CORRELATIONS BETWEEN COMPRESSION INDEX AND BASIC SOIL PARAMETERS FOR FINE GRAINED SOILS IN PENINSULAR MALAYSIA

NOORAINI BINTI HUMAM

UNIVERSITI TEKNOLOGI MALAYSIA

CORRELATIONS BETWEEN COMPRESSION INDEX AND BASIC SOIL PARAMETERS FOR FINE GRAINED SOILS IN PENINSULAR MALAYSIA

NOORAINI BINTI HUMAM

A project report submitted in partial fulfilment of the requirements for the award of the degree of Master of Engineering (Civil-Geotechnics)

Faculty of Civil Engineering
Universiti Teknologi Malaysia

JANUARY 2012

To my beloved father and mother, Hj Humam Mohamed and Hajah Nor Rizan, my other half which completes me which is my husband, Mohd Najmie Mohd and my soon-to-be-child in my tummy, who have been able to tolerate the weekends when I was away from them. They were the pillars of strength for me to come out with this study. May Allah bless them.

ACKNOWLEDGEMENTS

My special gratitude to my supervisor, Professor Dr. Khairul Anuar Kassim for his constant and undiminished guidance, encouragement, and advice during the development of this study. I am also thankful for the panel members for their constructive comments during the pre-project presentation.

I would also like to thank my colleagues from JKR Headquarters for their guidance during the early stages of the study. To Mr. Ezo Ezuan thank you very much for the SI Reports provided which is very useful for my study. Worth mentioning also are fellow postgraduate students in my class for their support.

Lastly, but not least, a special gratitude to my immediate superiors Ir Dzarif Yaacob and En. Ismail Abd. Aziz, my peers and also my sub-ordinates for been tolerable for the whole duration of the study.

ABSTRACT

Soil compressibility is very important element to be observed and analyzed in geotechnical design. Nowadays the young geotechnical engineers always encounter problems in using some geotechnical properties of fine grained soil. The study is based on data collected from proposed construction of upgrading roads in Perak, Melaka and Shah Alam. From the Soil Map of Peninsular Malaysia, the site chosen can be classified as decomposed limestone and granitic residual soil. By using Microsoft Excel, a set of correlations that have been obtained from the study were correlations between compressibility characteristics with basic soil properties which consisted of natural moisture content,Wn, liquid limit, LL and plasticity index, Ip. When combined the soil data of three regions in Peninsular Malaysia, it is shown that the highest value of coefficient of determination R^2 is the correlation of compression index versus liquid limit. This shows that the liquid limit figures were more consistent than others. When comparing the present study with same type of soils in Peninsular Malaysia, the correlation developed for soft soil in East Coast Expressway Kuala Terengganu and other regions Peninsular Malaysia best describes the characteristics of soils in this study. They had similar gradient and even the correlations were ± 5% difference. Meanwhile when comparing the present study with different type of soils in Malaysia, it was found that the present study were generally less compressible compared to marine clay in Peninsular Malaysia and Samarahan Alluvium soil in Sarawak. However, they were more compressible compared to granite residual soil in Peninsular Malaysia. From the equations established in this study, the proposed correlations showed not much different but still have some deviation with correlations from previous researchers. These findings are beneficial for further researchers especially on the compressibility study of the soft soils.

ABSTRAK

Kebolehmampatan tanah adalah unsur yang sangat penting untuk dikaji dan diteliti di dalam rekabentuk geoteknik. Di masakini, jurutera geoteknikal muda sering menghadapi masalah dalam menggunakan sebahagian daripada ciri-ciri geoteknikal bagi tanah lembut. Kajian ini adalah berdasarkan kepada data yang dikumpulkan dari beberapa lokasi cadangan menaiktaraf pembinaan jalan di negeri Perak, Melaka dan Shah Alam. Data lokasi-lokasi yang dipilih adalah tergolong dalam kategori pereputan batu kapur dan juga tanah granatik secara sisa. Dengan menggunakan Microsoft Excel, satu set korelasi yang akan diperolehi di akhir kajian ialah antara ciri-ciri kebolehmampatan dengan ciri-ciri fizikal tanah lembut yang merangkumi kandungan lembapan semulajadi,Wn, had cecair, LL, dan juga indeks keplastikan, Ip. Apabila menggabungkan data ketiga-tiga lokasi, adalah didapati nilai R^2 yang paling tinggi adalah index kemampatan melawan had cecair. Ini membuktikan data had cecair lebih konsisten berbanding dengan data kandungan lembapan semulajadi dan indeks keplastikan. Apabila membuat perbandingan dengan kajian terdahulu yang mana ciri-ciri tanahnya sama, adalah didapati, kajian ini hampir sama dengan kajian yang dibuat terdahulu untuk Lebuhraya Pantai Timur dan juga di beberapa lokasi di Semenanjung Malaysia. Julat perbezaan korelasi adalah lebih kurang 5% sahaja. Apabila membuat perbandingan dengan kajian terdahulu yang mana ciri-ciri tanahnya tidak sama, adalah didapati julat perbezaan kolerasi adalah sangat berbeza. Analisa kebolehmampatan kajian ini adalah kurang berbanding dengan kajian tanah marin yang jelekit di Semenanjung Malaysia dan juga tanah alluvium Samarahan di Sarawak. Walaubagaimanapun analisa kebolehmampatan kajian ini lebih besar berbanding dengan tanah granit secara sisa di Semenanjung Malaysia. Melalui kajian ini, dapat kita simpulkan kajian ini amat penting untuk kegunaan di masa hadapan.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	DECLARATION	**ii**
	DEDICATION	**iii**
	ACKNOWLEDGEMENTS	**iv**
	ABSTRACT	**v**
	ABSTRAK	**vi**
	TABLE OF CONTENTS	**vii**
	LIST OF TABLES	**xi**
	LIST OF FIGURES	**xii**
	LIST OF SYMBOLS	**xiv**
1.0	**INTRODUCTION**	**1**
1.0	Introduction	1
1.1	Background of the Study	2
1.2	Aim and Objectives of Study	3
1.3	Scope and Limitation of Study	3
1.4	Importance of the Study	4
1.5	Brief Research Methodology	4
2.0	**LITERATURE REVIEW**	**5**
2.1	Introduction	5
2.2	Compressibility of Soil	6

2.3	Compressibility Characteristics		7
	2.3.1	Coefficient of Compressibility (a_v)	7
	2.3.2	Coefficient of Volume Compressibility (m_v)	7
	2.3.3	Coefficient of Consolidation, (c_v)	8
2.4	Attenberg Limits and Moisture Content		8
2.5	General Characteristics of Cohesive Soil		9
2.6	Compression Index (Cc)		11
2.7	Soil Classification		15
3.0	**RESEARCH METHODOLOGY**		**18**
3.1	Introduction		18
3.2	Project Background		18
3.3	Overview of The Research		19
	3.3.1	Data Obtained	19
	3.3.2	Variable and Parameter Involved	19
	3.3.3	Data Analysis	20
	3.3.4	Comparison with Previous Researchers	20
4.0	**DATA COLLECTION AND ANALYSIS**		**23**
4.1	Introduction		23
4.2	Soil Properties and Classification		23
	4.2.1	Subsoil Classification	23
	4.2.2	Soil Properties	24
4.3	Natural Moisture Content		24
4.4	Correlations		25
4.5	Analysis of Compression Index Versus Natural Moisture Content		26

	4.5.1	Discussion of Analysis (Cc versus Wn)	26
		4.5.1.1 Discussion Graph of Cc Versus Wn for Three Different Locations	26
		4.5.1.2 Discussion Graph of Cc Versus Wn for Combination of Three Locations	27
4.6		Analysis of Compression Index Versus Liquid Limit	28
	4.6.1	Discussion of Analysis (Cc versus LL)	29
		4.6.1.1 Discussion Graph of Cc Versus LL for Three Different Locations	29
		4.6.1.2 Discussion Graph of Cc Versus LL for Combination of Three Locations	29
4.7		Analysis of Compression Index Versus Plasticity Index	31
	4.7.1	Discussion of Analysis (Cc versus Ip)	32
		4.7.1.1 Discussion Graph of Cc Versus Ip for Three Different Locations	32
		4.7.1.2 Discussion Graph of Cc Versus Ip for Combination of Three Locations	32
4.8		Comparison on the Compressibility Behaviour of Fine Grain Soil in Three Regions of Peninsular Malaysia with Same Type of Soils in Peninsular Malaysia	35
	4.8.1	Discussion on Compression Index and Moisture Content Correlations / Graphs	35
	4.8.2	Discussion on Compression Index and Liquid Limit Correlations / Graphs	37
	4.8.3	Discussion on Compression Index and Plasticity Index Correlations / Graphs	38
4.9		Comparison on the Compressibility Behaviour of Fine Grain Soil in three regions of Peninsular Malaysia with Other Type of Soils in Malaysia	39
	4.9.1	Discussion on Compression Index and Moisture	40

Content Correlations / Graphs

4.9.2 Discussion on Compression Index and Liquid Limit Correlations / Graphs 42

4.9.3 Discussion on Compression Index and Plasticity Index Correlations / Graphs 43

5.0 CONCLUSIONS AND RECOMMENDATIONS 45

5.1 Introduction 45

5.2 Conclusion Based on the Objective of Study 45

5.2.1 Objective #1: To Evaluate Soil Properties Collected Obtained From Collected Soil Samples 45

5.2.2 Objective #2: Established Empirical Correlation Between Compressibility Characteristics and Physical Soil Properties of Fine Grained Soils in Peninsular Malaysia 46

5.2.3 Objective #3: Comparison With The Previous Published Correlations 46

5.3 Overall Conclusions 47

5.4 Recommendations for Further Study 49

REFERENCES 50

APPENDICES 53

Appendix A – Laboratory Tests Results and Borelog Records

Appendix B – Summary of Data

LIST OF TABLES

TABLE NO.	TITLE	PAGE
2.1	Classification Properties of Cohesive Soil in Peninsular Malaysia	9
2.2	Compression Index and Compression Ratio Relationship with Other Soil Parameters	14
4.1	The Accuracy of Correlation	25
4.2	Compression Index and Moisture Content Correlations	36
4.3	Compression Index and Liquid Limit Correlations	37
4.4	Compression Index and Plasticity Index Correlations	39
4.5	Compression Index and Moisture Content Correlation	41
4.6	Compression Index and Liquid Limit Correlations	42
4.7	Compression Index and Plasticity Index Correlations	44
5.1	Summary of Correlations from Various Regions in Peninsular Malaysia	47

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
2.1	Phases of soil and the Atterberg Limits	9
2.2	Relationship between Compression Index and Liquid Limit	12
2.3	Relationship between Compression Index and Natural Water Content	13
2.4	British Soil Classification System for Engineering Purposes (BS 5030:1981)	16
2.5	Plasticity Chart for the Classification of Fine Soils and Finer Part of Coarse Soils	17
3.1	Flowchart of Project Methodology	21
3.2	Location of The Site of The Case Study Area	22
4.1	The Plots of Natural Moisture Content with Depth	25
4.2	Graph of Compression Index Versus Moisture Content (Perak, Melaka, Shah Alam)	27
4.3	Graph of Compression Index Versus Moisture Content	28
4.4	Graph of Compression Index Versus Liquid Limit (Perak, Melaka, Shah Alam)	30
4.5	Graph of Compression Index Versus Liquid Limit	31

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
4.6	Graph of Compression Index Versus Plasticity Index (Perak, Melaka, Shah Alam)	33
4.7	Graph of Compression Index Versus Plasticity Index	34
4.8	Graph of Compression Index Versus Moisture Content	36
4.9	Graph of Compression Index Versus Liquid Limit	38
4.10	Graph of Compression Index Versus Plasticity Index	39
4.11	Graph of Compression Index Versus Moisture Content	41
4.12	Graph of Compression Index Versus Liquid Limit	43
4.13	Graph of Compression Index Versus Plasticity Index	44

LIST OF SYMBOLS

Cc	Compression Index
Ip	Plasticity Index
LL	Liquid Limit
Wn	Natural Moisture Content
e_0	Void Ratio
Gs	Specific Gravity
PL	Plastic Limit
Cα	Secondary Consolidation
Cv	Coefficient Of Consolidation
a_v	Coefficient Of Compressibility
m_v	Coefficient Of Volume Compressibility
Pc	Preconsolidation Pressure
OCR	Overconsolidated Ratio

CHAPTER 1

INTRODUCTION

1.0 Introduction

Generally, soil is defined as a natural body comprised of solids (minerals and organic matter), liquid, and gases that occur on the land surface. There are two types of soil which are cohesionless soil and cohesion soil.

Cohesionless soil composed of soil materials that when unconfined have little or no strength when air-dried and that have little or no cohesion when submerged. It also has little tendency to stick together whether wet or dry, such as sands and gravels. Cohesive soil composed of particles of varying grain size. It does not crumble, can be excavated with vertical side slopes, and is plastic when moist. Cohesive soil is hard to break up when dry, and exhibits significant cohesion when submerged. Cohesive soils include clayey silt, sandy clay, silty clay, clay and organic clay.(Nur, 2008)

Shear strength is usually to be made up of internal friction which is the resistance due to the interlocking of the particles, and cohesion which is the resistance against the forces tending to hold the particles together in a solid mass. Shear strength of soil forms the basis of all the analysis of all stability problems. The problem of assessing the shear strength of cohesive soil appropriately and effectively is a question for every soil engineers. In term of time, changes will occur in strength, type of test taken, choice of apparatus as well as costs are always put into consideration.

1.1 Background of the Study

Cohesive soils are fine grained soils with high clay and water content. They have low strength and high compressibility. Compressibility of soils is an important engineering consideration as it is very useful in estimating the settlement under the additional structural loads. Several efforts to correlate compressibility with some simple index properties have been carried out before. The first well known correlation was presented by Skempton (1944) and then followed by Wroth and Wood (1978).

Silts and clays are known as fined grained soils. Fine grained soils are classified according to the grain size and plasticity properties. In other terms, how well these types of soils absorb water. The plasticity properties are called the Atterberg Limits, which are water contents at which the soil changes from a viscous liquid state to a plastic solid state known as liquid limit, LL, and from a plastic solid state to a brittle solid state known as plastic limit, PL. The difference between these is the plasticity index, PI = LL – PL. Normally, early indication on the compressibility of soil can be given by the natural moisture content which can be defined as the moisture content of natural undisturbed soil in situ and values from Atterberg Limit test. According to Raman et al. (1990), clay is very soft and compressible if the in situ moisture content is very close to or greater than the liquid limit.(Nur, 2008)

At the end of the study, the outcome will be the empirical relations. Empirical relations are an obvious step in data analysis when soil engineering practice relies heavily on soil parameters which can be easily determined. Generally, an empirical design relation is one that is based solely on the results of experiments or experience. Observations are used to establish correlations between the inputs and the outcomes of a process. These relationships generally do not have a firm scientific basis, although they must meet the tests of engineering reasonableness. Empirical approaches are often used as an expedient when it is too difficult to define theoretically the precise cause-and-effect relationships of a phenomenon. The principal advantages of empirical relation approaches are that they are usually simple

to apply and are based on actual real-world data. Their principal disadvantage is that the validity of the empirical relation is limited to the conditions in the underlying data from which they were inferred.

1.2 Aim and Objectives of Study

Three objectives have been set on why the study is carried out. They are:

1. To evaluate soil properties collected obtained from collected soil samples.
2. Established empirical correlation between compressibility characteristics and physical soil properties of fine grained soils in Peninsular Malaysia.
3. Comparison with the previous published correlations.

1.3 Scope and Limitation of Study

In terms of scope of study, the study was based on data collected from a few sites in various regions in Peninsular Malaysia such as, the proposed construction of upgrading Damar Laut Road to Changkat Jering, Perak, Bukit Kemuning Road to Taman Sri Muda, Shah Alam and Ayer Keroh Road to Melaka City. Soil investigation and laboratory test have been carried out by IKRAM Sdn.Bhd.,commercial laboratories and soil investigation contractors. The author has no control of the data obtained. The correlations that have been obtained from the study are correlation between compressibility characteristics with physical soil properties. The correlations have been analyzed limited to published correlations of compressibility characteristics with physical soil properties.

When comes to limitation, in general, there are other compressibility characteristics likewise coefficient of secondary consolidation, Cα, coefficient of consolidation, Cv, coefficient of compressibility, a_v, coefficient of volume

compressibility, *mv*, preconsolidation pressure, Pc, overconsolidated ratio, OCR, and initial void ratio, e_0 .Nevertheless, all the mentioned above will not take into consideration in this study.

1.4 Importance of the Study

To overcome the problems related to settlement and stability which frequently occurs nowadays, knowledge and understanding of geotechnical properties of fine grained soil is very important. The correlations obtained from the study not only can be used at the study area but also at other similar soil condition.

1.5 List of Chapters

The chapters that are included in this report are:

- Chapter 1 discussed on why the study is being carried out, the aim, objectives and the scope and limitation.
- Chapter 2 presented on the basic concept of compressibility of soil.
- Chapter 3 detailed out on the methodology used to carry out this study.
- Chapter 4 is on the data that has been collected and the analyses done on the data.
- Chapter 5 is the last chapter and concludes this study and presented the suggestions and also the recommendations for further study.

REFERENCES

Aysen, L.A.V., Atilla, M. (2001). Regression Analysis of Soil Compressibility. *Turkish Journal of Engineering & Environmental Science*. pp.101-109.

Azhar, S.A.T. (2004). *Engineering Characteristics, Mineralogy and Microstructure for Soft Clays in Peninsular Malaysia*. Thesis for Masters of Engineering (Civil-Geotechninc), Universiti Teknologi Malaysia, Skudai. In Bahasa Malaysia.

Balasubramaniam, A.S. and Brenner, R.P. (1981). *Consolidation and Settlement of Soft Clay. Dlm. Brand, E.W. and Brenner, R.P. Soft Clay Engineering.* (pp.481-566).Amsterdam : Elservier Scientific Publishing & Company.

Chong, S.Y. (2010). *Correlation Between Compression Index and Basic Soil Parameters for Samarahan Alluviums in Sarawak*, Thesis for PhD. (Civil-Geotechnic), University Teknologi Malaysia, Skudai.

Coduto, D.P. (1999). *Geotechnical Engineering Principles and Practices*. USA : Prentice Hall.

Das, B.M. (2002). *Principles of Geotechnical Engineering*. (5th Edition). USA : Brook/Cole Thomson Learning.

Head, K.H. (1992). *Manual of Soil Laboratory Testing. Volume 1 : Soil Classification and Compaction Tests*. (2nd Edition). New York : John Wiley & Sons.

Head, K.H (1994). *Manual of Soil Laboratory Testing. Volume 2 : Permeability, Shear Strength and Compressibility Tests*. (2nd Edition). New York : John Wiley & Sons.

Hussein, A.N. (1995). *The Formation, Properties and Behaviour of Coastal Soft Soil Deposits at Perlis and Other Sites in Peninsular Malaysia*. Thesis for PhD. University of Stratchlyde.

Jeremy, L.W. (2006). *The Comparison of Soil Classification between Dry and Wet Sieving on Coarse-, Medium-, and Fined-Grained Soils Adopting BSCS and USCS,* Thesis for Degree of Civil Engineering Universiti Teknologi Malaysia, Skudai.

Marto, A., Kasim, F., & Yusof, M. (2004). Characterization of Malaysia Granite Residual Soils for Geotechnical and Construction Engineering. *Civil Engineering Journal*. 16(2), 1-14.

Norziaty, M.N. (2007). *Correlations Between Compressibility Characteristics and Physical Properties of Cohesive Soil*. Thesis for Masters of Engineering (Civil-Geotechnic), University Teknologi Malaysia, Skudai.

Nur, M. O. (2008). *The Engineering Properties Of Soft Soils At Northern Region of Malaysia*, Thesis for Degree Civil Engineering, Universiti Teknologi Mara.

Ramamoorthy, S. (2007). *Correlation of Engineering Characteristics of Marine Clay from Central West Coast of Malaysia*. Thesis for Masters of Engineering (Civil Geotechninc). Universiti Teknologi Malaysia, Skudai.

Skempton, A. (1944). Notes on the compressibility of clays. *Quarterly Journal of the Geological Society of London*, 100(2), 119–135.

Tan, Y. C., Gue, S.S., Ng, H.B., Lee, P.T. (2000). Some Geotechnical Properties Of Klang Clay. *Seminar on Ground Improvement – Soft Clay (SOGISC)*. August 23-24. Dewan Jumaah, UTM, Kuala Lumpur.

Whitlow, R. (1995). *Basic Soil Mechanics*, (3rd Edition). United Kingdom : Addison Weslet Longman Limited.

Wroth, C.P. & Wood, D.M. (1978). The correlation of index properties with some basic engineering properties of soils. *Canadian Geotechnical Journal*, 15, 137–145.