

**PULLOUT CAPACITY OF VERTICAL GROUND  
ANCHOR IN HOMOGENEOUS SAND**



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**SCHOOL OF ENGINEERING AND INFORMATION  
TECHNOLOGY  
UNIVERSITI MALAYSIA SABAH  
2011**

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**MOHD RAFE BIN ABDUL MAJID**



**UNIVERSITI MALAYSIA SABAH**  
**THIS THESIS SUBMITTED IN FULFILLMENT FOR THE  
DEGREE OF MASTER OF SCIENCE**

**SCHOOL OF ENGINEERING AND INFORMATION  
TECHNOLOGY  
UNIVERSITI MALAYSIA SABAH  
2011**

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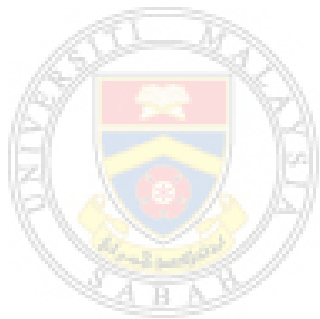
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## LIST OF SYMBOLS

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
$\gamma$	Unit Weight of Sand, mm
$\eta$	Porosity of Sand
$\phi$	Angle of Internal Friction
$\alpha$	Apex Angle from the Vertical through the Anchor Edge
$P$	Pullout Load on Vertical Anchor, kN
$P_u$	Pullout Capacity of Anchor, kN/m <sup>2</sup>
$D_r$	Relative Density of Sand
$e_{max}$	Maximum Void Ratio of Sand
$e_{min}$	Minimum Void Ratio of Sand
$\delta$	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
$\bar{A}$	$\frac{\pi}{8} \cdot \gamma \cdot B^2 \cdot a$
$\bar{B}$	$\pi \cdot B \cdot k_1 \cdot \left(\frac{B}{2a}\right)^{k_2} \cdot \frac{a^2}{(k_2 + 1)^2} \cdot \gamma \cdot \sin \phi$

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

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

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

$$k_1 \quad \frac{1}{2} B \cdot k_1 \cdot \left(\frac{B}{2a}\right)^{k_2} \cdot \gamma \cdot \sin \varphi$$

$$k_2 \quad \frac{1}{16} \cdot \frac{B^3}{a^2} \cdot k_1 \cdot \left(\frac{B}{2a}\right)^{k_2} \cdot \gamma \cdot \sin \varphi$$

a Constant parameter



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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<sup>3</sup>, 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*