DURABILITY OF SOIL-CEMENT COLUMNS IN COASTAL AREAS

by

PHAM VAN NGOC

School of Engineering,
Faculty of Engineering and Built Environment,
The University of Newcastle, Australia

A thesis submitted in partial fulfillment of the requirement of the degree of
Master of Philosophy

July 2016

DECLARATION

The thesis contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. I give consent to the final version of my thesis being made available worldwide when deposited in the University's Digital Repository**, subject to the provisions of the Copyright Act 1968.

***Unless an Embargo has been approved for a determined period.*

Signed

ACKNOWLEDGEMENTS

After two years studying at the University of Newcastle with a lot of unforgettable memories, my thesis was finished with the supports and helps from many kind people. Therefore, I would like to express my gratitude to my supervisors, friends and families who always stood by me through the good times and the bad.

First of all, I would like to express my deepest gratitude to Dr. Brett Turner as the principal supervisor. Your enthusiasm and friendliness made me feel more confident in my work. I am grateful for your time to instruct me in TGA analysis, to correct my papers and the thesis. Your kind comments and supports helped me to finish this thesis smoothly. In my mind, I am really happy to work with you, and I wish I can study PhD course under your instructions.

Secondly, I would like to express my sincere gratitude to Dr. Jinsong Huang and Dr. Richard Kelly. I was really happy with your instructions and insightful comments related to the thesis and my writing.

In addition, I acknowledge the spiritual and financial supports of Australia Awards Scholarship, who gave me a chance to study in the professional education environment. Furthermore, I am very thankful for the financial assistance provided by the ARC Centre of Excellence for Geotechnical Science and Engineering at the University of Newcastle. Besides, I would like to express my gratitude to Keller Australia, who provided the soil samples from their site and useful information related to their project. Special thanks also go to Mr. Lachlan Bates, Mr. Michele Spadari, Mrs. Kirstin Dunncliff, Mrs. Helen Thursby, Dr. Duy Ngo, Dr. Van Le and Dr. Shane Pascoe for their precious supports during last two years.

Finally, I would like to thank my parents and my wife. They always support and encourage me with their best wishes.

ABSTRACT

Global warming and sea level rise have become major concerns of the modern world with the Intergovernmental Panel on Climate Change (IPCC) reporting that sea levels may rise by 52-98 cm in the 21st century. At the upper end of predicted sea level rise, 50% of the world's population will be affected, with 33% of coastal land lost. As the majority of buildings and transport infrastructure are concentrated in these coastal areas, it is very important to understand of the longevity of these structures in the face of sea level rise.

Soil-cement columns are a geotechnical solution used for ground improvement in coastal areas. However, after long periods of exposure, the strength of these columns may decrease to below their designed safe bearing capacity ultimately resulting in failure. In this study, needle penetration resistance tests, uniaxial compression tests, thermogravimetric analysis, chemical and image analyses were applied to determine the extent of deterioration in scaled soil-cement columns exposed to synthetic seawater. The effects of high sulphate concentrations (100%, 200%, 500% and 1000% that of seawater) on the durability of soil-cement samples were also studied. The experimental results show that the effects of seawater (sulphate) are significant on the outer surface strength development. For samples exposed to seawater, inhibition of the portlandite and formation of gypsum and ettringite are the main reasons leading to the destruction of soil-cement samples. Moreover, the deterioration is strong at the surface and develops inward with time.

An analytical model has been developed and calibrated using the experimental data to predict the deterioration depths and total strength change of the soil-cement columns as a function of time and sulphate concentration. Results show that for the 0.5 m diameter column exposed to 200% SW, the strength will fall below the minimum design strength after 75 years. For higher sulphate environments (500% and 1000% that of seawater), the same column would never reach the minimum design strength requirement. Consequently, this has significant implications to

stabilising soils in high sulphate environments such as those containing pyrite which makes up approximate 95,000 km^2 of the Australian coastline.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

NOTIATION

The following symbols are used in this thesis:

A	cross area of the sample
a_w	cement ratio;
C	cement content;
C-A-H	calcium aluminate hydrate;
C-H	porlandite – $Ca(OH)_2$;
C-S-H	calcium silicate hydrate;
CV	coefficient of variation;
D	diameter;
DMM	deep mixing method;
F	resistance force;
F_s	safety factor;
$L_{eq.}$	equivalent deterioration depth;
ML	mass loss;
MM	molar mass;
M-S-H	magnesium silicate hydrate;
NPR	needle penetration resistance;
P	total bearing capacity;

$[P]$	required bearing capacity;
P_a	allowable bearing capacity;
P_{nd}	bearing capacity of non-deteriorated soil-cement column;
P_d	bearing capacity of deteriorated soil-cement column;
R^2	correlation coefficient;
R_P	loss ratio;
SW	seawater;
TGA	thermogravimetric analysis;
UCS	unconfined compressive strength;
W	water content;
W/C	ratio of water and cement;
α	coefficient of effective width;
β	reliability coefficient of overlapping;
γ	correction factor for strength variability;
d	diameter of non-deteriorated portion;
h	height;
q_u	unconfined compressive strength;
$[q_u]$	required unconfined compressive strength;
$[q_u^{28}]$	required unconfined compressive strength at 28 days;

ρ density of soil;

s sample standard deviation;

$\bar{x}$ sample mean;

w deterioration depth;