



THE UNIVERSITY OF
NEWCASTLE
AUSTRALIA

**DURABILITY OF SOIL-CEMENT COLUMNS
IN COASTAL AREAS**

by

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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.

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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 km² of the Australian coastline.

TABLE OF CONTENTS

DECLARATION.....	i
ACKNOWLEDGEMENTS.....	ii
ABSTRACT.....	iii
TABLE OF CONTENTS.....	v
LIST OF TABLES.....	xii
LIST OF FIGURES.....	xv
NOTIATION.....	xxi
PUBLICATIONS AND AWARD.....	xxiv
CHAPTER 1. INTRODUCTION	1
1.1 Deep mixing method.....	1
1.2 Soil-cement columns.....	2
1.3 Current research problems	4
1.4 Research objective and scope.....	5
1.5 Structure of thesis.....	6
CHAPTER 2. LITERATURE REVIEW	8
2.1 Soft soil in coastal areas.....	8
2.1.1 General characteristics of soft soil	8
2.1.2 Soft soil in coastal areas	8

2.1.3	Soft soil improvement methods.....	9
2.1.3.1	Compaction techniques.....	9
2.1.3.2	Reinforcement techniques	10
2.1.3.3	Fixation techniques.....	10
2.2	Binders	10
2.2.1	Cement binder	10
2.2.2	Binders.....	12
2.3	Soil-cement columns.....	13
2.4	Factors affecting characteristics of soil-cement columns	14
2.4.1	Soil characteristics.....	14
2.4.2	Mixing and curing conditions.....	17
2.5	Effects of seawater on soil-cement columns.....	17
2.5.1	Seawater	17
2.5.2	Mechanism of chemical reactions	18
2.6	Reducing the effects of sulphate attack.....	20
2.6.1	Cement content and clay-water/cement ratio	20
2.6.2	Alternative pozzolans	21
2.6.3	Using sulphate resistance cement.....	22
2.7	Historical review on strength gain of cementitious materials.....	22

2.7.1	Concrete strength gain theory.....	22
2.7.2	Strength gain of soil-cement columns.....	23
2.8	Long-term strength of soil-cement columns in marine areas.....	25
2.8.1	Prediction of deterioration depths.....	26
2.8.2	Long-term effects of sulphate concentrations.....	28
CHAPTER 3. EXPERIMENTAL PROCEDURE AND		
METHODOLOGY		30
3.1	Soil sample.....	30
3.1.1	Water content.....	31
3.1.2	Plastic limit.....	31
3.1.3	Liquid limit.....	31
3.1.4	Plastic index.....	31
3.1.5	Grain size distribution.....	32
3.1.6	Bulk density of soil.....	32
3.1.7	Chemical analysis.....	32
3.2	Soil-cement mixing sample.....	32
3.3	Uniaxial compression test.....	36
3.4	Needle penetration resistance test.....	38
3.5	Thermogravimetric analysis.....	40

3.6	Image analysis	44
CHAPTER 4. EXPERIMENTAL RESULTS AND DISCUSSION		48
4.1	Properties of soft soil	48
4.1.1	Water content.....	48
4.1.2	Liquid limit	49
4.1.3	Plastic limit	50
4.1.4	Plastic index.....	50
4.1.5	Grain distribution.....	51
4.1.6	Density of soil.....	53
4.1.7	Chemical analysis results	53
4.2	Soil-cement columns core strength gain	54
4.2.1	Unconfined compressive strength	54
4.2.2	Prediction of soil-cement columns core strength gain	55
4.3	Long-term strength of soil-cement columns	56
4.3.1	Needle resistance calibration.....	56
4.3.2	Deterioration at T1 (58 days)	58
4.3.2.1	Needle penetration resistance test at T1 (58 days)	58
4.3.2.2	TGA analysis at T1 (58 days).....	60
4.3.2.3	Chemical analysis at T1 (58 days).....	63

4.3.3	Deterioration at T3 (118 days)	64
4.3.3.1	Needle penetration resistance test at T3 (118 days)	64
4.3.3.2	TGA analysis at T3 (118 days).....	66
4.3.4	Deterioration at T6 (208 days)	68
4.3.4.1	Needle penetration resistance test at T6 (208 days)	68
4.3.4.2	TGA analysis at T6 (208 days).....	69
4.3.4.3	Chemical analysis at T6 (208 days).....	70
4.3.5	Deterioration at T12 (388 days)	72
4.3.5.1	Needle penetration resistance test at T12 (388 days)	72
4.3.5.2	TGA analysis at T12 (388 days).....	73
4.3.5.3	Image analysis at T12 (388 days).....	74
4.3.6	Result analysis	76
4.3.6.1	Control samples	76
4.3.6.2	100% seawater	78
4.3.6.3	200% seawater	80
4.4	Prediction of deterioration depth of the soil-cement columns	82
4.4.1	Depth of deterioration	82
4.4.1.1	Needle penetration resistance results.....	82
4.4.1.2	TGA results.....	85

4.4.1.3	Prediction of deterioration depth	87
4.4.2	Prediction of the long-term strength of the soil-cement columns	88
4.5	Conclusions	100
CHAPTER 5. DETERIORATION IN HIGH SULPHATE ENVIRONMENTS		101
5.1	Experimental procedure	101
5.2	Experimental results and evaluation	102
5.2.1	Deterioration at T0.5 (42 days)	102
5.2.2	Deterioration at T1 (58 days)	103
5.2.3	Deterioration at T3 (118 days)	104
5.2.4	Deterioration at T6 (208 days)	105
5.3	Discussion	106
5.4	Equivalent deterioration depth prediction model.....	112
CHAPTER 6. CONCLUSIONS.....		118
6.1	Conclusions	118
6.2	Limitations and possible development trends	120
REFERENCES		122
APPENDICES		133
APPENDIX I: Uniaxial compression tests and needle penetration resistance tests (Part 1)		134

APPENDIX II: Uniaxial compression tests and needle penetration resistance tests (Part 2)	140
APPENDIX III: TGA curves	144
APPENDIX IV: TGA results	147
APPENDIX V: Chemical analysis results	149
APPENDIX VI: Strength prediction model application	151

LIST OF TABLES

Table 2.1. Major mineral constituents of ordinary Portland cement	11
Table 2.2. The ion concentration of seawater.....	18
Table 3.1. Groups of specimens	36
Table 4.1. Soil characteristic	48
Table 4.2. Water content.....	49
Table 4.3. Liquid limit.....	49
Table 4.4. Plastic limit.....	50
Table 4.5. Sieve analysis.....	51
Table 4.6. Hydrometer analysis	51
Table 4.7. Density of soil.....	53
Table 4.8. Chemical analysis of the original soil.....	53
Table 4.9. UCS results	55
Table 4.10. Needle resistance calibration tests.....	57
Table 4.11. Needle penetration resistance tests at T1 (58 days).....	59
Table 4.12. TGA results at T1 (58 days)	61
Table 4.13. Extent of calcium consumption at T1 (58 days).....	62
Table 4.14. Calcium and magnesium concentrations at T1 (58 days).....	63
Table 4.15. Needle penetration resistance tests at T3 (118 days).....	64

Table 4.16. TGA results at T3 (118 days)	66
Table 4.17. Extent of calcium consumption at T3 (118 days).....	67
Table 4.18. Needle penetration resistance tests at T6 (208 days).....	68
Table 4.19. TGA results at T6 (208 days)	69
Table 4.20. Extent of calcium consumption at T6 (208 days).....	70
Table 4.21. Calcium and magnesium concentrations at T6 (208 days).....	71
Table 4.22. Needle penetration resistance tests at T12 (388 days).....	72
Table 4.23. TGA results at T12 (388 days)	73
Table 4.24. Extent of calcium consumption at T12 (388 days).....	74
Table 4.25. Image analysis results at T12 (388 days)	75
Table 4.26. Strength change by time in the control samples	77
Table 4.27. Strength change by depth in the control samples	77
Table 4.28. Strength change by time in the case of 100% SW.....	79
Table 4.29. Strength change by depth in the case of 100% SW	79
Table 4.30. Strength change by time in the case of 200% SW.....	81
Table 4.31. Strength change by depth in the case of 200% SW	82
Table 4.32. Depths of deterioration	87
Table 4.33. Strength change trend	92

Table 4.34. The comparison between prediction model and experimental results	93
Table 4.35. Model application	94
Table 4.36. Strength loss rate	95
Table 4.37. Durability of soil-cement columns	98
Table 5.1. Specimens and testing time matrix	101
Table 5.2. Needle penetration resistance test at T0.5 (42 days)	102
Table 5.3. Needle penetration resistance test at T1 (58 days)	103
Table 5.4. Needle penetration resistance test at T3 (118 days)	104
Table 5.5. Needle penetration resistance test at T6 (208 days)	105
Table 5.6. Total compression force	110
Table 5.7. Equivalent diameter of the deteriorated samples	110
Table 5.8. Equivalent deterioration depth of the samples	111
Table 5.9. Total bearing capacity of soil-cement column ($D = 0.5$ m) in high sulphate environments	114

LIST OF FIGURES

Fig. 1.1. Deep mixing method	1
Fig. 1.2. Applications of deep mixing methods.....	3
Fig. 2.1. Influences of binder type and amount of binder	13
Fig. 2.2. Soil-cement columns	13
Fig. 2.3. Applications of wet and dry mixing methods	14
Fig. 2.4. Effect of soil types on the strength of stabilised soil.....	15
Fig. 2.5. Effect of pH on the unconfined compressive strength	16
Fig. 2.6. Effect of water/cement ratio	16
Fig. 2.7. Effect of curing time.....	17
Fig. 2.8. Class C fly ash, Metakaolin, Silica Fume, Class F fly ash, Slag, and Calcined Shale.	21
Fig. 2.9. Strength gain of concrete.....	23
Fig. 2.10. Strength gain of stabilised soil	24
Fig. 2.11. Strength gain over time	25
Fig. 2.12. Strength development of the soil-cement columns	26
Fig. 2.13. Depth of deterioration	27
Fig. 2.14. Effects of sulphate concentration on the deterioration.....	29
Fig. 3.1. Soil sample	30

Fig. 3.2. Moulds	33
Fig. 3.3. Mixer machine.....	33
Fig. 3.4. Soil-cement samples stored in the fog room	35
Fig. 3.5. Curing conditions	35
Fig. 3.6. Testing time	35
Fig. 3.7. Uniaxial compression test	37
Fig. 3.8. Uniaxial compression test result.....	38
Fig. 3.9. Concrete needle penetrometer and its parts.....	39
Fig. 3.10. Needle penetration resistance test system	40
Fig. 3.11. Samples preparation for TGA analysis	41
Fig. 3.12. TGA 1 – Thermogravimetric Analyser (METTLER TOLEDO)	42
Fig. 3.13. TGA curve	44
Fig. 3.14. Rhodamine B dye	45
Fig. 3.15. Microscope	45
Fig. 3.16. Relationship between coefficient of permeability and unconfined compressive strength of stabilised soil	46
Fig. 3.17. Sample preparation.....	46
Fig. 3.18. Image analysis	47
Fig. 4.1. Water content.....	50

Fig. 4.2. Grain size distribution	52
Fig. 4.3. Strength gain of the control samples	55
Fig. 4.4. Strength gain of soil-cement column ($C = 120 \text{ kg/m}^3$)	56
Fig. 4.5. Relationship between the UCS and the NPR	58
Fig. 4.6. Needle penetration resistance results at T1 (58 days)	59
Fig. 4.7. Strength distribution at T1 (58 days).....	60
Fig. 4.8. TGA results at T1 (58 days).....	62
Fig. 4.9. Extent of calcium consumption at T1 (58 days)	63
Fig. 4.10. Calcium and magnesium concentrations at T1 (58 days)	64
Fig. 4.11. Needle penetration resistance results at T3 (118 days).....	65
Fig. 4.12. Strength distribution at T3 (118 days).....	65
Fig. 4.13. TGA results at T3 (118 days).....	67
Fig. 4.14. Extent of calcium consumption at T3 (118 days)	67
Fig. 4.15. Needle penetration resistance results at T6 (208 days).....	68
Fig. 4.16. Strength distribution at T6 (208 days).....	69
Fig. 4.17. TGA results at T6 (208 days).....	70
Fig. 4.18. Extent of calcium consumption at T6 (208 days)	71
Fig. 4.19. Calcium and magnesium concentration at T6 (208 days).....	71
Fig. 4.20. Needle penetration resistance results at T12 (388 days).....	72

Fig. 4.21. Strength distribution at T12 (388 days).....	73
Fig. 4.22. TGA results at T12 (388 days).....	74
Fig. 4.23. Extent of calcium consumption at T12 (388 days)	75
Fig. 4.24. Image analysis at T12 (388 days).....	75
Fig. 4.25. Red dye distribution in the samples at T12 (388 days).....	76
Fig. 4.26. Strength change by time of the control samples	77
Fig. 4.27. Strength change by depth of the control samples.....	78
Fig. 4.28. Soil-cement samples exposed to 100% SW	78
Fig. 4.29. Strength change by time in the case of 100% SW	79
Fig. 4.30. Strength change by depth in the case of 100% SW.....	80
Fig. 4.31. Soil-cement samples exposed to 200% SW	80
Fig. 4.32. Cross-section of the soil-cement samples exposed to 200% SW.....	81
Fig. 4.33. Strength change by time in the case of 200% SW	81
Fig. 4.34. Strength change by depth in the case of 200% SW.....	82
Fig. 4.35. Deterioration depth at T1 (58 days)	83
Fig. 4.36. Deterioration depth at T3 (118 days)	84
Fig. 4.37. Deterioration depth at T6 (208 days)	84
Fig. 4.38. Deterioration depth at T12 (388 days)	85
Fig. 4.39. TGA results at T1 (58 days).....	86

Fig. 4.40. TGA results at T3 (118 days)	86
Fig. 4.41. TGA results at T6 (208 days)	86
Fig. 4.42. TGA results at T12 (388 days)	87
Fig. 4.43. Deterioration depth by time in the case of 100% SW	88
Fig. 4.44. Strength distribution in the soil-cement column	88
Fig. 4.45. Strength change at the near surface of the soil-cement column	90
Fig. 4.46. Strength change at the deteriorated portion	92
Fig. 4.47. Strength distribution when $t \geq 228318$ days	92
Fig. 4.48. Total bearing capacity of the soil-cement columns ($D = 54\text{mm}$)	93
Fig. 4.49. Predicting bearing capacity of soil-cement columns exposed to 100% SW	96
Fig. 4.50. Strength loss of soil-cement columns exposed to 100% SW	97
Fig. 4.51. Durability of soil-cement columns	99
Fig. 5.1. Strength distribution at T0.5 (42 days)	103
Fig. 5.2. Strength distribution at T1 (58 days)	104
Fig. 5.3. Strength distribution at T3 (118 days)	105
Fig. 5.4. Strength distribution at T6 (208 days)	106
Fig. 5.5. Soil-cement samples exposed to 500% SW	106
Fig. 5.6. Soil-cement samples exposed to 1000% SW	107

Fig. 5.7. Needle penetration resistance results at T1 (58 days)	107
Fig. 5.8. Needle penetration resistance results at T3 (118 days)	108
Fig. 5.9. Needle penetration resistance results at T6 (208 days)	108
Fig. 5.10. Equivalent diameter method	109
Fig. 5.11. Equivalent deterioration depths	112
Fig. 5.12. Relationship between factor $f(M)$ and sulphate environment (M)	113
Fig. 5.13. Total bearing capacity of soil-cement columns in high sulphate environments ($D = 0.5$ m)	115
Fig. 5.14. Strength loss rate ($D = 0.5$ m)	116
Fig. 5.15. Durability of the soil-cement columns in high sulphate environments	117

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 – $\text{Ca}(\text{OH})_2$;
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;