NUMERICAL MODELLING OF THE UNDRAINED VERTICAL BEARING CAPACITY OF SHALLOW FOUNDATIONS

by

VAN NGUYEN QUOC

A Thesis submitted for the Degree of

Master of Philosophy

at the University of Southern Queensland

October 2008

Certification of Dissertation

I certify that the ideas, results and analyses, conclusions reported in this dissertation are entirely my own effort, except where otherwise acknowledged. I also certify that the work is original and has not been previously submitted for any other award or higher degree to any other University or Institute.

VAN NGUYEN QUOC, Candidate *Date*

Endorsement

Dr RICHARD SIMON MERIFIELD, *Supervisor* *Date*

ABSTRACT

The bearing capacity of foundations is a fundamental problem in geotechnical engineering. For all structures placed on a soil foundation, geotechnical engineers must ensure that the soil has sufficient load carrying capacity so that the foundation does not collapse or become unstable under any conceivable loading. The ultimate bearing capacity is the magnitude of bearing pressure at which the supporting ground is expected to fail in shear, i.e. a collapse will take place.

During the last fifty years various researchers have proposed approximate techniques to estimate the short term undrained bearing capacity of foundations. The majority of existing theories are not entirely rigorous and contain many underlying assumptions. As a consequence, current design practices include a great deal of empiricism. Throughout recent decades, there has also been a dramatic expansion in numerical techniques and analyses, however, very few rigorous numerical analyses have been performed to determine the ultimate bearing capacity of undrained soils.

In this study, finite element analysis has been used to analyse a range of bearing capacity problems in undrained soil. The numerical models account for a range of variables including footing size, shape, embedment depth, soil layering and undrained bearing capacity of footings on slopes.

By using the powerful ability of computers a comprehensive set of solutions have been obtained therefore reducing the uncertainties apparent in previous solutions.

ACKNOWLEDGMENTS

I gratefully acknowledge the Research Scholarship from Vietnamese Government and officers of The Committee on Overseas Training Projects, Ministry of Education and Training of Vietnam.

I would like to express my deepest appreciation to Dr Richard Simon Merifield, Prof Thanh Tran–Cong, Dr Amar Khennane and Assoc Prof David Buttsworth for their effective guidance. Without their continuing dedication and encouragement this dissertation would not have been possible.

Finally, I am indebted to my family, my parents, my wife Huong and my son Viet for much support and encouragement over the years of my studies.

PREFACE

The research work presented in this thesis was conducted in the Faculty of Engineering and Surveying at the University of Southern Queensland from August 2004 to August 2006. This work was performed under the supervision of Dr Richard Simon Merifield. During the term of the candidature, the following paper was published:

1. Merifield R. S. and Nguyen V. Q. (2006). "Two and three−dimensional bearing capacity solutions for footings on two−layered clays." *Geomechanics and Geoengineering,* Taylor and Francis, 1(2) , pp.151−162.

NOTATION

All variables used in this thesis are defined as they are introduced into the text. For convenience, frequently used variables are described below. The general convention adopted is that vector and matrix variables are shown in bold print while scalar variables are shown in italic.

A	area of footing.
B	footing width.
C_1, C_2	constant coefficients.
c	soil cohesion.
c'	drained soil cohesion.
c_u, s_u	undrained soil cohesion.
c_1, c_1'	horizontal shear strengths at the top of the first and second layer respectively;
c_2, c_2'	vertical shear strengths at the top of the first and second layer respectively;
c_{u1}, C_t	undrained soil cohesion of top layer.
c_{u2}, C_b	undrained soil cohesion of bottom layer.
c_0	cohesive strength on the surface
D	problem dimensionality, diameter of circular footing, the embedded depth of footing.
D_f	footing depth.
D_e	distance from footing to the crest of slope.
d/b	ratio between thickness of the top layer and the width of footing.
E	total number of elements in finite element mesh, Youngs Modulus.
E_u	undrained Youngs modulus.
$F_{cs}, F_{qs}, F_{\gamma s}, s_c, s_s$	shape factors.

$F_{cd}, F_{qd}, F_{\gamma d}, d_c$ depth factors.

$F_{ci}, F_{qi}, F_{\gamma i}$ inclination correction factors.

F, F_S, F_R dimensionless factor of footing/soil interaction, that for smooth, rough case.

$\mathbf{g}, g_i$ vector/components of prescribed body force, gravity.

H slope height, top layer thickness.

K relative shear strengths between horizontal and vertical direction.

L length of rectangular footing, distance from the edge of slope to footing.

$N_c, N_q, N_\gamma, N_{c\gamma\rho}, N_{c\phi}, N_{cq}, N_{\gamma q}$ bearing capacity factors.

N total number of nodes in finite element mesh, stability number.

N_f stability number.

N_{ms}, N_{mc}, N_{mr} modified bearing capacity factors of strip, circular and rectangular footing.

N_s slope stability factor.

N_c^* modified bearing capacity factor.

n relative shear strengths between the top of first layer and the top of the second layer.

Q_n net footing capacity.

Q_u ultimate footing capacity.

q_u, q_f, q_{ult} ultimate bearing capacity/pressure of the footing.

$\mathbf{q}, q_i$ vector/components of optimisable surface traction.

q_{bL}^{net}/s_u ratio of net bearing capacity to undrained shear strength.

q uniform pressure, surcharge.

R radius of circular footing.

s_1, s_2 characteristic lines.

$u_j, \dot{u}_j$ displacement/velocity components.

ur_j, $\dot{ur}_j$	rotational displacement/velocity components.
u_{if}, $\dot{ur}_{\mathrm{if}}$	displacement/velocity components of footing.
τ_f	soil shear strength.
α	parameter of hyperbolic approximation of Mohr–Coulomb yield criterion.
γ	unit weight of soil.
δ	footing displacement, soil footing interface roughness/friction.
ρ	change in soil cohesion with depth dc_u/dz.
ζ_{cs}	empirical shape factor.
σ_{ij}	stress tensor.
σ_i	principal stresses.
ϕ	internal friction angle of soil.
$\phi^{'}$	drained friction angle of soil.
ϕ_{u}	undrained friction angle of soil.
ν	Poissons ratio.