ESTIMATION OF BEARING CAPACITY OF DRIVEN PILES USING NUMERICAL MODELING

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(198330H)

Degree of Master of Science in Geotechnical Engineering

Department of Civil Engineering

University of Moratuwa

Sri Lanka

March 2024

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DECLARATION

"I declare that this is my own work and this thesis does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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Prof. N. H. Priyankara,

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ABSTRACT

Pilling is a blend of art and science. While choosing a suitable pile type and the installation method lie in the artistic aspect, scientific dimensions allow engineers to study the behavior of installed elements under different types of loading.

The nature of the interaction between a pile and the soil it contacts is significantly influenced by the method of installation used. This interaction cannot be accurately predicted based solely on the physical properties of the materials involved. Different methods are used to determine the bearing capacity of piles, including static equations, dynamic equations, empirical methods, numerical methods, computer software programs, and pile static load tests. However, it is important to note that each of these approaches may yield different values for the bearing capacity of piles, and rarely do any two methods produce identical computed capacities.

According to Randolph M. F. (1992), achieving precise estimates of axial pile capacity in various soil types is a challenge and often results in a margin of error of approximately ±30%

During the last few decades, there has been swift and substantial progress in the analytical methods employed in pile design. This advancement not only validated traditional empirical approaches but also led to their replacement with more robust theoretical foundations.

In intricate geotechnical projects, when dealing with complex load combinations or substantial interaction with adjacent structures, engineers often turn to the Finite Element Method (FEM) for analysis. However, an exception to this trend is observed in the design of driven piles or soil-displacement piles, where a different approach is typically employed to determine factors such as pile capacity and performance.

In the modeling of displacement piles, it is essential to compile the installation effects resulting from different installing techniques with the most applicable constitutive model to obtain an accurate result by simulating real soil behavior. With the evolution of computational power, different numerical techniques can be employed successfully in standard FE analysis using soil parameters obtained from cost-effective site investigations to lead to a more realistic load-settlement response for driven piles or soil-displacement piles.

Key words: *Empirical methods; Finite Element Method; Installation effects; Displacement piles*

ACKNOWLEDGEMENT

First, I would like to express my deepest gratitude to the principal supervisor of my research, Prof. N. H. Priyankara, Professor of the Department of Civil and Environmental Engineering, Faculty of Engineering, University of Ruhuna for his enormous support, valuable suggestions, diligent efforts and strong encouragement given to me throughout the thesis work. His deep insight and vast experience in the field of Geotechnical Engineering, contributed greatly to the success of this work.

Further, I extend my sincerest gratitude to Prof. L.I.N. de Silva, Professor of the Department of Civil Engineering, Faculty of Engineering, University of Moratuwa for his pivotal role as the core supervisor and the course coordinators of the MSc program.

Furthermore, I would like to express my sincere thanks to Dr. (Mrs.) Ashani Ranathunga, former lecturer of the Department of Civil Engineering, Faculty of Engineering, University of Moratuwa for her encouragement of the Master of Engineering Degree program.

Finally, I would like to express my sincere thanks and appreciation to all the lecturers who delivered their valuable knowledge throughout the degree program, and I wish to thank my family members for their support and encouragement throughout this period.

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NOTATIONS

All symbols and abbreviations used in this thesis are provided and defined directly in text, figures or they are enclosed to the equations. Here, the full notation is additionally submitted.

Symbols

Latin Letters

c	-	Cohesion
c_a	-	Undrained pile-soil adhesion
c_u, s_u	-	Characteristic undisturbed undrained shear strength
$\overline{c_u}$	-	Peak undrained cohesion
d	-	Diameter
d_i	-	Depth factors
e	-	Void ratio
f_R	-	Friction ratio
f_{avg}	-	Average unit skin frictional resistance
f_u	-	Unit ultimate skin friction
l or h	-	Length
m	-	Gradient
p^{ref}	-	Reference stress level
p'_o	-	Effective overburden pressure
q_b	-	Unit base resistance
q_c	-	Point resistance
q_l	-	Limiting resistance
q_u	-	Undrained compressive strength
q_{ult}	-	Ultimate bearing pressure
q_s	-	Sleeve resistance

r or r_o - radius

s_i - Shape factors

w_L - Plastic limit

z - Depth

A_b - Area of pile base

B - Breadth of the foundation

C - Perimeter/ Constant for chapter 2.9.3.3

C_1, C_2 - Constants for chapter 2.12.2.2

C_c - Compression index

C_N - Adjustment factor for effective overburden pressure

C_s - Swelling index

D - Depth of the foundation

D_r or RD - Relative density

E_a - Actual hammer Energy

E_{in} - Input Energy

E_r - Energy Ratio

E_{rb} - Standard Energy Ratio

E_{oed}^{ref} - Reference oedometer stiffness

E_{50}^{ref} - Triaxial stiffness at 50% strength

E_0 - Initial stiffness

F - Length factor

G' - Shear modulus

I_p, PI - Plasticity Index

I_r - Rigidity index

I_{rr} - Reduced rigidity index

I_p - Plasticity index

K_s - Coefficient of lateral earth pressure

K_o - Coefficient of lateral earth pressure at rest

L - Length

N - SPT blow count

N_i - Bearing capacity factor

P_a - Atmospheric pressure

P° - Limiting effective stress at the base level of the pile

Q - Total load

Q_b - Base resistance

Q_s - Shaft resistance

Q_u - Total ultimate load

Q_{su} - Ultimate shaft resistance

Q_{bu} - Ultimate base resistance

S - Settlement

W - Weight of the pile

Z_c - Critical Depth

Greek Letters

α - Adhesion factor

β - Coefficient in chapter 2.9.3.4

γ - Unit Weight

δ - Angle of friction between pile and soil

ηi - SPT adjustment factors

κ^* - Parameter for Chapter 3.13.3.6

λ - Dimensionless coefficient in chapter 2.9.3.2

λ^* - Parameter for Chapter 3.13.3.6

$\overline{\sigma'_o}$ - Mean effective vertical stress

σ_v - Vertical stress

σ'_v - Effective vertical stress

σ_{vb} - Vertical stress of the soil at level of pile base

σ'_{vb} - Limiting effective vertical stress of the soil at level of pile base

$\bar{\sigma}'_0$ - Average effective vertical stress

τ - Shear strength

$\bar{\tau}_s$ - Unit shaft resistance

Ø - Angle of Internal Friction

$Ø_u$ - Friction angle at undrained condition

$Ø'_1$ - Original drained value of angle of friction

$Ø'_2$ or $Ø'_R$ - Remolded drained value of angle of friction

ψ - Dilatancy angle

ϵ_v - Volumetric strain

Abbreviations

ASTM - American Society for Testing and Materials

API - American Petroleum Institute

BH - Bore hole

CAPWAP - Case Pile Wave Analysis Program

CD - Consolidated Drained

CPT - Cone Penetration Test

CU - Consolidated Undrained

EPRI - Electric Power Research Institute

Eq. - Equation

FEM - Finite Element Method

Fig. - Figure

HS - Hardening Soil

ICTAD - Institute for Construction Training and Development

LE - Linear Elastic

MC - Mohr- Coulomb

MLT - Maintained Load Test

NC - Normally Consolidated

NGI - Norwegian Geotechnical Institute

OC - Over Consolidated

PDA - Pile Dynamic Analysis

PDI - Pile Dynamic Integrity

PI - Plasticity Index

SPT - Standard Penetration Test

FEM - Finite Element Method