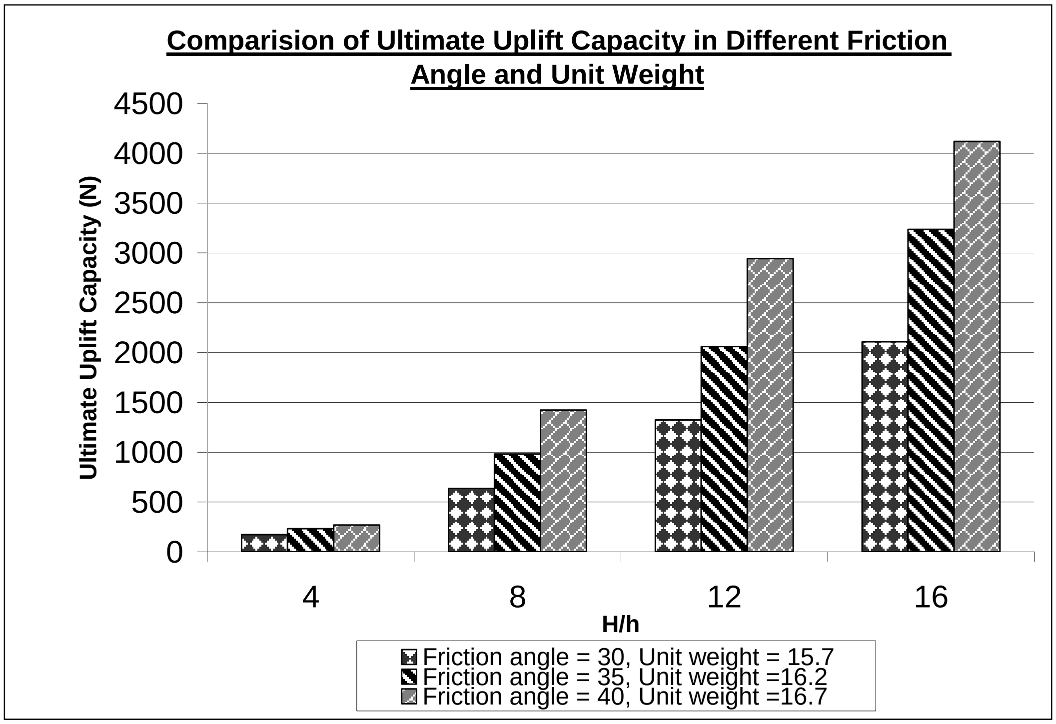

Figure 6: Comparison of Ultimate Uplift Capacity in Different Soil Characteristics (Ghaly et. al, 1991 –Table 2 and 3)

UPLIFT CAPACITY OF HELICAL ANCHOR IN SAND

Several different methods have proposed to predict the ultimate uplift capacity of helical anchor in sand but commonly there are two types of methods. These methods are theoretical method and empirical method. The theoretical method is representing the method which conducted from laboratory and field test. A lot of researcher such as Mitsch and Clemence (1985) has developed this type of method. However, the empirical method mentioned above is the installation torque method. The installation torque method based on the empirical data and some engineering judgments. In this research, the theoretical analysis has been focus.

Theoretical Method

The uplift capacity of helical anchors in sand has been studied by a number of researchers including Mitsch and Clemence (1985) and Ghaly et al. (1991). Based on laboratory and field test, Mitsch and Clemence (1985) have proposed a semi empirical solution to predict the ultimate uplift capacity for multi helical anchor in sand. They recommended that the bearing resistance of top helix, frictional cylindrical resistance and friction on the anchor’s shaft provide the uplift resistance of multihelical anchor. Based on laboratory tests, Ghaly et. al. (1991) suggested a similar solution with the Mitsch and Clemence (1985) for the pullout resistance of single helical anchors in sand. Nevertheless, in their solution, they have ignored the effect of friction of anchor’s shaft in the uplift resistance.

Mitsch and Clemence Theory

Mitsch and Clemence(1985) have present the uplift capacity of multihelical anchor in sand is equal to the sum of bearing resistance of upper helix, frictional resistance acting on a cylinder of sand between the helixes and anchor shaft's friction.

$$Q_u = (\text{bearing resistance}, Q_p) + (\text{frictional cylinder resistance}, \ Q_f) + (\text{friction on anchor shaft}, \ Q_{sh})$$

To predict the pullout capacity, each components contributed to the uplift resistance will be considered individually.

Bearing Resistance of Top Helix

Due to the failure mode for shallow and deep anchor is different, therefore the method to compute the bearing resistance of top helix is different. In estimating the uplift capacity for shallow anchor, the shear resistance along the rupture surface and the weight of soil within the rupture surface will be consider. For shallow anchor, anchor fail in a truncated cone shapes shown in Figure 7. The cone shape of failure surface is inclining with the vertical axis approximately $\frac{\phi}{2}$.

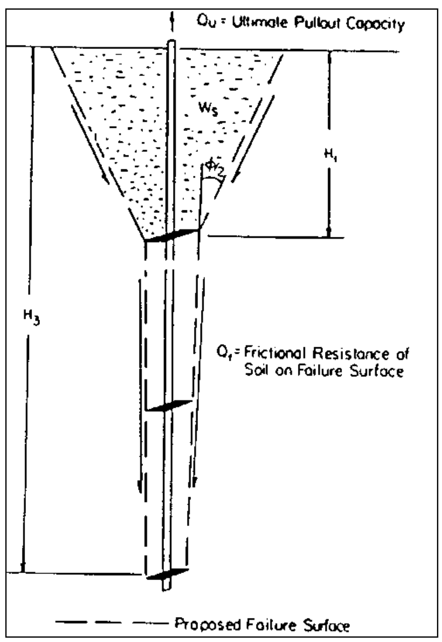

Figure 7: Failure Surface of Shallow Helical Anchor in Sand (Mitsch and Clemence, 1985)

However, the uplift behavior for the deep anchor is similar to the end bearing of deep foundation as shown in Figure 8. Therefore, the bearing capacity theory is used as the computation method for the uplift capacity of deep helical anchor. The simplified bearing equation can give as:

$$Q_p = \gamma' H_1 A_1 N_q \tag{1}$$

where,

Q_p= pullout capacity of the top helix plate

γ' = effective unit weight of soil

H_1= depth of helix

A_1= area of helix

N_q= uplift capacity/breakout factor

Several uplift capacity tests have been conduct on the helical angle and breakout factor values computed using Equation 1. The results of breakout factor as shown in Figure 5. From Figure 5, the breakout factor in the range of 15 to 18 for friction angle is 25^o can be taking as maximum values since when a deep anchor mobilizes the full component of the soil strength, it will act as if it were in bearing.

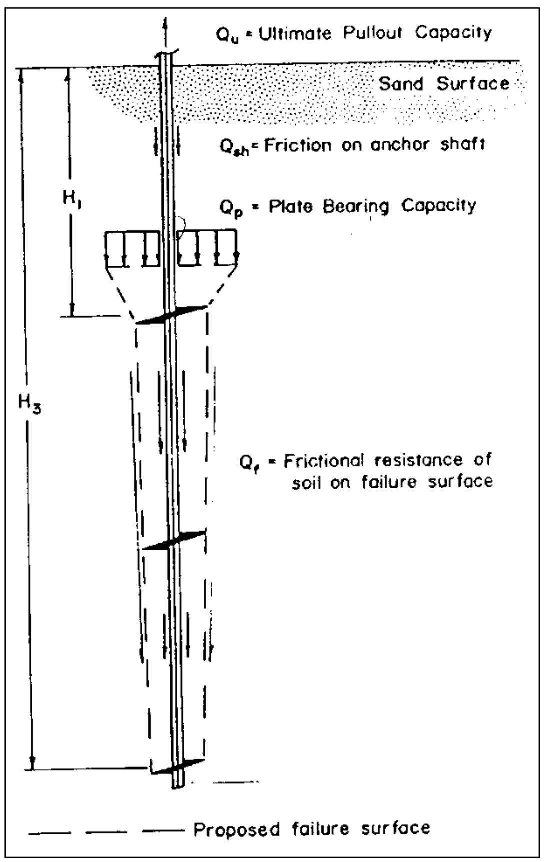

Figure 8: Failure Surface for Deep Helical Anchor in Sand (Mitsch and Clemence, 1985)

Frictional Resistance on Intra-helical Soil

The soil around helixes below the top helix will fail in a frictional cylinder shape as shown in Figure 8. In predicting the friction acting on the cylinder shape failure surface, Mitsch and Clemence (1985) have proposed an equation as shown as below:

$$Q_f = \frac{\pi}{2} D_a \gamma' \left(H_3^2 - H_1^2\right) K_u \tan\phi \tag{2}$$

where,

D_a = average helix diameter
γ' = effective unit weight of soil
H_3 = depth to bottom helix
H_1 = depth to top helix
K_u = lateral earth pressure coefficient in uplift
ϕ = friction angle of soil

In the equation, the lateral earth pressure coefficient in uplift (K_u) is the major variable that affects the pullout capacity for frictional uplift. During anchor uplift, the measure value for the lateral pressure of soil called K_u. This coefficient will change from rest condition to the failure condition as shown in Table 1. Table 1 shows that the coefficient is increasing from rest condition to disturb condition and finally reach maximum K_u at failure condition. During installation of anchor, displacement and disturbance of surrounding soil will occurs and produce an additional lateral earth pressure to soil (Clemence and Pepe, 1984). The magnitude of additional lateral pressure is depending on the level of soil disturbance. The lateral pressure increases when the amount of soil disturbance increases. During the anchor is uplifted, the lateral earth pressure will develop in passive state.

Table 1: Lateral Stress Ratio for Anchor Installation and Pullout in Sand (Mitsch and Clemence, 1985)

H/D	Relative Density, Dr (%)	At Rest, K_D	After Anchor Installation, K	At Maximum Uplift Load, K_u
4	46	0.53	0.93	1.61
8	46	0.48	0.74	1.42
4	90	0.75	2.78	3.32
8	90	0.67	3.16	3.89

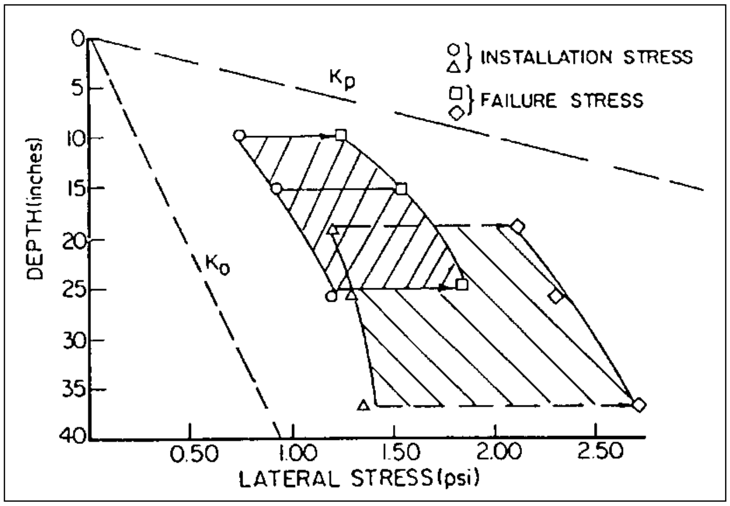

Figure 9: Lateral Stress versus Depth for Anchor Installation and Pullout in Medium Dense Sand (Mitsch and Clemence, 1985)

A series of tests have conducted to obtain the lateral earth pressure coefficient in uplift and the average values for the coefficient for the various conditions have summarized in the Table 1. From the observation towards the Figure 9 shows that the lateral earth pressure coefficient in uplift will large increase when anchor reach the failure condition. Based on investigation of laboratory and field test, Mitsch and Clemence (1985) have suggested the lateral earth pressure coefficient for helical anchor in sand as shown in Figure 10. Their recommended values are lower than the values proposed by Meyerhof and Adams approximately 30% to 40%. Mitsch and Clemence (1985) explained that the reduction of lateral pressure coefficient caused by the different installation method for anchor. Meyerhof theoretical values are based on the essentially undisturbed soil however Mitsch and Clemence (1985) displace the surrounding soil during the installation and create a disturbed zone. The disturbed zone allows a lower uplift capacity to pullout the anchor compared with undisturbed soil condition.

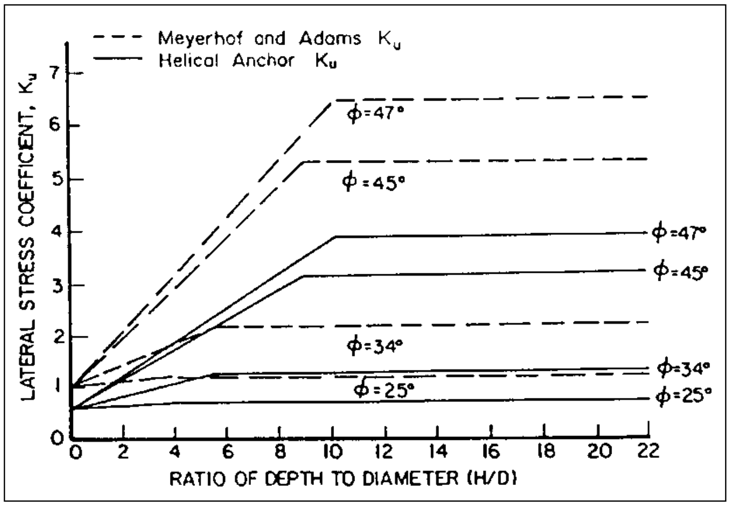

Figure 10: Recommended Lateral Stress Values (Ku) for Helical Anchors (Mitsch and Clemence, 1985)

Anchor Shaft Friction

In the deep anchor, the friction of shaft provides an obvious effect to the uplift capacity, however in shallow anchor; the shaft friction is not providing a significant resistance for the uplift capacity. The friction will develop along the anchor shaft similar to that developed by cylindrical piles. The value of shaft friction is depending upon the shaft diameter. The friction along shaft will increase when the diameter of shaft increase. The computation of shaft friction needs to pay attention when the anchor installed in a layered soil. In a layered soil, the friction angles are varies for each layer of soil, so the developed friction will be different for each layer. In order to find out the total shaft friction value, the friction of each layer must be accumulated.

Ghaly et al. Theory

Ghaly et al. (1991) presented experimental and theoretical investigations on the behavior of single helical anchors in sand. In the experiment investigation, they have conducted a laboratory test consisted five models of anchors installed in loose, medium and dense sand. In the experiment, they have observed the failure mode of anchor and the relationship between the uplift capacities with the relative density of sand, installation depth of anchor and the friction angle of sand.

Mode of Failure

On the same time, a theoretical analysis also has been carry out and a mathematical model developed by using the limit equilibrium method and the failure mode obtained from the experimental tests. In this theoretical analysis, Ghaly et al. (1991) have assume the failure surface of anchor in a truncated cone shape which a plane failure surface inclined at an angle of θ to the vertical plane projected on the outer edge of the screw as shown in Figure 11. Their suggested failure mode is quite similar to the proposal of Meyerhof and Adams. Meyerhof and Adams recommended the angle of θ is varies from $\frac{\phi}{4}$ to $\frac{\phi}{2}$ for circular plate anchor in sand. Based on the present investigation and the observation from the failure surface in experimental work, Ghaly et. al, (1991) have recommended the angle of θ is equal to $\frac{2}{3}\phi$ for shallow anchor.

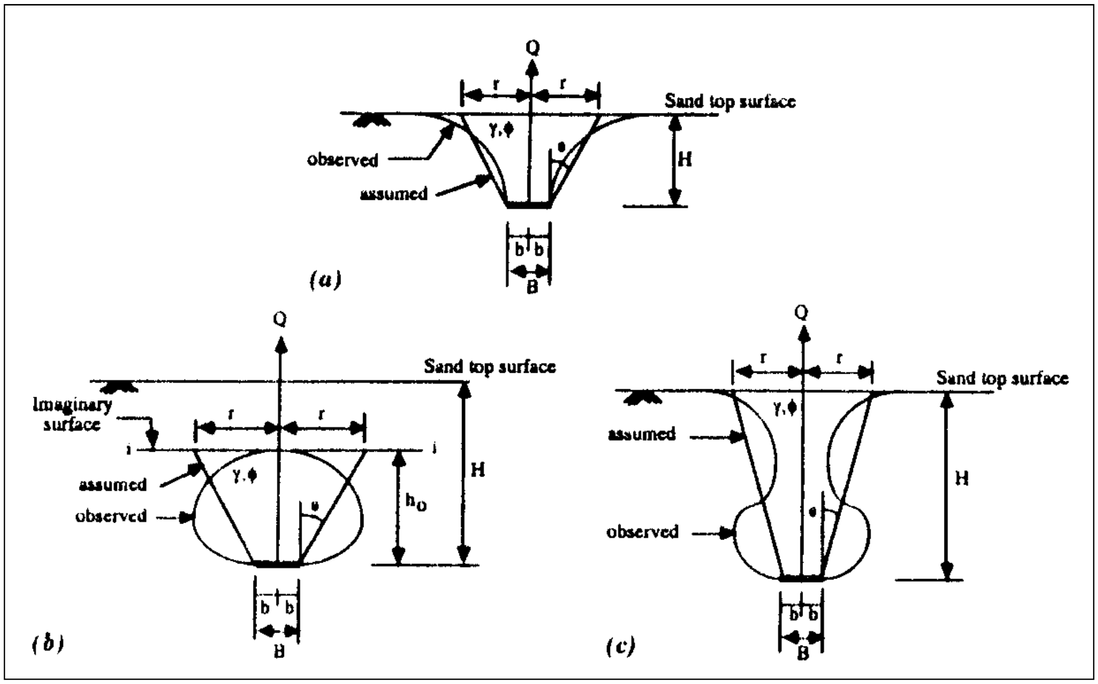

Figure 11: Failure Surface for (a) Shallow Helical Anchor; (b) Transit Helical Anchor (c) Deep Helical Anchor (Ghaly et. al, 1991)

However, for anchor installed in deep depth, Ghaly et al. (1991) assumed that the failure mechanism of anchor is local nature failure mode. Based on the observation of the laboratory tests, the height of the closed bulb for the failure surface, h_o are 4D for loose sand, 5D for medium density sand and 6D for dense sand as shown in Figure 12. Due to the failure surface for deep anchor is similar to the shallow anchor, therefore they proposed that the angle of θ in the case of deep anchor is also equal to $\frac{2}{3}\phi$.

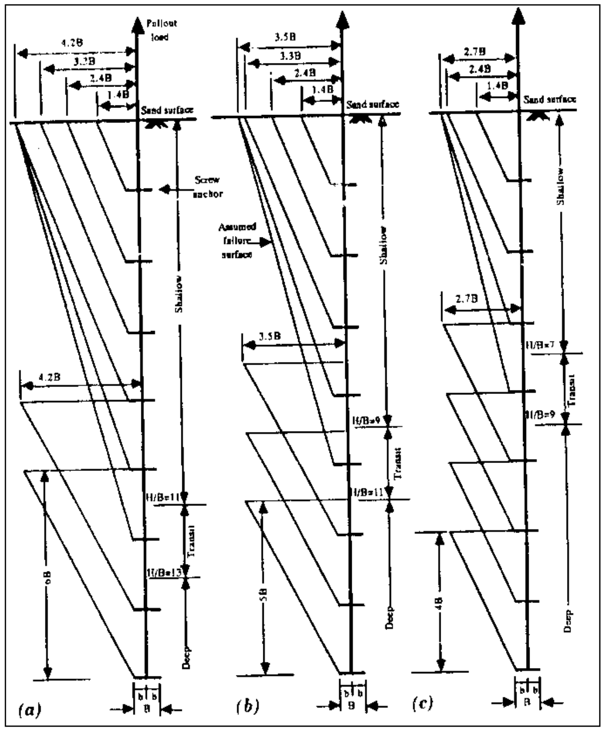

Figure 12: Assumed Failure Surface (a) Dense Sand; (b) Medium Dense Sand (c) Loose Sand (Ghaly et. al, 1991)

In the case of anchors installed in transit zone, Ghaly et al. (1991) proposed the failure surface integrate an inverted truncated cone with walls that inclined at angle of θ to vertical plane. They suggested the values for angle of θ could be determined from the measurement of radius of inverted cone(r) and the embedded depth (H). In the transit case, when the r for failure surface is exceed the r maximum, the r maximum will taken as r and the values for angle θ will be determined by using Equation 3.

$$\theta = \tan^{-1}\left(\frac{r-b}{H}\right) \tag{3}$$

where,

r	= radius of inverted cone
b	= radius of helix
H	= embedded depth
θ	= inclined angle from plane of failure to vertical plane

Based on the result of laboratory test, the values of r and the limit of extension of shallow, transit and deep zones have summarized in Table 2.

Table 2: Geometry Properties of Assumed Failure Surface (Ghaly et. al, 1991)

Sand state (1)	Zone definition (2)	Extension range (3)	Radius of inverted cone base $(r)^a$ (4)	Maximum (r) (5)	h_0 (6)
Dense; $\phi = 40°$; $D_r = 80\%$	Shallow	$<11B$	$r = b + H \tan(2\phi/3)$	$4.2B$	—
Dense; $\phi = 40°$; $D_r = 80\%$	Transit	$11B \rightarrow 13B$	$r = b + H \tan(2\phi/3)$	$4.2B$	—
Dense; $\phi = 40°$; $D_r = 80\%$	Deep	$\geq 13B$	$4.2B$	$4.2B$	$6B$
Medium; $\phi = 35°$; $D_r = 50\%$	Shallow	$<8B$	$r = b + H \tan(2\phi/3)$	$3.5B$	—
Medium; $\phi = 35°$; $D_r = 50\%$	Transit	$8B \rightarrow 10B$	$r = b + H \tan(2\phi/3)$	$3.5B$	—
Medium; $\phi = 35°$; $D_r = 50\%$	Deep	$\geq 10B$	$3.5B$	$3.5B$	$5B$
Loose; $\phi = 30°$; $D_r = 35\%$	Shallow	$<7B$	$r = b + H \tan(2\phi/3)$	$2.7B$	—
Loose; $\phi = 30°$; $D_r = 35\%$	Transit	$7B \rightarrow 9B$	$r = b + H \tan(2\phi/3)$	$2.7B$	—
Loose; $\phi = 30°$; $D_r = 35\%$	Deep	$\geq 9B$	$2.7B$	$2.7B$	$4B$

^{a}If produced $r >$ maximum r, then $r = r_{max}$ and find corresponding θ.

THE DESIGN METHOD

By using limit equilibrium techniques, Ghaly et. al, (1991) presented a theoretical model to estimate the ultimate uplift capacity of single helical anchor in sand. In their theoretical method, they assumed the helical anchor fail in cone shape as shown in Figure 11.

By assuming this failure surface, they suggested that generally the ultimate uplift capacity is equal to the sum of the forces acting along the failure surface against the pullout and the weight of soil within the failure surface. Due to the mode of failure for the shallow and transit anchor with the deep anchor is different, therefore the estimating method for the uplift capacity will not same. In the computation of uplift capacity for shallow and transit anchor, the uplift capacity is the weight of soil within the failure surface plus the friction along the failure surface.

Uplift capacity = (friction along failure surface) +

(weight of soil within the failure surface)

$$Q_u = P_p + W \tag{4}$$

where,

$$P_p = \frac{\pi}{2}\gamma H^2 K_p' \left[\frac{B + H\tan\theta}{\cos\theta}\right]\tan\delta$$

$$W = \frac{\pi}{3}\gamma H\left(b^2 + r^2 + br\right)$$

However in the case of deep anchor, Ghaly et. al, (1991) proposed that the ultimate uplift capacity is equal to the sum of weight of soil within the failure surface, friction along the failure surface and the downward force from the vertical earth pressure.

Uplift capacity = (friction along failure surface) +

(weight of soil within the failure surface)+

(vertical load due to the vertical earth pressure)

$$Q_u = P_p + W + N \tag{5}$$

where,

$$P_p = \frac{\pi}{2}\gamma K'_p h_0 (2H - h_0)\left[\frac{B + h_0 \tan\theta}{\cos\theta}\right]\tan\delta$$

$$W = \frac{\pi}{3}\gamma h_0 \left(b^2 + r^2 + br\right)$$

$$N = \gamma \pi r^2 (H - h_0)$$

in which,

Q_u	= ultimate uplift capacity
P_p	= vertical component of the total passive earth pressure
W	= weight of sand wedge within the failure surface
N	= downward force due to vertical earth pressure
ϕ	= friction angle of sand
δ	= average modified angle of shearing resistance on the assumed failure plane
θ	= surface inclination angle of inverted failure cone with respected to vertical plane
B	= Diameter of helix
b	= radius of helix
h_0	= height of the assumed inverted zone

From observation toward both equations for estimating the uplift capacity for shallow, transit and deep anchor, the vertical component of passive earth pressure (P_p) provide significant uplift resistance to the total uplift capacity (Q_u). From the equation above, it can be observe that modified coefficient of passive earth pressure (K'_p) and the average mobilized angle of shearing resistance (δ) are the major variables in the calculation of the vertical component of passive earth pressure (P_p). Based on the experiment result and the theoretical model, Ghaly et al, (1991) have done evaluation toward K'_p as well as δ and assume the ratio of $\frac{\delta}{\phi}$ as a value of the modified coefficient of passive earth pressure (K'_p). After analysis of the experimental results and theoretical models, they concluded that the values of angle δ is varies from zero to the maximum values, $\delta = \phi$, in increments of 5%. After calculation, they suggested a relationship between the values K'_p and the relative depth ratio as well as the relative density of sand as shown in Figure 13.

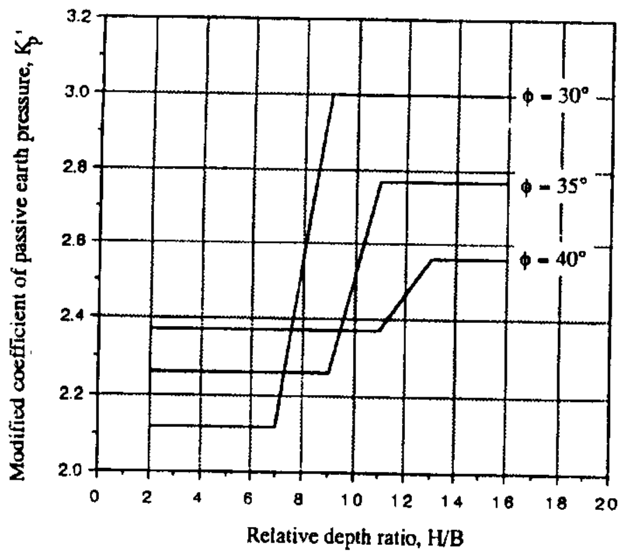

Figure 13: Relationship of Modified Coefficient of Passive Earth Pressure and Relative Depth Ratio (Ghaly et. al, 1991)

CONCLUSION

In process of formulating a satisfactory theory for estimating the uplift capacity of helical anchor, there are several difficulties and variables need to be decided. In order to reduce the complexity in the theoretical analysis, a number of researchers have done some simplifying assumption in their theoretical models.

Researcher such as Mitsch and Clemence (1985) assumed that the mode of failure for the helical anchor in sand is a truncated cone failure surface. They assumed the failure surface for shallow anchor is extending to the surface of soil but for the deep anchor, the local failure mode will occur when anchor fail. They recommended plane failure surface inclined at an angle approximately $\frac{\phi}{2}$ degree to the vertical axis. They proposed that when the ratio of anchor depth to diameter of helix (H/B) is not greater than 5, the anchor will behaves as shallow anchor. However, when H/B ratio greater than 5, the anchor will behave as deep anchor. They assumed that there are not anchor embedded in transit zone and the mode of failure will change from shallow to deep depth immediately.

Ghaly et al, (1991) noted that the cone shape failure surface which proposed by the Mitsch and Clemence (1985) is used in their theoretical solution. In their solution, they assumed that the sand is homogeneous, isotropic and behaves in a nonlinear stress-strain relationship. In their theoretical model, the shaft and the helixes do not provide any uplift resistance to the ultimate uplift capacity. They assumed that the helical anchor is full contact with the surrounding sand medium and the disk of the helical anchor is thin and rigid so that its deformation ignored. They also suggested that the weight of helical anchor is negligible as compared with the ultimate uplift capacity. According to discussion on current research, It has reach the helical system is a good system for compression and tension structures.

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