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UPLIFT CAPACITY OF A GROUP OF HELICAL SCREW ANCHORS IN SAND" REVIEW

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ABSTRACT

Helical Anchor piles are a steel screw-in piling and ground anchoring system used for building deep foundations. Helical steel plates are welded to the pile shaft in accordance with the intended ground conditions. Helices can be press-formed to a specified pitch or simply consist of flat plates welded at a specified pitch to the pile's shaft. The number of helices, their diameters and position on the pile shaft as well as steel plate thickness determine the total capacity of the Helical Anchor.

This paper will give a brief review of the installation- the effect of depth, the friction angle and the type of failure mechanism for helical anchors.

***Keywords*: Helical Anchors, Failure Mechanism, Friction angle, L/D ratio.**

I. INTRODUCTION

Helical Anchor piles or Screw Piles are a steel screw-in piling and ground anchoring system used for building deep foundations. Screw piles are manufactured using varying sizes of tubular hollow sections for the pile or anchors shaft.

The pile shaft transfers a structure's load into the pile. Helical steel plates are welded to the pile shaft in accordance with the intended ground conditions. Helices can be press-formed to a specified pitch or simply consist of flat plates welded at a specified pitch to the pile's shaft. The number of helices, their diameters and position on the pile shaft as well as steel plate thickness are all determined by a combination of:

1. The combined structure design load requirement
2. The geotechnical parameters
3. Environmental corrosion parameters
4. The minimum design life of the structure being supported or restrained.

Screw pile steel shaft sections are subjected to design parameters and building codes standards for the region of manufacture. Screw piles were first described by the Irish civil engineer **Alexander Mitchell** in a paper in *Civil Engineer's and Architects Journal* in 1848 - however, helical piles had been used for almost a decade by this point. Screw foundations first appeared in the 1800s as pile foundations for lighthouses, and were extensively used for piers in harbours. Made originally from cast or wrought iron, they had limited bearing and tension capacities. Modern screw pile load capacities are in excess of 2000 kN, (approx. 200 tonne). Large load capacity screw piles may have various componentry such as flat half helices, Bisalloy cutting tips and helices, cap plates or re-bar interfaces for connection to various concrete or steel structures.

Figure1. Helical Screw Anchors

More recently, composite technology has been developed and patented for use in small screw piles. Composites offer significant advantages over steel in small screw pile manufacture and installed performance.

Screw pile design is based on standard structural and geotechnical principles. Screw pile designers typically use their own design software which has been developed through field testing of differing compression pile and tension anchor configurations in various soil profiles. Corrosion is addressed based on extended field trials, combined with worldwide databases on steel in ground corrosion.

II. LITERATURE REVIEW

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 semi empirical 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 self-weight 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.

2.1 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.

A) 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 $\theta = 2\varphi/3$ as shown in Figure2. 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.

They also reported that the angle of inclination of the failure cone θ with respect to the vertical axis does not exceed $2\varphi/3$ 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 $\varphi/2$. In their test, the truncated cone failure surface was just occurring at the upper helix and the lower helix will fail in another method.

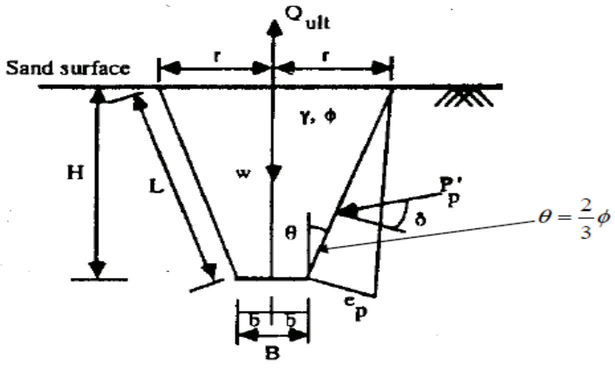

Figure 2: Cone Shaped Failure Surface

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B) 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.

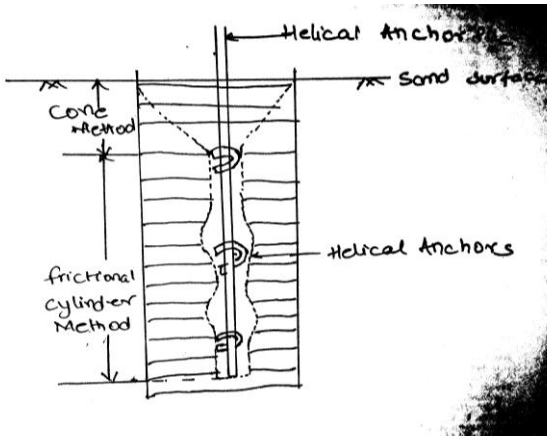

Figure 3: Friction Cylinder Method

C) 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.

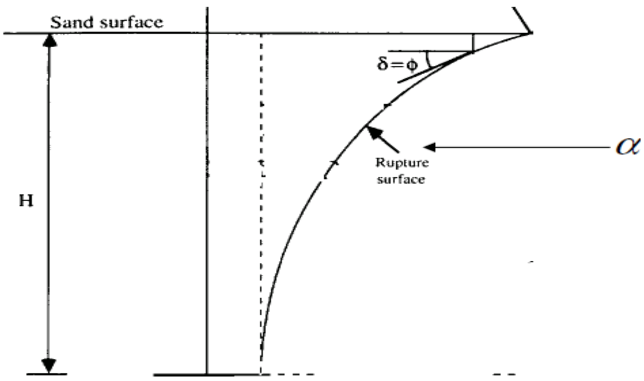

Figure 4: Ghaly Et Al. Curved Spiral Failure Plane.

2.2 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

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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.

2.2.1 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/Dh) is the ratio that the depth of anchor (H) divided by the diameter of anchor's helix (Dh).

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.

2.2.2 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. 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.

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