THE EFFECT OF CHEMICALS ON PERMEABILITY AND SHEAR STRENGTH CHARACTERISTICS OF SOILS

SHIN TO AMIRI

A project report submitted in partial fulfillment of the

requirements for the award of the degree of

Master of Engineering (Civil Geotechnics)

Faculty of Civil Engineering

Universiti Teknologi Malaysia

AUGUST 2012

This project is dedicated to my beloved mother and father

ACKNOWLEDGEMENT

I wish to express my sincere appreciation to my supervisor, Prof. Dr. Khairul Anuar Kasim. I am truly indebted for his advice and guidance. Besides, I am thankful for his guidance, encouragement and motivation because my supervisor has contributed a lot, towards my understanding and thoughts.

My sincere appreciation is also extended to all technicians of the Geotechnics laboratory. I am grateful for their assistance in preparing the test specimens and setup needed for the purpose of my study. Besides that, I am also thankful the laboratory technicians for giving full cooperation in my laboratory works.

Finally, I wish to express my gratitude to all my family members for their support and motivation.

ABSTRACT

The geotechnical properties of soils containing high amounts of clay minerals can be altered through chemical stabilization, resulting in a material suitable for construction purposes. The primary objective of this investigation was to study the changes in the geotechnical properties, such as compression, permeability and shear strength characteristics in laterite soil induced by adding various percentages of *Sodium Carbonate (*NA_2CO_3*)*. Based on the obtained data it found that the soda ash increased pH value of soil from 4.87 to 9.82 while increasing in shear stress and cohesion of soil. On the other hand, liquid limit growth by more admixing of soda ash whereas the maximum dry density experienced its peak by 10% soda ash of weight of soil. The results show natural laterite soil has coefficient permeability of 8.83E-5 cm/sec while results show reduction in permeability value in all tests by various percentages of treating soil by soda ash.

ABSTRAK

Sifat-sifat geoteknikal tanah yang mengandungi jumlah mineral tanah liat yang tinggi boleh diubah melalui penstabilan kimia, supaya sesuai untuk tujuan pembinaan. Objektif utama penyiasatan ini adalah untuk mengkaji perubahan dalam ciri-ciri geoteknik, seperti ciri-ciri kekuatan mampatan, ketelapan dan ricih dalam tanah laterit yang didorong dengan menambah peratusan pelbagai Natrium Karbonat (Na2CO3). Berdasarkan data yang diperolehi mendapati bahawa abu soda meningkatkan nilai pH tanah dari 4.87 kepada 9.82 serta meningkatkan tegasan ricih dan jelekitan tanah. Disamping itu peningkatan had cecair dengar pertambahan abu soda manakala ketumpatan kering maksimum mengalami kemuncaknya dengan kandungan abu soda 10% daripada berat tanah. Hasil kajian menunjukkan tanah laterit semulajadi mempunyai pekali kebolehtelapan 8.83E-5 cm / saat, manakala keputusan menunjukkan pengurangan teboleh telapan dalam semua ujian bagi pelbagi abu soda.

TABLE OF CONTENT

CHAPTER	TITLE		PAGE
	DECLARARION		**ii**
	DEDICATIONS		**iii**
	ACKNOWLEDGMENTS		**iv**
	ABSTRACT		**v**
	ABSTRAK		**vi**
	TABLE OF CONTENTS		**vii**
	LIST OF TABLES		**xi**
	LIST OF FIGURES		**xii**
	LIST OF SYMBOLS		**xiii**
1	**INTRODUCTION**		**1**
	1.1	Introduction	1
	1.2	Research Significance	2
	1.3	Research Objectives	2
	1.4	Problem Statement	3
	1.5	Scope of Research	3
2	**LITERATURE REVIEW**		**4**
	2.1	Introduction	4
3	**METHODOLOGY**		**7**
	3.1	Introduction	7
	3.2	Material Preparation	8
	3.3	Laboratory Tests	8

3.4 Standard Test Method for Particle-Size Analysis of Soil 9
3.4.1 Standard Reference 9
3.4.2 Principle 9
3.4.3 Equipment 10
3.4.4 Test Procedure 10
3.4.4.1 Sieve Analysis 10
3.4.4.2 Hydrometer Analysis 11
3.4.4.3 Data Analysis 13
3.4.4.3.1 Sieve Analysis 13
3.4.4.3.2 Hydrometer Analysis 13
3.5 Standard Test Method For Ph Of Soils 17
3.5.1 Introduction 17
3.5.2 Standard Refrence 17
3.5.3 Application Of Test 18
3.5.4 Sample Preparation 18
3.5.5 Procedure of Test 18
3.5.5.1 Note 1 20
3.5.5.2 Note 2 20
3.5.5.3 Note 3 20
3.6 Standard Test for Specific Gravity of Soil Solids by Water Pycnometer. 21
3.6.1 Purpose 21
3.6.2 Standard Reference 21
3.6.3 Significance 21
3.6.4 Equipment 22
3.6.5 Test Procedure 22
3.6.6. Data Analysis 23
3.7 Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils 23
3.7.1 Standard Reference 24
3.7.2 Purpose 24
3.7.3 Significance 24
3.7.4 Equipment 25

3.7.5 Test Procedure 25
3.7.6 Liquid Limit 25
3.7.7 Plastic Limit 27
3.7.8 Analysis 28
3.7.8.1 Liquid Limit 28
3.7.8.2 Plastic Limit 28
3.8 Standard Test Method For Permeability 29
3.8.1 Standard Reference 29
3.8.2 Purpose 29
3.8.3 Significance 30
3.8.4 Procedure 30
3.9 Standard Test Methods For Laboratory Compaction Characteristics Of Soil 31
3.9.1 Standard Reference 31
3.9.2 Purpose 31
3.9.3 Significance 32
3.9.4 Test Procedure 33
3.9.5 Analysis 35
3.10 Standard Test Method For Direct Shear Test Of Soils Under Consolidated Drained Conditions 36
3.10.1 Standard Reference 36
3.10.2 Purpose 36
3.10.3 Significance 37
3.10.4 Test Procedure 37
3.10.5 Analysis 39

4 RESULTS AND ANALYSIS 40
4.1 Introduction 40
4.2 Chemical Properties Results 41
4.2.1 Introduction 41
4.2.2 Details 41
4.2.3 pH Test Results 44
4.3 Physical Properties Test Results 44

	4.3.1	Compaction Test	44
		4.3.1.1 Introduction	44
		4.3.1.2 Standard Reference	45
		4.3.1.3 Results and Discussion	45
	4.3.2	Atterberg Limits Test Results	47
		4.3.2.1 Introduction	47
		4.3.2.2 Results and Discussion	47
	4.3.3	Hydraulic Conductivity (Falling Head Procedure)	48
		4.3.3.1 Introduction	48
		4.3.3.2 Sample Preparation	49
		4.3.3.3 Results and Discussion	49
	4.3.4	Shear Strength Characteristics Test Results	51
		4.3.4.1 Introduction	51
		4.3.4.2 Standard Reference	51
		4.3.4.3 Sample Preparation	51
		4.3.4.4 Results And Discussion	52
5	**CONCLUSION AND RECOMMENDATIONS**		**53**
	5.1	Conclusions	53
	5.2	Recommendations	53
	REFRENCES		**55**
	APPENDICES		**57-73**

LIST OF TABLES

TABLE NO.	TITLE	PAGE
3.1	Values of Effective Depth Based on Hydrometer and Sedimentation Cylinder of Specific Sizes	15
3.2	Values of k for Use in Equation for Computing Diameter of Particle in Hydrometer Analysis	16
3.3	Temperature Correction Factors CT	16
3.4	Correction Factors a for Unit Weight of Solids	17
4.1	Changing of dry density and moisture content due to effect of various percentages of sodium carbonate	46
4.2	Changing of Atterberg limits due to effect of various percentages of sodium carbonate	48
4.3	Decreasing in permeability coefficient by various percentages and curing time of sodium carbonate.	50
4.4	Changing in of shear strength characteristics of soil by various percentages of sodium carbonate	52

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
4.1	Double diffuse layer of laterite soil induced by sodium	43
4.2	Dry density versus soda ash percentages	46
4.3	Decreasing in permeability coefficient by various percentages and curing time of sodium carbonate.	50

LIST OF SYMBOLS

A		Area
C		Cohesion
CT	-	Temperature correction
C_c	-	coefficient of curvature
C_u	-	coefficient of uniformity
D	-	Equivalent particle diameter
F_h		Shear stress
Gs	-	Specific Gravity
K	-	Permeability coefficient
L	-	Effective Depth
LI		Plasticity index
LL		Liquid limit
N_v		Normal vertical force
P	-	Percent finer
P_A	-	Adjusted percent fines
Pf	-	Failure load
PL		Plastic limit
S_v		Normal vertical stress
t	-	Temperature
W_0	-	Weight of sample of oven-dry soil
W_A	-	Weight of pycnometer filled with water
W_B	-	Weight of pycnometer filled with water and soil
W_s	-	Weight of the soil
w_{sat}		Moisture content in percent for complete saturation
γ_d	-	Unit Weight of Solids

ω	-	Water moisture content
ρ		Wet density
ρ_d		Dry density
φ		Friction angle of soils particles

LIST OF APPENDICES

A	**Calculation of the bond Strength of the Specimens**
B	**Axial Strain of the Reinforcement Bar**
C	**Axial Strain of the FRP Sleeve**
D	**Bond Stress of the Reinforcement Bar**

CHAPTER 1

INTRODUCTION

1.1 Introduction

The environmental pollution has become a matter of great concern to engineers and planners. Until recently the role of geotechnical engineers were limited to achieving solutions to well defined problems. However, the situation now has drastically changed with the present awareness of environmental problems associated with developmental activities. The concept of environmental Geotechnics is emerging as an area of interest to Geotechnical engineers who are interested basically in the investigation, planning, identification, characterization, foreseeing and forecasting and designing of engineering works to protect the environment and also to avoid to take appropriate measure before hand in case of Geotechnical activities which may become future environmental problems.

This research has been underway to investigate the suitability of the local Malaysian soil polluted by sodium carbonate. This project is aimed at determining the some properties such as compressibility, permeability and shear strength characteristics.

1.2 Research Significant

With human activities cited in the introduction, the geotechnical engineers are concerned with effect of contamination on the geotechnical and mineralogical properties of the soils. They may face with situations in which they had to place new structures on site with contaminated soils. The present research program is an attempt to provide answers to these question.

The significant of this study is to study the polluted Malaysian laterite soil under permeability and shear strength characteristics tests; Moreover, to obtain the Geotechnical properties of represented soil.

Also, this research is important for geotechnical engineers who are interested basically in the investigation, planing, identification, characterisation, foreseeing and forecasting and designing of engineering works to protect the environment and also to avoid or take appropriate measure before hand in case of geotechnical activities which may become future environmental problems.

1.3 Research Objectives

1. To acquire the best percentage of *Soda Ash* in the matter of improving the *Shear strength characteristics (friction angle and cohesion of soils)* of laterite soils.
2. To obtain the effect of *Sodium Carbonate* on permeability coefficient of laterite soils.
3. To procure the Geotechnical properties of either polluted and unpolluted laterite soils.

4. To achieve the changes in the pH value of soil after became contaminated.

1.4 Problem Statement

Majority of the research work in the field of enviromental geotechnology is concerned with the disposal of wastes by different means the ground. The major sources of surface and subsurface contamination are on land disposal of industrial, mining, agricultural waters, accidental spillage of chemicals during the course of industrial operations and also due to human activities. This ground contamination causes the change in the physical and mechanical properties of soil and rock.

1.5 Scope of Research

The scope of the research is detailed as follow:

1. Soil samples will be taken from UTM, Johor Bahru and available white clay.
2. Chemical used in this investigation is Sodium carbonate Na_2Co_3.
3. Experiments will be conducted on contaminated soils during “short” and “long” terms.
4. The scope of thesis is to determine the effect of contamination on the soil(s) and the mechanism by which the effect takes place.

REFERENCES

1. Kumapley, N. K. and Ishola, A (1985). ” Effect of chemical contamination on soil strength”. *Proceedings of the XI th ICSMFE,* Sanfrancisco, vol.3, pp.1199-1201.
2. Sridharan, A., Nagaraj, T. S., and Sivapullaiah, P. V. (1981). ” Heaving of soil due to acid contamination”. *Proceedings of the Xth ICSMFE,* Stockholm, Vol.2, 383-386.
3. Sivapullaiah, P. V., Sankara G. and M. Allam (2010). ” Mineralogical change and geotechnical properties of an expensive soil interacted with caustic solution”. *Environ Earth SCI60:1189-1199.*
4. Sivapullaiah, P. V. and Reddy P. H. (2010). Potassium Chloride Treatment to control alkali induced heave in black cotton soil. *Geotech Geol ENG 28:27-36.*
5. Kumar, P. R. (1998). Environmental Geotechnics - Effects of contaminants on the engineering behavior of shedi soil, M Tech thesis submitted to National Institute of Technology Surathkal, India.
6. Kumar, P. R. (2004),” Effect of Ground Contamination on the Engineering behavior of Silty soil ”, *Indian Geotechnical Conference 2004,* NIT Warangal, India in December 2004. Pp: 97-99.
7. Kumar, P. R. and Khairul, A. K. (2010)” Effect of chemicals on settlement characteristics of soils ”, paper accepted for GEOTROPIKA 2010 at Sabah, Malaysia.
8. Kumar, P. R., Fatin H. And Khairul, A. K. (2011),” Effect of chemical byproducts on the plasticity characteristics of soils”, paper accepted for 14 th ARC at Hong Kong.

9. Sivapullaiah, P. V. and Manju (2006). ” Ferric chloride treatment to control alkali induced heave in weathered red earth”, *Geotech Geol Eng 24: 1115-1130.*
10. Attoh-Okine, B (1990), ” Stabilising effect locally produced lime on selected lateritic soils”, Construction and building materials, Vol. 4 (2): 8691.
11. Sitaram Nayak, B. M. Sunil, S. Shrihari (2007), ” Hydraulic and compaction characteristics of leachate-contaminated lateritic soil ”, Engineering Geology 94 (2007) 137–144.
12. B.M. Sunil, S. Shrihari, Sitaram Nayak, (2008),” Shear strength characteristics and chemical characteristics of leachate-contaminated lateritic soil ”, Department of Civil Engineering, National Institute of Technology Karnataka, Surathkal. Paper accepted on science direct.