# OF EXPANSIVE SOIL IN SRI LANKA

# R.A.I. Senarathne

# University of Moratuwa, Sri Lanka

This thesis was submitted to the Department of Civil Engineering of the University of Moratuwa in partial fulfillment of the requirements for the Degree of Master of Engineering in Foundation Engineering

Department of Civil Engineering
University of Moratuwa
Sri Lanka
July, 2008

#### **CONTENTS**

## Acknowledgement

Declaration

Contents

# **Chapter 1- Introduction**

- 1.1 Expansive soil
- 1.2 Occurrence of expansive soils

#### **CONTENTS**

- 1.3 Approaches of expansive soil in expansive soil
- 1.4 Identification of Expansive soils



## Chapter 2- Reasons for expansiveness in soil

- 2.1 Formation of clay minerals
- 2.2 Formation of expansive clays
- 2.3 Shrinkage and swelling processes of expansive clays
- 2.4 Expansive potential

## Chapter 3- Identification of expansive soils in Sri Lanka

- 3.1 Soils Types in Sri Lanka
- 3.2 Expansive soils in Sri Lanka-Some Identified location
- 3.3 Sites studied in this project
- 3.3 .1. Post Harvesting Institute- Anuradhapura
- 3.3.2. Aurvedic Hospital- Anuradhapura
- 3.3.3. Sahana Child Care Center- Saliyapura
- 3.3.4. Maithreegama Tsunami Housing Project-Hambanthota
- 3.4 Investigations, laboratory study program

# **Chapter 4- Laboratory studies on collected samples**

- 4.1. Introduction 24
- 4.2. Basic laboratory test 24
- 4.3 swell pressure and free swell test 25
- 4.3.1 Swellpressuretest 25
- 4.3.2 Free swell test 25
- 4.4. Test Results. 26

Chapter 5- Reduction of expansiveness of a soil by the use of additives 29

- 5.1. Current practices 29
- 5.2. Studies done in this project

# chapter 6- Reduction of the Effect on Structures by Enhancement of 34

#### **Foundation Stiffness**

6.1 Introduction

University of Moratuwa, Sri Lanka.

- 6.2. Basic frame work of the Finite Element Analysis of SAP 2000
- 6.3. Results of Finite Element analysis of SAP 2000

## **Chapter7- Conclusions**

- 7.1. Summary
- 7.2.Conclsions

#### Annex 1.

- A.l.Laboratary test studies
- A.l.1.Swell pressure
- A.1.2. Wet sieve analysis and Hydrometer analysis
- A.1.3. Atterberg limit

ACKNOWLEDGEMENT

First of all I would like to express my sincere thanks to my project supervisor,

Prof. S.A.S. Kulathilaka, of Department of Civil Engineering of University of Moratuwa,

who gave me a valuable guidance and very kind hearted co-operation in carrying out this

project and also thank Prof. Puswewala, of University of Moratuwa, for the

encouragement extended during this study.

My very special thank goes to Mr. I.A.S. Tissera, my husband who provided valuable

guidance and cooperation to carry out this project.

would also like to acknowledge the staff at The National Engineering Research and

Development Centre of Sri Lanka for providing facilities to carry out the project. My

special thanks goes to the Former Deputy General Manager of NERD Centre, Mr. Y.R.

Thilakarathne for his encouraging thoughts during the time and carried out this project.

+ express my thanks to Civil Engineering Department of NERD Centre, and especially to

Mrs. P.R.C.P.W. Paranawithana who supported me in laboratory testing throughout the

project. Also very especially to Mr. W.W.P.K.Perera, Civil Engineer, who extended his

corporation in various ways.

Finally, I would express my sincere gratitude to all those who helped me in numerous

ways at different stages to make this project a success.

R.A.I. Senarathne

July 2008

i

#### **DECLARATION**

I hereby declare that this submission is my own work and that, to the best of my knowledge and behalf, it contains no material previously published or written by another person nor material, which to substantial extent, has been accepted for the award of any other academic qualification of an university or institute of higher learning except where acknowledgment is made in the text.



# CONTENTS

	Page
Acknowledgement	i
Declaration	ii
Contents	iii
Chapter 1- Introduction	1
1.1 Expansive soil	2
1.2 Occurrence of expansive soils	2
1.3 Approaches of expansive soil in expansive soil	4
1.4 Identification of Expansive soils	5
1.5 Out line of the present study and thesis	6
Chapter 2- Reasons for expansiveness in soil	8
2.1 Formation of clay minerals Iniversity of Moratuwa, Sri Lanka.	8
2.2 Formation of expansive clays ectronic Theses & Dissertations	10
2.3 Shrinkage and swelling processes of expansive clays	11
2.4 Expansive potential	11
Chapter 3- Identification of expansive soils in Sri Lanka	12
3.1 Soils Types in Sri Lanka	14
<ul><li>3.2 Expansive soils in Sri Lanka-Some Identified location</li><li>3.3 Sites studied in this project</li><li>3.3.1. Post Harvesting Institute – Anuradhapura</li></ul>	15 18 18
3.3.2. Aurvedic Hospital- Anuradhapura	20
3.3.3. Sahana Child Care Center- Saliyapura	22
3.3.4. Maithreegama Tsunami Housing Project-Hambanthota	22
3 4 Investigations, laboratory study program	23

	Page
Chapter 4- Laboratory studies on collected samples	24
4.1. Introduction	24
4.2. Basic laboratory test	24
4.3 swell pressure and free swell test	25
4.3.1 Swell pressure test	25
4.3.2 Free swell test	25
4.4. Test Results.	26
Chapter 5- Reduction of expansiveness of a soil by the use of additives	29
5.1. Current practices	29
5.2. Studies done in this project	30
5.3. Result of the test	31
Chapter 6- Reduction of the Effect on Structures by Enhancement of	34
Foundation Stiffness	
6.1 Introduction	34
6.2.Basic frame work of the Finite Element Analysis of SAP 2000	34
6.3. Results of Finite Element analysis of SAP 2000	37
Chapter7- Conclusions	49
7.1. Summary	49
7.2.Conclsions	49
Annex 1. A.1.Laboratary test studies	A-1 A-1
A.1.1.Swell pressure	A-1
A.1.2. Wet sieve analysis and Hydrometer analysis	A-2
A.1.3. Atterberg limit	Δ_10

	Page
Annex 2.	A-14
A.2. Soil improvement using paddy husk	A-14
A.2.1. Observation of swell pressure of Natural soil sample with burn paddy hus	k A-14
A.2.1.1 mix proportion 5%	A-14
A.2.1.2 mix proportion 10%	A-16
A.2.1.3 mix proportion 15%	A-18
A.2.2. Observation of swell pressure of oven dried soil sample	A-20
with burn paddy husk	
A.2.2.1 mix proportion 5%	A-20
A.2.2.2 mix proportion 10%	A-21
A.2.2.3 mix proportion 15%	A-22
A.2.3. Observation of swell pressure of sieved soil sample	A-23
by 425mm sieve with burned paddy husk	
A.2.3.1 mix proportion 5%	A-23
A.2.3.2 mix proportion 10%	A-24
A.2.3.3 mix proportion 15% University of Moratuwa, Sri Land Electronic Theses & Dissertations www.lib.mrt ac.lk	\$2.A-25 \$

# LIST OF FIGURES

	Page
Figure 1.1 Typical distress patterns resulting from heave	1
of expansive soils as indicated in foundations	
on expansive soils	
Figure 1.2 Swelling mechanism of clay mineral layer	2
Figure 1.3.Expansive soil showing cracks.	3
Figure 2.1. Silica tetrahedron, silica sheet	8,
aluminum octahedron and	
aluminum octahedron sheet	
Figure 2.2. Diagram of the structures of Kaolinite, Illite	9
and Montmorillonite	
Figure 2.3. Diffuse double layer	9
Figure 2.4. Clay water	10
Figure 2.5. Expansive clay  University of Moratuwa, Sri Lanka.	11
Figure 2.6. Swell potential as a function of initial Second Dissertations	12
moisture content and surcharge load ac lk	
Figure 2.7. Swell potential to compacted clay	13
Figure 3.1. Distribution of reported locations of expansive soils	15
in Sri Lanka	
Figure 3.2. The graph of plasticity index vs liquid limit.	16
Figure 3.3. The graph of plasticity index vs. clay content	17
Figure 3.4. The graph of activity vs clay content	17
Figure 3.5. Appearance of the ground surface cracked in dry season	18
Figure. 3.6. Failures in pavement and walls	19
Figure 3.7. Failures in pavement	19
Figure 3.8. New building constructed according to NERDC construction	19
technology with foundation constructed on sand bedding	
Figure 3.9. Cracks appearing at the wall	20
Figure 3.10. Cracks appearing at corner of door	21

Figure 3.11. Cracks appearing at corner of window	21
Figure 3.12. Vertical cracks along the column and wall	21
Figure 3.13. Wall cracks	22
Figure 3.14. Wall cracks along the window	22
Figure 3.15. Soil sample collecting at foundation level	23
Figure 4.1. Disturbed soil samples collected for the laboratory tests	24
Figure 4.2. Use of CBR mould to identify the free swell.	26
Figure 4.3. The graph of finer percentage to particle size for four sites.	27
Figure 4.4. Variation of plasticity vs clay content	28
Figure 4.5. Variation of activity vs clay content	28
Figure 5.2. Variations of swell pressure with time for natural soil	32
sample with different mix proportion of paddy husk ash.	
Figure 5.3. Variations of swell pressure with time for oven dry soil	33
sample with different mix proportion of paddy husk ash.	
Figure 5.4. Variations of swell pressure with time for sieved soil sample	33
by 425 mm sieve with different mix proportion of paddy husk ash.	
Figure 6.1. Stresses defined in the sap2000 ty of Moratuwa, Sri Lanka.	35
Figure 6.1. Stresses defined in the sap2000 Figure 6.2. Coordinate systems defined in SAP2000  Figure 6.1. Stresses defined in SAP2000	36
Figure 6.3. Three types of Foundation systems	36
Figure 6.4. Mesh elements X-Z plane defined for the sap 2000 Analysis.	37
Figure 6.5. Horizontal stress (S11), vertical stress (S22),	37
minimum principal stress (SMIN) and	
maximum principal stress (SMAX) as indicated in SAP2000.	
Figure 6.6. Stress distribution for rubble foundation with brick wall	39
when swell pressure is $80 \text{ kN/m}^2$ .	
Figure 6.7 Stress distribution for rubble masonry wall foundation on	4(
reinforced concrete base with brick wall when swell pressure is	
$80 \text{ kN/m}^2$ .	
Figure 6.8. Stress distribution for inverted tee reinforced concrete	4
strip footing with brick wall when swell pressure is 80 kN/m <sup>2</sup> .	

Figure 6.9. Stress distribution for rubble foundation with brick wall when swell pressure is 150 kN/m <sup>2</sup> .	42
Figure 6.10. Stress distribution for rubble masonry wall foundation on reinforced concrete base with brick wall when swell pressure is 150 kN/m <sup>2</sup> .	43
Figure 6.11. Stress distribution for inverted tee reinforced concrete strip footing with brick wall when swell pressure is 150 kN/m <sup>2</sup> .	44
Figure 6.12. Stress distribution for rubble foundation with brick wall when swell pressure is 250 kN/m <sup>2</sup> .	45
Figure 6.13. Stress distribution for rubble masonry wall foundation on reinforced concrete base with brick wall when swell pressure is 250 kN/m <sup>2</sup> .	46
Figure 6.14. Stress distribution for inverted tee reinforced concrete strip footing with brick wall when swell pressure is 250 kN/m <sup>2</sup> .	47



# LIST OF TABLES

	Page
Table 1.1. Correlations with common soil tests	4
Table 1.2. Correlations with common soil tests	4
Table 2.1. Swell potential of pure clay minerals	10
Table4.1. Laboratory tests done to identify the expansiveness	26
Table 5.1. Variations of swell pressure and densities for	32
natural soil sample with different mix proportion	
of paddy husk ash.	
Table 6.1. Selective material properties used in SAP 2000 analysis	36
Table 6.2. Pressure under foundation due to self weight of wall,	48
foundation and roof.	

