SHEAR STRENGTH IMPROVEMENT OF PEAT SOIL DUE TO CONSOLIDATION

VIVI ANGGRAINI

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

NOVEMBER 2006

Especially for papa and mama, Abdullah and Rasiha.

My beloved siblings Lutfi Machmud and Rabbi Quraisyah."

You give me strength to carry on.

ACKNOWLEDGEMENT

The author would extremely grateful to her supervisor, Dr. Nurly Gofar for her enthusiastic guidance, invaluable help, and encouragement in all aspects of this Master Project. Her numerous comments, criticisms and suggestions during the preparation of this project are gratefully acknowledged. Her patience and availability for any help whenever needed with her heavy workload is appreciated.

I would like to thank fellow postgraduate students in Civil Engineering for their discussions, support, and social interaction during my study. My appreciation is also extended to all academic and non-academic member of Civil Engineering, for their warm hearted co-operation during my stay in of Universiti Teknologi Malaysia. Acknowledgement is not complete without thanking to En.Zulkifli, En.Azman Kassim and Lee Min lee in UTM Geotechnical Laboratory for assisting either directly or indirectly in my laboratory work. Their assistance enabled me to complete this project report on time. Ka Yulinda thanks for the data and nice advice to improve my Thesis. Mohamed Muftah and Mukhtar Abukhettala, my classmate and my brother in Malaysia, thank for your kindness and always support me when I felt down in my study. Really thankful for my family at L12 KTHO; Farah , Bu jati, ka Mala, ka Isal, Sylvia and Aliya Asraff.

Heartfelt acknowledgements are expressed to my father. Without his sacrifices, guidance, support, and encouragement in providing my higher education, I may never have overcome this long journey in my studies. Heartfelt and sincere acknowledgements are extended to my mother for her sacrifices, support and encouragement and for my siblings for their friendship and support during the difficult times of my study. Very special and sincere gratitude is offered to Uda for his constant support and patience, especially at various sufferings during my Master programme.

ABSTRACT

One major problem related to construction on peat deposit is the low shear strength of the soil. However previous researches have shown that the shear strength could increase significantly upon consolidation and hence some improvement methods have been developed to increase the bearing capacity of the peat deposit by utilizing consolidation pressure. The aim of this project is to evaluate the increase of shear strength of fibrous peat due to application of consolidation pressure. The initial undrained shear strength was obtained from vane shear test in-situ. For this study, samples were prepared under several consolidation pressures: 50 kPa, 100 kPa, 150 kPa, and 200 kPa. The shear strength of the samples was obtained by triaxial compression test under unconsolidated undrained condition. The results proved that there is an increase in shear strength due to application of consolidation pressure. The initial shear strength predicted based on the equation developed for the results of Triaxial testing agreed with the in-situ strength obtained by field vane shear test, however the ratio of strength increase for peat in this study is 0.06 which is very low as compared to published data.

ABSTRAK

Satu dari masalah utama dalam pembinaan yang melibatkan tanah gambut adalah kekuatan ricih yang rendah dari tanah. Walaubagaimanapun kajian terdahulu telah menunjukkan bahawa kekuatan ricih tanah akan meningkat apabila dikukuhkan, maka kaedah pembaikan telah dibangunkan untuk meningkatkan keupayaan galas tanah gambut dengan meningkatkan tekanan pengukuhan. Tujuan projek ini ialah untuk menilai peningkatan kekuatan ricih untuk tanah gambut berserat disebabkan oleh aplikasi tekanan pengukuhan. Kekuatan ricih awal diperoleh daripada ujian ricih bilah ditapak. Untuk kajian ini, sample disediakan dibawah tekanan pengukuhan yang berbeza iaitu: 50 kPa, 100 kPa, 150 kPa dan 200 kPa. Kekuatan ricih bagi sampel diperoleh dari ujian pemampatan dalam radas tiga paksi dibawah keadaan tak terkukuh tak tersalir. Keputusan kajian menunjukkan bahawa adanya penambahan dari kekuatan ricih tanah kerana penggunaan tekanan pengukuhan. Kekuatan ricih mula yang diramalkan berpandukan kepada persamaan yang diwujudkan untuk keputusan kekuatan ricih dari ujian tiga paksi adalah sama dengan keputusan kekuatan ricih bilah ditapak, walaubagaimanapun nisbah kekuatan tanah gambut bertambah bagi kajian ini iaitu 0.06, adalah sangat rendah jika dibandingkan dengan data terdahulu.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

A	-	Pore pressure parameter
B	-	Pore pressure parameter
c	-	Cohesion value of soil
c'	-	Apparent cohesion in terms of effective stress
c_u	-	Undrained shear stress
$c_{u\ (mod)}$	-	Undrained shear stress modify
$c_{u\ (initial)}$	-	Undrained shear stress initial
d	-	Diameter blade of vane
h	-	Height blade of vane
q_f	-	Deviator stress
s_u	-	Insitu undrained shear strength
T	-	Torque
ϕ	-	Angle of internal friction soil
ϕ_u	-	Undrained angle of internal friction soil
τ_f	-	Shear stress at failure of soil
τ	-	Shear stress of soil
ε	-	strain
Δu	-	Change in pre pressure
$\Delta\sigma$	-	The change in total normal stress

$\Delta\sigma'$	-	The change in effective stress
σ_n	-	Normal stress due to applied vertical load
σ_1	-	Major principal stresses
σ_2	-	Intermediate principal stresses
σ_3	-	Minor principal stresses
σ_1'	-	Effective major principal stresses
σ_3'	-	Effective minor principal stresses
$\sigma_1-\sigma_3$	-	Principal total stress difference
$\sigma_1'-\sigma_3'$	-	Principal effective stress difference
σ_1/σ_3	-	Principal effective stress ratio
σ_1'/σ_3'	-	Principal total stress ratio
λ_{cu}	-	Coefficient ratio of shear strength
λ	-	Coefficient ratio of shear strength

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction

Major construction problem related to structure on soft soils such as peat are low shear strength and large compressibility. In particular, the high water content and low dry density gives peat exceptionally low shear strength. In addition, since peat is still in the process of decomposition, the stability of any structure build on peat soil would be affected by the overall change of peat soil with time. Hence, the construction over peat deposit may experience bearing capacity failure and excessive settlement. Because of the low shear strength and hence the low bearing capacity, a surface foundation on peat has to be generally improved before any engineering works can commence. Conventional solution is to replace the poor soil by suitable imported fill materials. This practice is naturally very expensive. In addition, there must be an environmentally acceptable location to waste excavated soil within an economically acceptable haul distance (Jarret, 1997). This method also need maintenance work related to long term settlement and horizontal movement (Magnan, 1994).

Simple preloading and surcharge is used as an alternative method to reduce post construction settlement. The surcharge is left in place until most of preliminary settlement is completed before the thickness of the fill is reduced to the thickness of final design. Problem related to this method is the initial thickness of the fill is very small due to low shear strength, thus application of surcharge preload takes a significant amount of time to complete. A more realistic method is the stage construction method in which the thickness of the fill could be improved subsequently to the increases of the shear strength of the soil. Other effective method for the improvement of peat deposit is the application of vertical drain which is effective as long the possibility of peat particle blocking the drainage path could be minimized. However, the effectiveness of the strip drains may be additionally limited by deterioration and buckling of the drain and the consequent decline in discharge capacity.

Stage construction on peat deposit is performed by utilizing the excavated soil from canals on the left and right sides of the construction site. The excavated soil is used as fill material on the construction area to increase the overburden pressure and subsequently increase the shear strength of the soil and reduce the amount of post construction settlement. The geotextile and geogrids can be laid on the top of the organic soil fill as separator to reduce loss of good quality fill material and to distribute contact pressure on the embankment base. At the same time, the geotextile and geogrids serves surface reinforcement.

The fill induces a consolidation pressure, thus increases the shear strength of the peat. Laboratory compression tests have to be performed in order to estimate and take into account the rate of increase of undrained shear strength as a function of consolidation and subsequent densification of peat. The undrained shear strength of peat is typically determined by vane shear in the field and undrained triaxial compression test in the laboratory. The ratio of increase can be applied to the in-situ shear strength obtained from vane shear test. Therefore the thickness of fill for each stage can be increased as a consequence of the increase in shear strength.

Based on his study, Magnan (1994) suggested a ratio of shear strength increase due to increase in overburden pressure of 0.5 for peat soil. Furthermore, Edil and Wang (2000) collected normalized undrained strength (c_u/σ'_{3c} or c_u/σ'_{1c}) as a function of organic content for all peat and organic soil. The study showed that fibrous and amorphous peat presents no perceptible differences and gives an average normalized undrained strength to consolidation pressure of 0.59 with most of the data falling between 0.5 and 0.7. These c_u/σ'_v values appear unusually high compared to the typical values for inorganic clays that lay between 0.2 and 0.25. Chen and Tan (2003) found that the ratio of shear strength increase due to consolidation for clay obtained from Klang, Malaysia is 0.25. No published data for the ratio of shear strength increase for peat found in Malaysia.

1.2 Problem Statement

Initial stability of construction on peat is the most critical problem due to low undrained shear strength of peat in normally consolidated state and hence low bearing capacity of foundation soil. However some researches found that shear strength could increase significantly upon consolidation. This study evaluates the increase of shear strength of fibrous peat due to consolidation pressure by comparing the results of triaxial compression test done on samples prepared under specified consolidation pressures at laboratory to the initial strength obtained from field vane test.

1.3 Objectives of study

The objectives of this study are:

1. To study the effect of consolidation pressures on shear strength increase of peat.
2. To quantify the ratio of shear strength increment of peat soil obtained in Pontian based on triaxial compression test under UU condition.

1.4 Scope of Project

The study focused on the shear strength characteristics of fibrous peat soil and the increase of the shear strength due to consolidation. The soil samples were remolded samples prepared from peat samples obtained at Kampung Bahru, Pontian, Johor. The triaxial compression test (BS 1377-7) was used to determine the shear strength parameters. The results were compared with published data.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATION

5.1 Conclusions

The study on the shear strength improvement of peat due to application of consolidation pressure was conducted on this project for fibrous peat sampled from Pontian, Johor. The objective was to find the ratio of strength increase with the increase in consolidation pressure. The following conclusion can be derived from this study:

1. Consolidation pressure applied to the soil prior to Triaxial Compression Test under Undrained Unconsolidated condition have the effect of increasing the shear strength obtained from the test. The average value of undrained shear strength from test results are 13 kPa, 15.66 kPa, 21 kPa and 21.66 kPa under consolidation pressure of 50 kPa, 100kPa, 150 kPa, and 200 kPa respectively.

2. The relationship derived from the Triaxial test results shows an initial undrained shear strength equal to that obtained from field vane shear test (c_u = 10.10 kPa), with the ratio of strength increase 0.06 which is very low compared with the published data.

5.2 Recommendation

Improvement of fibrous peat should be recommended only after careful evaluation on the mechanical properties of the soil. As such, it is recommended that further study involving field investigation on the fibrous peat soil need to be done to justify the laboratory investigation on the soil from this study. Field investigation on the soil is beyond scope of this study. Regardless of the type of soil investigation performed on fibrous peat soil, the shear strengths theory should be emphasized since it provides a reliable basis of economic considerations of soil improvement.

REFERENCES

Adam, J. (1965). The Engineering Behavior of a Canadian Muskeg. *Proc., 6th Int.Conf. Soil and Found. Engrg*. Montreal, Canada, 1 : 3-7.

Ajlouni, M. A. (2000) *Geotechnical Properties of Peat and Related Engineering Problems*. Ph.D Thesis. University of Illinois at Urbana Champaign.

Al-Raziqi, A. A., Huat, B. B. K. and Munzir, H. A. (2003). Potential Usage of Hyperbolic Method for Prediction of Organics Soil Settlement. In *Proceeding of 2nd International Conferences on Advances in Soft Soil Engineering and Technology*, ed. Huat et al., Putrajaya Malaysia, 439-445.

Bishop, A. W. (1962). *Measurement of Soil Properties in the Triaxial Test*. Edward Arnold Limited. London.

Bowles, J. E. (1979). *Physical and geotechnical Properties of Soils*. Mc Graw Hill. United State of America.

Berry, P. L. (1983). Application of Consolidation Theory for Peat to the Design of a Reclamation Scheme by Preloading. *Q. J. Eng. Geol*., London, 16(9):103-112.

British Standards Institution (1990). *Methods of Test for Soils for Civil Engineering Purposes*. London,BS 1377.

Chynoweth, D. P. (1983). A novel Process for Biogasification of Peat. *Proc. Int. Symp. On Peat Utilization*, Bemidji, Minnesota, 159-171.

Cameron, C. C., Esterle, J. S. and Palmer, C. A. (1989). The Geology, Botany and Chemistry of Selected Peat Forming Environments from Temperate and Tropical Latitudes, *Int. J. Coal geology*, (12):105-156.

Craig, R. F. (1992). *Soil Mechanics*. 6th Edition. Spon Press. London.

Colleselli, F., Cortellazo G. and Cola, S. (2000). Laboratory testing of Italian peaty soils, *Geotechnics of High Water content Materials*, ASTM STP1374, ed. Edil and Fox, 226-242.

Cortellazo, G. and Cola, S. (2005). The shear strength behavior of peaty soils. *Geotechnical and Geological Engineering*. . Italy 23:679-695.

Dhowian, A.W. and Edil, T. B. (1980). Consolidation Behavior of Peats. *Geotech Testing J.*, 3(3):105-114.

Davis, J. H. (1997). The Peat Deposits of Florida their Occurrence, Development and Uses. *Florida Geological Survey*. Geological Bulletin, 3.

Edil, T. B. and Dhowian, A. W. (1981). At-rest Lateral Pressure of Peat Soils. *Conf. on Sedimentation and Consolidation Model*, ASCE, San Fransisco, 411-424.

Edil, T. B. (2003). Recent advances in geotechnical characterization and construction over peats and organic soils, *Procedings 2nd International Conferences on Advances in Soft Soil Engineering and Technology, Putra Jaya*, Malaysia,3-24.

Hanrahan, E. T. (1954). An Investigation of Some Physical Properties of Peat. *Geotechnique*, London, England, 4(2):108-123.

Head, K.H. (1981). *Manual of Soil laboratory Testing*, Volume 1,2 and 3. Pentech Press, London.

Holtz, R. D. and William, D K. (1981). *An Introduction to Geotechnical Engineering*. Prentice Hall. New Jersey.

Hobbs, N. B. (1986). Mire Morphology and the Properties and Behavior of Some British and Foreign Peats. Q. I Eng. Geol., London, 19(1): 7-80.

Huat, B. B. K. (2004). *Organic and Peat soil Engineering*. Univ Putra Malaysia Press.

Kogure, K., Yamaguchi, H. and Shogaki, T. (1993). Physical and Pore Properties of Fibrous Peat Deposit. *11th Southtest Asian Geotechnical Conferences*. Singapore .4(8): 135-139.

Lechowicz, Z., Szymanski, A. and Baranski, T. (1996). Laboratory Investigation. *Proc. Embankments on Organic Soils, Delft*, Netherlands, 167-179.

Macfarlane, I. C. (1969). Engineering Characteristics of Peat. *Muskeg Engineering Handbook. Proc*., Ottawa, Canada, 3-30.

Muskeg Engineering Handbook. (1969). University of Toronto Press.

Mandal J. N. (1995). *Soil Testing in Civil Engineering*.A.A Balkema. Rotterdam.

Mochtar, N. E. (1997). Perbedaan Perilaku teknis Tanah Lempung dan Tanah gambut (Peat soil), Jurnal Geoteknik, Himpunan Ahli Tanah Indonesia, 3(1): 16-34.

Noto, S. (1991). *Peat Engineering Handbook*. Civil engineering Research Institute Hokkaido development Agency, Prime Minister’s Office, Japan.

Nurly Gofar and Yulindasari Sutejo. (2005). Properties of Fibrous Peat. Senai (Malaysia): *Seminar Penyelidikan Kejuruteraan Awam (SEPKA)*, Universiti Teknologi Malaysia (UTM).

Soper, E. K. and Obson, C. C. (1922). The Occurrence and uses of Peat in the United States, U.S.G.S. Bulletin. 728: 1-207.

Schelkoph, G. M. and Hasset, D.J. (1983). A Comparative Study of Preparation and Analytical Methods for Peat. *Testing of Peat and Organic Soils*, ASTM STP 820, 99-110.

von Post, L. (1992). Sveriges Geologiska Undersoknings Torvinventering Och nagre av Dess Hittills Vunna Resultat, Sr.Mosskulturfor. Tidskr 1:1-27.

Whitlow, R. (2001). *Basic Soil Mechanic*. 4^{th} edition. Pearson Education Limited. England.

Yamaguchi, H., Ohira, Y., Kogure, K. and Mori, S. (1985). Undrained Shear Characteristic of Normally Consolidated Peat Under Triaxial Compression and Extension Conditions. *Japanese Society of Soil Mich. And Found. Engrg*., 25(3):1-18.