PULLOUT CAPACITY OF VERTICAL GROUND ANCHOR IN HOMOGENEOUS SAND

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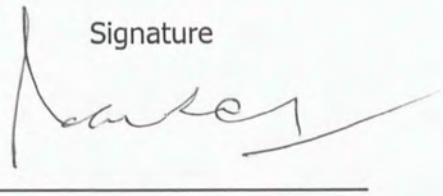

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ABSTRACT

PULLOUT CAPACITY OF VERTICAL GROUND ANCHOR IN HOMOGENEOUS SAND

Vertical ground anchors are commonly used in foundation systems for structures requiring pullout resistance such as transmission towers, structures requiring lateral resistance, such as sheet pile walls. The work described in this research was primarily concerned with the pullout capacity of a vertical ground anchor embedded in dry homogeneous sand. One-laboratory model of anchor test apparatus is fabricated, with dry sand as a medium in sand box to form the homogeneous sand bed. Three models of circular anchors namely 25, 50 and 75 mm diameter and three states of homogeneous sand bed with different unit weights i.e., 15.89, 16.29 and 17.13 kN/m^3, where the relative densities are 29%, 37% and 53% respectively were used in this research. The range of depth/ diameter (D/B) ratios are from 1 to 24 in order to cover shallow and deep anchors with the anchors being subjected to vertical loads under displacement control. A delineation technique is used to define the general failure surface of anchor in the soil mass during pullout. From the test, results show that the behavior and general failure surface of vertical ground anchor in dry homogeneous sand are similar to those reported by previous studies. The predicted formulae of pullout capacity for shallow and deep anchors in dry homogeneous sand are developed using semi-empirical method i.e., prediction of failure surface from pullout test and analytical method. From the comparison, results show that the predicted formula in similar trend with previous studies and experimental test. Overall, the study provides insights about pullout capacity of vertical ground anchor in homogeneous sand. At end of the research finding, suggestions are given for the further works in future.

Keywords: Vertical Pullout capacity, Vertical Ground Anchor, Homogeneous sand, Failure surface

ABSTRAK

Penambat bumi tegak kebiasaannya digunakan sebagai sistem asas untuk struktur yang memerlukan rintangan tarik-keluar seperti menara penghantaran, struktur yang memerlukan rintangan sisi seperti tembok cerucuk keping. Kerja yang diterangkan dalam kajian ini menitikberatkan terutamanya berkenaan keupayaan tarik-keluar penambat bumi tegak yang terbenam di dalam pasir homogen. Satu model makmal ujian penambat bumi dibuat, dengan pasir kering digunakan sebagai bahantara dalam kotak pasir untuk membentuk lapisan pasir homogen. Tiga model penambat berbentuk bulat digunakan adalah bersaiz 25, 50 dan 75 mm diameter. Tiga keadaan pasir homogen dengan berat unit berbeza seperti 15.89, 16.29 dan 17.13 kN/m^3, dimana ketumpatan nisbi masing-masing adalah 29%, 37% dan 53% digunakan dalam kajian ini. Julat kedalaman/diameter (D/B) dengan nisbah dari 1 sehingga 24 adalah untuk meliputi penambat cetek dan dalam dengan setiap penambat dikenakan beban tegak dibawah kawalan anjakan. Kaedah penyahlelurusan digunakan untuk mengenal pasti bentuk kegagalan permukaan dalam jisim tanah semasa tarik-keluar. Daripada ujian, keputusan menunjukkan tingkah laku dan kegagalan am permukaan penambat bumi tegak dalam pasir kering homogen adalah sama sebagaimana yang dilaporkan oleh kajian terdahulu. Formula pernyataan keupayaan tarik-keluar untuk penambat cetek dan dalam bagi pasir kering homogen dibentuk dengan menggunakan kaedah semi-empirical iaitu ramalan dari kaedah kegagalan permukaan daripada ujian keupayaan tarik-keluar serta kaedah matematik. Daripada perbandingan, keputusan menunjukkan bahawa formula pernyataan keupayaan tarik-keluar adalah selari dengan kajian terdahulu dan ujian makmal . Secara keseluruhannya, kajian ini memberi kefahaman tentang keupayaan tarik-keluar penambat bumi tegak di dalam pasir homogen. Di akhir penemuan kajian, saranan diberi untuk kerja-kerja selanjutnya untuk masa hadapan.

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LIST OF SYMBOLS

B	Size or Diameter of Anchor, mm
D	Depth of Embedment of Shallow Anchor, mm
H	Depth of Embedment of Deep Anchor, mm
D/B	Depth to Diameter ratio
k	Coefficient of Lateral Earth Pressure
γ	Unit Weight of Sand, mm
η	Porosity of Sand
ϕ	Angle of Internal Friction
α	Apex Angle from the Vertical through the Anchor Edge
P	Pullout Load on Vertical Anchor, kN
P_u	Pullout Capacity of Anchor, kN/m^2
D_r	Relative Density of Sand
e_{max}	Maximum Void Ratio of Sand
e_{min}	Minimum Void Ratio of Sand
δ	Displacement of Vertical Anchor, mm
$\bar{c}$	$D_r \cos \phi$
k_o	$1 - \sin\phi$
M	$1.2[D_r (1 + \cos^2\phi) + (1 + \sin^2\phi)]$
A_s	PL
P	perimeter of pile cross section
L	length of pile embedment
$\bar{A}$	$\frac{\pi}{8}.\gamma.B^2.a$
$\bar{B}$	$\pi.B\,k_1.(\frac{B}{2a})^{k2}.\frac{a^2}{(k_2+1)^2}.\gamma.\sin\varphi$

$\bar{C}$ $\frac{1}{8}\pi.k_1.(\frac{B}{2a})^{k_2}.\frac{B^3}{(k_2+3)^2}.\gamma.\sin\varphi$

$\bar{D}$ $\frac{1}{8}\pi.k_1.(\frac{B}{2a})^{k_2}.\frac{B^3}{a^2}.\gamma.\sin\varphi.(\frac{a^2}{(k_2+1)^2}+\frac{a}{(k_2+3)}.H)$

$-\pi.B.k_1.(\frac{B}{2a})^{k_2}.\gamma.\sin\varphi.(\frac{a^2}{(k_2+1)^2}+\frac{a}{(k_2+1)}.H)$

k_1 $\frac{1}{2}B.k_1(\frac{B}{2a})^{k_2}.\gamma.\sin\varphi$

k_2 $\frac{1}{16}.\frac{B^3}{a^2}.k_1(\frac{B}{2a})^{k_2}.\gamma.\sin\varphi$

a Constant parameter

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CHAPTER 1

INTRODUCTION

1.1 Background

The drastic development in construction industry especially in our country has imposed our engineers to design a safe, economic and attractive structure. In civil engineering works, sometimes the structures have requirements to resist tensile forces acting on foundations embedded in the ground by use of tension members. These members are referred to as ground anchors which the direction can be vertical, horizontal or inclined. This study interested on vertical ground anchor which use as foundation structure on transmission tower, retaining wall and suspension bridge. The transmission tower (Figure 1.1) is built to withstand the load of electric cables. Apart from its own load and electric cable, it also faces the lateral wind load. Thus, the assessment of transmission tower foundation under tension is similar to the assessment of pullout capacity of vertical ground anchors. The suspension bridge (Figure 1.2) is widely used to connect one place to another place which is separated by river or lake or sea, where by it will bear the heavy burden of its own weight and live load to pass through. When the load is on it, the suspension bridge foundation will have a direct tensile load. Thus, the assessment of suspension bridge foundation is also similar to the assessment of pullout capacity of vertical ground anchors. According to Hanna, Sparks and Yilmaz (1972), anchors may be used singly or in groups depending on the magnitude of the applied load, the ground conditions present and details of the structure. The size of an anchor varies widely and anchors of a few to several hundred tons working capacities are in use.

Today, so many types of anchors are produced in a large scale to meet the large demand. However, there is still structural foundation failure which is caused by excessive tensile load, for example when the suspension bridge collapses at Kuala Dipang, Perak (Figure 1.3) which involves three fatalities. The investigation committee found out that the concrete block connection in pylon A could not

handle the pullout force from the back-stayed cable (Humayun Kabir, 2009). It was shown that the pullout capacity of the concrete block which functions as anchor in suspension bridge was not calculated properly during designing process. It is our responsibility to find out the solutions so that the incidents would not happen again.

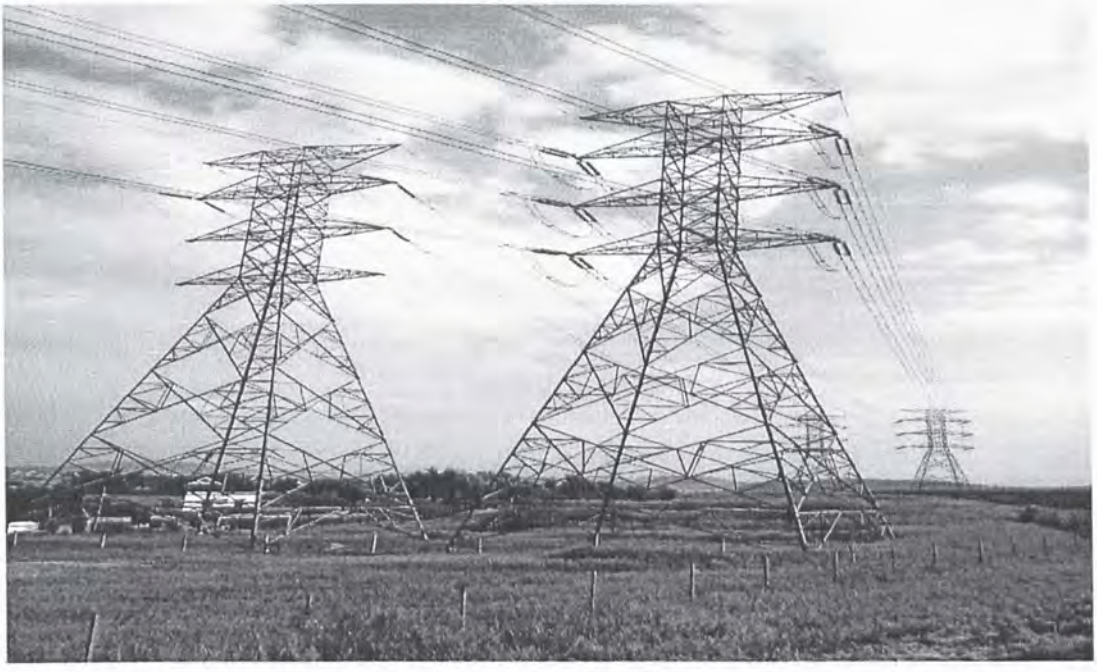

Figure 1.1: Transmission Tower

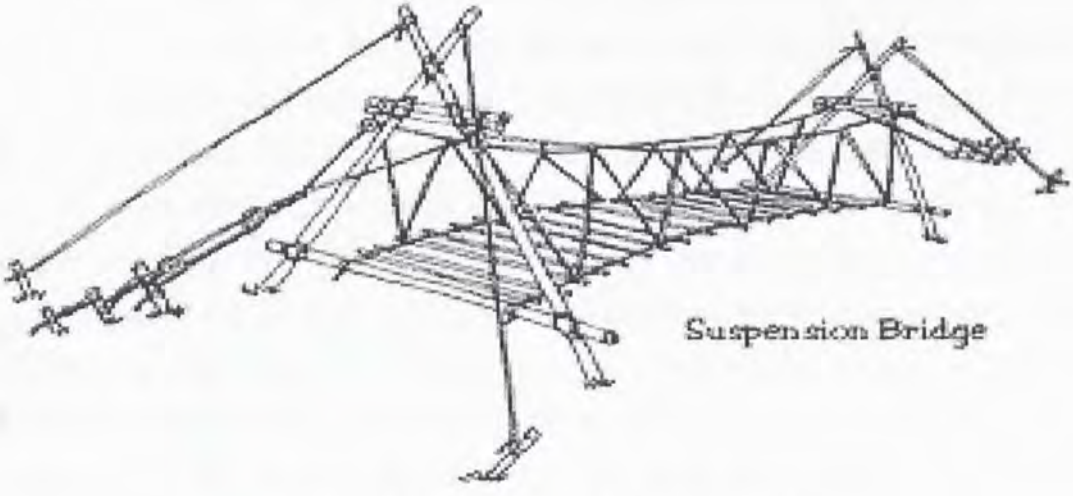

Figure 1.2: Suspension Bridge Model

Figure 1.3: Suspension Bridge Collapse at Kuala Dipang, Perak (26/10/2009)
Source: http://www.malaysiakini.com

Several methods are available in the literature in order to calculate the pullout capacity of anchors. Basically, the methods are divided by two (2) type's i.e. experimental test and empirical method. According to Niroumand and Kassim (2010), experimental test can provide a better understanding and predicting the ultimate pullout capacity of the anchors in a range of soil types, but current researches on pullout capacity are focused on empirical method. The advancement in finite element method, the option of simulating varies type of anchor foundation and the attractive cost associated with it has resulted in research focusing on using empirical method. However, because of the complexity of soil stratigraphy and the inability of current soil mechanics theories to fully describe the actual field performance of a soil, some previous researches used a semi-empirical method in order to study the behavior of ground anchor embedded in sand. Semi-empirical method is a combination method between experimental test and analytical method. In this research, the semi-empirical method used to find the appropriate pullout expression for the vertical ground anchor in dry homogeneous sand.

1.2 Problem Statement

According to Fadl (1981), "None of the theories gave a comprehensive solution to the behaviors of anchors at failure for a wide range of soil types and conditions". Many researchers have worked on this topic in other countries but the physical properties of sand and experimental method used are different. As such no single theory is fit to study the behaviors of vertical ground anchor. This is because of many variables involved and also depends on the method used e.g., preparation of homogeneous sand bed and Anchor test model. This research try to find out the comprehensive solution to the behaviors of vertical ground anchor embedded in dry homogeneous sand using semi-empirical method. Based on that, this research was aimed to study the pullout capacity of vertical ground anchor in specifically prepared dry homogeneous sand and compare with finding of previous work. Experimental work and analysis were conducted and described in this thesis.

1.3 Objectives of Research

The research aims to study the pullout capacity of vertical ground anchor embedded in dry homogeneous sand using semi-empirical method. Specifically designed experimental model and prepared homogeneous sand were used in conducting pullout test for vertical ground anchor. Some of objectives are set in order to achieve the aim of this research. They are:

1. To develop a physical experimental method in order to study the behavior of vertical ground anchor in dry homogeneous sand bed.
2. To determine the pullout capacity of vertical ground anchor in dry homogeneous sand at different relative densities.
3. To define the general failure surface of circular vertical anchor in dry homogeneous sand bed.
4. To suggest an appropriate pullout expression for the vertical ground anchor in dry homogeneous sand.

1.4 Scope of Work

To achieve the objectives of this research, one experimental model anchor test was designed and fabricated for dry homogeneous sand bed. The experimental test using in this study because of the following:

1. Using dry homogeneous sand as an embedment medium.
2. To create physical experimental model that could be applied to represent the behavior of circular vertical ground anchor. This model could be used for further research on foundation in tension.
3. Researchers are currently focused on empirical method only. Experimental testing needed to be improved by incorporating better technique so that advancement can be made in the area. Combination methods between experimental test and empirical method will give more comprehensive to study the behavior of anchor in homogeneous sand.

A Pluviation technique used to fill the dry homogeneous sand in box. Two methods were used to calibrate the sand spreader in order to make sure the sand bed is perfectly homogeneous. Three sizes of diameter circular anchor that are 25 mm, 50 mm and 75 mm were used in this test. The tests done were in medium sand at three values of relative density i.e. 29%, 37% and 53%, given as three rates of deposition namely low, medium and high which produced loose, medium dense and dense beds in the context of the research. The test covered a range of depth/ diameter (D/B) ratios from 1 up to 24 to cover shallow and deep anchor, with the anchors being subjected to vertical loads under displacement control. To identify the failure surface, half-cut of 50 mm diameter model circular anchor was used with change color to color of soil for delineating the mode of failure in the soil mass during pullout. The predicted formula of pullout capacity in shallow and deep anchor was predicted using semi-empirical method i.e., combination method between physical experimental test and analytical method. The comparison applied against predicted formula, experimental test and previous studies in order to validate the predicted formula obtain is a proper formula for pullout capacity of vertical ground anchor in dry homogeneous sand.

1.5 Result Expectations

From this research, the result expectations will be:

1. Development of a laboratory experimental model for pullout testing of vertical ground anchor.

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