

CE 22/17

LB/DON/30/2016

LIBRARY  
UNIVERSITY OF MORATUWA, SRI LANKA  
MORATUWA

# SOIL AS A FOUNDATION MATERIAL

A Dissertation Submitted to  
The University of Moratuwa  
in Partial Fulfillment of the  
Requirements for the Degree of

**Master of Engineering** *Foundation Engineering.*

By

**S. Wijesinghe**

(MEng/FE/15/2002)

Supervised By

**Professor U.G.A. Puswewala**

**Department of Civil Engineering  
University of Moratuwa**

**Moratuwa  
Sri Lanka**

December 2015

*GR4 "15"  
GR4.15 (043)*

*109999*

*TH3047*

University of Moratuwa

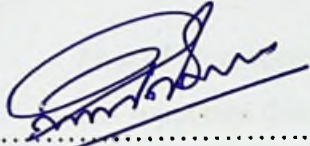


109999

109999

## DECLARATION

The research work included in this dissertation, in part or whole has not been previously presented for any other academic qualification at any institution.

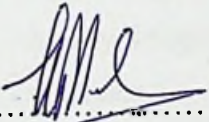


.....  
Sanjeewa Wijesinghe

(MEng./ FE/ 15/2002)

December 2015

I have supervised and accepted this dissertation for the submission of the degree.



.....  
Prof. U. G. A. Puswewala

(Supervisor)

## ACKNOWLEDGEMENT

Towards the completion of this study, the author is grateful to a number of individuals and institutions for their kind help and guidance in making this research work possible.

First of all special thanks are due to the course coordinator Prof. S. A. S. Kulathilaka who has supported this research work by providing laboratory and computer facilities.

I wish to express my profound gratitude to Prof. U. G. A. Puswewala, my supervisor for his valuable suggestions, comments and patience. The very valuable guidance of Prof. Puswewala gave me much confidence and paved the way towards making this research a success.

Special thanks are due to the National Engineering Research and Development Centre and its engineer Eng. W. K. R. Peries for providing of improved, modified version of the locally designed and manufactured soil compressing machine on time and for his valuable guidance.

Considerable laboratory works were involved in his research. The laboratory staff of the Soil Engineering Laboratory, University of Moratuwa and the laboratory staff of CECB have helped me in many ways to make this research work possible. The excellent support extended by Mr. Pitipana, Soil Engineering Laboratory, University of Moratuwa, Eng. Bulathsinghe, DGM (Lab and Site Investigation), CECB and Eng. R. M. K. R. Bandara who is in-charge of the Laboratory, CECB are acknowledged with immense gratitude. And a special thanks to Mr. Somadasa, driver, CECB who voluntarily helped me to handle the Tri axial equipment in the Soil Engineering Laboratory, University of Moratuwa at times of absence of technical assistance due to busy day to day schedules of staff.

My sincere gratitude to Eng. U. S. Karunaratne, DGM (Research & Development), CECB who paved my mind, at the very beginning, towards the field of soil stabilized

construction giving valuable instructions and also to Eng. M. A. C. Perera, AGM (Projects), CECB who is head of my working section in CECB and who was kind enough to recommend special leave to me to attend to this work. Without having this special leave it would have been unable to succeed in my research work within this very short period of time. And a special thanks to our former General Manager, Eng. Sarath Piyadasa who approved this special leave.

Finally I wish to express my profound gratitude to my wife for her support in the midst of her complicated health conditions, and to my late father and my mother who dedicated their entire life to our success in life.

## ABSTRACT

Cement Stabilized Soil Blocks are now considerably popular in the construction industry as an alternative building material to burnt bricks and cement sand blocks. It provides a timely solution for the over exploitation of clay (for bricks) and sand which has resulted in several severe environmental problems. However, as a foundation material there has been little focus on the use of soil. Apart from concrete, rubble stones with cement and sand are widely used as a foundation material even in construction of one or two storied buildings. However, in some parts of the country burnt bricks are also used as a foundation material especially in construction of single story houses. All these materials used for foundation are transported from sources concentrated in particular areas. In this context if compressed soil (stabilized with cement) could be used as a foundation material it will also provide a solution against over exploitation of sources of rock and sand.

This dissertation presents the research work carried out to introduce compressed soil blocks stabilized with cement as a foundation material alternative to random rubble masonry and burnt brick work. These blocks are manufactured using lateritic soils and a locally designed and manufactured manually operated soil compressing machine.

# CONTENTS

List of Figures	i
List of Tables	iii
List of Charts	v
<b>CHAPTER 1 Introduction</b>	<b>1</b>
1.1 General Introduction	1
1.2 Objectives	1
1.3 Methodology	2
<b>CHAPTER 2 Literature Review</b>	<b>3</b>
2.1 Introduction	3
2.2 Compressed Soil Blocks	4
2.3 Methods of Stabilization of Soil Blocks	4
2.3.1. Compressive Strength of Compressed Soil Blocks Stabilized with Cement	5
2.4 Locally Manufactured Soil Compressing Machines	6
<b>CHAPTER 3 Experiment on Cement Stabilized Soil Blocks and Results</b>	<b>7</b>
3.1 Introduction	7
3.2 Manufacturing of Compressed Soil Blocks	9
3.3 Testing Carried out on Compressed Soil Blocks Stabilized with Cement	10
3.3.1 Compression Testing	10
3.3.2 Testing of Core Samples Taken from Compressed Soil Blocks	11
3.3.2.1 Unconfined Compression Testing of the Blocks	11
3.3.2.2 Unconsolidated Undrained Triaxial Testing of Compressed Soil Blocks	20
	36

## **CHAPTER 4 - Numerical Analysis**

4.1	Introduction	36
4.2	Load Calculation	37
4.2.1.	Dead Loads	37
4.2.2	Imposed Loads	37
4.2.3	Loads from Roof and Floors	38
4.3	Use of Plaxis Version 8.0 Computer Programme	39
4.3.1	Introduction	39
4.3.2	Sign Convention	39
4.3.3	Model	40
4.3.4	Elements	40
4.3.5	Loads	40
4.3.6	Boundary Conditions	41
4.3.7	Material Properties	41
4.3.8	Modeling of Material Behaviour	42
4.3.9	Finite Element Mesh	43
4.3.10	Calculations	47
4.4	Output	48
4.4.1	Deformations	48
4.4.1.1	Deformed Mesh	48
4.4.1.2	Total, Horizontal and Vertical Displacements	50
4.4.1.3	Total Strains	57
4.4.2	Stresses	59
4.4.2.1	Total Stresses	59
4.4.2.2.	Cartesian Total Stress	64
4.4.2.3	Plastic Points	64
4.4.2.4	Load - displacement curves	69

## **CHAPTER 5 - Cost Comparison** 71

5.1	Cost Comparison for Construction of Foundation	71
5.1.1	Cost of Foundation Construction with Random Rubble masonry in cement mortar 1:5	71
5.1.2	Cost of Foundation Construction with Compressed Soil	71

	Blocks with cement content 4%.	
5.1.3	Cost of Foundation Construction with Compressed Soil	73
	Blocks with cement content 6.25%.	
<b>CHAPTER 6.0</b>	<b>- Discussion and Future Work</b>	<b>76</b>
6.1	Discussions	76
6.1.1	Discussion on the results from Experimental Programme	77
6.1.2	Discussion on the Numerical Analysis	79
6.1.3	Future Works	81
	References	82
	Appendix A : Cartesian Total Stresses	83



## LIST OF FIGURES

Figure 3.1:	Failure pattern of the Compressed Soil Blocks for cell pressure 50 kPa, 100 kPa and 150 kPa for the core samples in complete dry condition, with cement content 4.0%.	27
Figure 3.2:	Failure pattern of the Compressed Soil Blocks for cell pressures 50 kPa, 100 kPa and 150 kPa for the core samples in complete dry condition, with cement content 6.25%.	28
Figure 3.3:	Failure pattern of the Compressed Soil Blocks for cell pressures 50 kPa, 100 kPa and 150 kPa for the core samples 4 days after total immersion in water, with cement content 4%.	29
Figure 3.4:	Failure pattern of the Compressed Soil Blocks for cell pressures 50 kPa, 100 kPa and 150 kPa for the core samples 4 days after total immersion in water, with cement content 6.25%.	30
Figure 4.1:	The Foundation Section used for numerical analysis	36
Figure 4.2:	Coordinate system and indication of positive stress components.	39
Figure 4.3:	A Plane Strain Model	40
Figure 4.4 :	Nodes and Stress points	40
Figure 4.4:	Finite Elements generated, with identification numbers	44
Figure 4.5:	Nodes in Finite Elements generated, with identification numbers	45
Figure 4.6:	Stress points in Finite Elements generated, with identification numbers.	46
Figure 4.7:	Deformation Mesh for Case 01	48
Figure 4.8:	Deformation Mesh for Case 02	49
Figure 4.9:	Deformation Mesh for Case 03	49
Figure 4.10:	Deformation Mesh for Case 04	50
Figure 4.11:	Total, Horizontal & Vertical Displacements for Case 01.	51
Figure 4.12:	Total, Horizontal & Vertical Displacements for Case 02.	52
Figure 4.13:	Total, Horizontal & Vertical Displacements for Case 03.	54
Figure 4.14:	Total, Horizontal & Vertical Displacements for Case 04.	55

Figure 4.15:	Total Strains in Principal Directions for Case 01	57
Figure 4.16:	Total Strains in Principal Directions for Case 02	58
Figure 4.17:	Total Strains in Principal Directions for Case 03	58
Figure 4.18:	Total Strains in Principal Directions for Case 04	59
Figure 4.19:	Total Stress in Principal Directions for Case 01	60
Figure 4.20:	Total Stress in Principal Directions for Case 02	61
Figure 4.21:	Total Stress in Principal Directions for Case 03	62
Figure 4.22:	Total Stress in Principal Directions for Case 04	63
Figure 4.23:	Sign Convention Adopted for Cartesian Stresses	64
Figure 4.24:	Plastic Points for Case 01	65
Figure 4.25:	Plastic Points for Case 02	66
Figure 4.26:	Plastic Points for Case 03	67
Figure 4.27:	Plastic Points for Case 04	68
Figure 4.28:	Displacement curve for Case 01	68
Figure 4.29:	Displacement curve for Case 02	68
Figure 4.30:	Displacement curve for Case 03	69
Figure 4.31:	Displacement curve for Case 04	69

## LIST OF TABLES

Table 2.1:	Characteristics of soil Types S-01, S-02 & S-03 (Peiris & Wijesinghe, 2004)	5
Table 2.2:	2.2 Characteristics of cement stabilized soil blocks made with the machine 'Mihisura' for soil types S-01, S-02 & S-03.(Peiris & Wijesinghe, 2004)	5
Table 3.1:	Details of Experimental Programme	8
Table 3.2:	Characteristics of the Soil Type used for manufacturing of compressed soil blocks.	10
Table 3.3:	Mix Proportions and corresponding cement percentages	10
Table 3.4:	Average compressive strength of compressed soil blocks.	11
Table 3.5:	Water Absorption Ratio.	11
Table 3.6:	Characteristics of core samples used in Unconfined Compression Test (UCT)	12
Table 3.7:	Test results of Unconfined Compression Test for samples in complete dry condition, with cement content 4%.	13
Table 3.8:	Test results of Unconfined Compression Test for samples in complete dry condition with cement content 6.25%.	13
Table 3.9:	Test results of Unconfined Compression Test for samples of 4 days after immersion in water, with cement content 4%.	14
Table 3.10:	Test results of Unconfined Compression Test for samples of 4 days after immersion in water with cement content 6.25%.	15
Table 3.11:	Values of deformation modulus	19
Table 3.12:	Characteristics of core samples used in tri axial tests	20
Table 3.13:	Deviator Stress and Axial Strain information received for the cell pressures 50 kPa, 100 kPa and 150 kPa for the samples in complete	21
Table 3.14:	Deviator Stress and Axial Strain information received for cell pressures 50 kPa, 100 kPa and 150 kPa for samples in complete dry condition, with cement content 6.25%.	22
Table 3.15:	Deviator Stress and Axial Strain information received for cell	23

pressures 50 kPa, 100 kPa and 150 kPa for samples after 4 days total immersion in water, with cement content 4%.

Table 3.16:	Deviator Stress and Axial Strain information received for cell pressures 50 kPa, 100 kPa and 150 kPa for samples after 4 days total immersion in water, with cement content 4%.	24
Table 3.17:	C and $\phi$ values of the compressed soil blocks determined in Unconsolidated Undrained Tri axial Test.	35
Table 4.1:	Material Properties of the Sub Surface Soil (Sand)	41
Table 4.2:	Material Properties of compressed soil blocks used in Finite Element Analysis.	42
Table 4.3:	Values of Vertical Displacements ( $U_y$ ) at Critical Nodes for Cases 01 ; 02 ; 03 and 04.	57
Table 5.:	Cost Savings	75
Table A.:	Cartesian Total Stresses for Case 1	83
Table A.2:	Cartesian Total Stresses for Case 2	108
Table A.3:	Cartesian Total Stresses for Case 3	134
Table A.4:	Cartesian Total Stresses for Case 4	159

## LIST OF CHARTS

Chart 3.1:	Variation of Deviator Stress with Strain for the sample in complete dry condition with cement content 4%.	16
Chart 3.2:	Variation of Deviator Stress with Strain for the sample in complete dry condition with cement content 6.25%.	17
Chart 3.3:	Variation of Deviator Stress with Strain for the sample of 4 days total immersion in water with cement content 4%.	18
Chart 3.4:	Variation of Deviator Stress with Strain for the sample of 4 days total immersion in water with cement content 6.25%.	19
Chart 3.5:	Deviator Stress Vs Strain curves for cell pressures 50 kPa 100 kPa and 150 kPa for samples in complete dry condition with cement content 4%	25
Chart 3.6:	Deviator Stress Vs Strain curves for cell pressures 50 kPa 100 kPa and 150 kPa for samples at complete dry condition with cement content 6.25 %	25
Chart 3.7:	Deviator Stress Vs Strain curves for cell pressures 50 kPa 100 kPa and 150 kPa for samples after 4 days total immersion in water with cement content 4%	26
Chart 3.8:	Deviator Stress Vs Strain curves for cell pressures 50 kPa 100 kPa and 150 kPa for samples after 4 days total immersion in water with cement content 6.25%	26
Chart 3.9 :	Mohr Circles of Stress at Failure for the Cell Pressure 50KPa 100KPa and 150Kpa for Block Type A at Complete Dry Condition	31
Chart 3.10 :	Mohr Circles of Stress at Failure for the Cell Pressure 50KPa 100KPa and 150Kpa for Block Type B at Complete Dry Condition	32
Chart 3.11 :	Mohr Circles of Stress at Failure for the Cell Pressure 50KPa 100KPa and 150Kpa for Block Type A after 4 days total immersion in Water.	33

Chart 3.12 : Mohr Circles of Stress at Failure for the Cell Pressure 50KPa 34  
100KPa and 150Kpa for Block Type B after 4 days total  
immersion in Water.

