AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
STRUCTURAL ENGINEERING DEPARTMENT

REINFORCING OF SOFT COHESIVE SOILS WITH STONE PILES

By

IBRAHIM EZZAT AZIZ

A THESIS

Submitted In Partial Fulfillment For Requirements
Of The Degree Of Master Of Science In Civil Engineering
(Structural Department)

Supervised By

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CAIRO – 1991

بسم الله الرحمن الرحيم

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STATEMENT

This dissertation is submitted to Ain-Shams University for the degree of Master of Science in Civil Engineering.

The work included in this thesis was carried out by the author in the Department of Structural Engineering, Ain-Shams University, from September 1986 to December 1990.

No part of this thesis has been submitted for a degree or a qualification at any other University or Institute.

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AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING

Department of : Civil Engineering
(Structural Section)

Abstract of M.Sc. Thesis Submitted By :

Ibrahim Ezzat Aziz

Title of Thesis :

"REINFORCING OF SOFT COHESIVE SOILS WITH STONE PILES"

Supervisors: (1) Prof. Dr. Farouk Ibrahim El-Kadi
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Rigistration Date : 13/10/1986 Examination Date :

ABSTRACT

Along the Egyptian Mediterranean Coast, deep soft clay deposits have been formed over the years as a result of the Nile sedimentations. Nowadays, with the continuous growth in the construction industry in this region, effective methods for soil reinforcement have to be developed, in order to improve its mechanical properties. One of the most effective, simple, and well known techniques is the use of partially concreted granular piles to stabilize soft clay. However, using this technique, the behaviour of single and group piles under applied loads have been based on empirical and semi-empirical relations.

In this thesis, two numerical models based on the FINITE ELEMENT METHOD are prepared. The first model, represents a single pile penetrating a soft cohesive soil. The Second model represents a group of piles supporting a rigid circular footing.
The two models account for the following variables:
(a) Pile Length, Diameter, and Length of Concrete Part.
(b) The Clay Layer is infinite, or has a limited depth and underlaid by a relatively hard layer.
(c) Nonlinear stress-strain relationship of soil.
(d) Pile-soil interfacial chacteristics in case of single pile.

Results of the analysis are presented in a series of charts showing the effect of the above variables on :
(a) Load-settlement behaviour of a single pile.
(b) Shape of settlement diagram of ground surface.
(c) Settlement ratio in case of piles group.
(d) Vertical stress distribution along the center line of a single pile, and along an central pile in a group.

KEYWORDS :*Soft Clay, Reinforcement, Granular Piles, Single Pile, Piles Group, Nonlinear Stress-Strain Behaviour, Interface Nature, Finite Element Method, Settlement Ratio, Concrete Part Length, Pile Diameter, Pile Length.*

ACKNOWLEDGMENTS

I am greatly indebted to Prof. Dr. Farouk I. El-Kadi, Professor of Geotechnical Engineering, Ain-Shams University, for his direct supervision, generous assistance, continuous support, and useful advice and discussions during the course of this study.

I wish to express special thanks to Dr. Ezzat Abd El-Fattah, and Dr. Mona Eid for their helpful suggestions, constructive criticism during the course of this study, and kind encouragement during the writing of this thesis.

Deep appreciation is extended to my parents and my wife for their assistance, understanding, and continuous encouragement throughout this study.

Finally, thanks are also to the Technicians in the Soil Mechanics Labratory, and Colleges especially Ihab Emile, and Khaled Ali for their continuous assistanse.

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NOTATION

The following notations are those generally used in the present work. Other notations required for the purpose of analysis are mentioned in their appropriate places.

Symbol		Represents
a, b	:	Empirical Coeficients whose values are determined experemintally from Direct Shear Test.
a_s	:	Replacement Ratio.
β	:	Settlement Ratio.
C	:	Cohesion of Soil.
c_c	:	Compression Index.
c_v	:	Coefficient of Consolidation.
D	:	Diameter.
[D]	:	Elasticity Matrix.
E	:	Modulus of Elasticity.
G	:	Shear Modulus.
H	:	Length, or Depth.
K_s	:	Interface Shear Stiffness Modulus.
K_n	:	Interface Normal Stiffness Modulus.
[N]	:	Shape Function.

n	: Stress Concentration Ratio.
P	: Applied Load.
p, q	: Applied Stress.
r_i	: Radial Co-ordinate of point (i).
$\bar{r}$	: Radial Co-ordinate of element centroid.
u_o	: Pore Water Pressure.
u_i	: Displacement at nodal (i) in r direction.
v_i	: Displacement at nodal (i) in z direction.
w^s_{top}	: Relative Displacement along the top of interface element.
w^s_{bottom}	: Relative Displacement along the bottom of interface element.
w^n_{top}	: Relative Displacement normal to the top of interface element.
w^n_{bottom}	: Relative Displacement normal to the bottom of interface element.
z_i	: Axial Co-ordinate of point (i).
$\bar{z}$	: Axial Co-ordinate of element centroid.
δ_i	: Displacement at point (i).
σ_z , σ_r, σ_θ	: Vertical, Radial, and Tangential stresses respectively.

τ_{rz} : Shear Stress.

$\varepsilon_z, \varepsilon_r, \varepsilon_\theta$: Vertical, radial, and Tangential Strains respectively.

γ_{rz} : Shear Strain.

μ or ν : Poisson's ratio.

Δ : Area of Triangle Element.

Δ_s : Average Relative Shear Displacement across interface element.

Δ_n : Average Relative Normal Displacement across interface element.

α, K : Two Coefficients describe the ground Settlement around a loaded single pile.

ϕ : Angle of Friction of Soil.

γ : Density of Soil.

SUFFIX NOTATION

(o) Initial, (r) Radial, (z) Vertical, (h) Horizontal,
(c) Granular Pile, (s) Clay, (c.p.) Concrete Part,
(') Effective, (u) Undrained, (f) Rigid Footing.

LIST OF FIGURES

FIG. NO. PAGE