SOFT GROUND IMPROVEMENT USING PILE EMBANKMENT

NOR ASHIKIN BINTI YAHAYA

A project report submitted in partial fulfilment of the
requirement for the award of degree of
Master of Engineering (Geotechnic)

School of Civil Engineering
Faculty of Engineering
Universiti Teknologi Malaysia

JANUARY 2019

DEDICATION

This project report is dedicated to my late father, who taught me that the best kind of knowledge to have is that which is learned for its own sake. It is also dedicated to my mother, who taught me that even the largest task can be accomplished if it is done one step at a time.

ACKNOWLEDGEMENT

In preparing this project report, I was in contact with many people, researchers, academicians, and practitioners. They have contributed towards my understanding and thoughts. In particular, I wish to express my sincere appreciation to my supervisor, PM. Ir. Dr. Azman Bin Kassim, for encouragement, guidance, critics and friendship. I am also very thankful to my parents and husband for their guidance, advices and motivation. Without their continued support and interest, this Master's Project Report would not have been the same as presented here.

I am also indebted to Universiti Teknologi Malaysia (UTM) for funding my Master study. Librarians at UTM also deserve special thanks for their assistance in supplying the relevant literatures.

My fellow postgraduate student should also be recognised for their support. My sincere appreciation also extends to all my colleagues and others who have provided assistance at various occasions. Their views and tips are useful indeed. Unfortunately, it is not possible to list all of them in this limited space. I am grateful to all my family member.

ABSTRACT

Construction on soft ground area is a great challenge to the field of Geotechnical Engineering. Soft ground area often affected by stability and settlement problems. The soft ground cannot take external load without having large deformations. Thus, soft soil improvement is needed. Soft ground improvement methods have been used in many parts of the world to minimize these problems. The problem could be minimized by many techniques such as Remove and Replace (R&R), Preloading technique with or without Prefabricated Vertical Drain and Pile Embankment. This study aimed to determine the suitable method to improve the soft ground in area of Lahad Datu, Sabah. This study conduct the interpretation of bore log obtains from the site investigations at the area of construction site need to be develop. From the bore log interpretation, the subsoil profile of this area consist of the very soft soils to soft soils which comprise a clayey soils and silty soils with varying thickness below the ground surface. The characteristic of soft soil is non-uniform and complicated which have high moisture content and loose sand deposit because this area is located near to the river. This research also analysed the primary consolidation settlement based on one-dimensional consolidation theory by Terzaghi (1984) due to the expected loading on site. This research has focus to eliminate the excessive settlement due to the heavy fill embankment and high bearing capacity. The settlement under 8.0m permanent fills about 473.4mm shows the settlement at this project area is a very excessive settlement. The Remove and Replace R&R method is not suitable to implement for this study because the soft soils layer is thicker which is about 15.0m of soft soils need to be removed and another 8.0 of embankment need to be filled to reach the finished level. The prefabricated vertical drain (PVD) method also not suitable as ground improvement method for this study area because PVDs are used to shorten the surcharging period and accelerate settlement not to reduce it. PVDs cannot load the high bearing capacity which is about 160 kN/m^2 of loading need to support for embankment fill. Therefore, this study was decided to choose the pile embankment to load heavy fill embankment and to eliminate the effect of excessive settlement.

ABSTRAK

Pembinaan di kawasan tanah yang lembut adalah satu cabaran besar dalam bidang Kejuruteraan Geoteknik. Kawasan tanah yang lembut sering dipengaruhi oleh masalah kestabilan dan mendapan tanah. Tanah lembut tidak dapat menanggung beban luaran tanpa mengubah bentuk tanah. Oleh itu, penambahbaikan tanah lembut diperlukan. Kaedah pembaikan tanah lembut telah digunakan di kebanyakan dunia untuk mengurangkan masalah kegagalan tanah lembut. Antaranya ialah masalah ini dapat dikurangkan dengan pelbagai kaedah seperti 'Remove and Replace' (R & R), teknik 'Preloading' dengan atau tanpa 'Prefabricated Vertical Drain' (PVD) dan 'Pile Embankment'. Kajian ini bertujuan untuk menentukan kaedah yang sesuai untuk penambahbaikan tanah lembut di kawasan Lahad Datu, Sabah. Kajian ini dijalankan dengan penafsiran 'bore log' yang diperoleh daripada penyiasatan tanah di kawasan tapak pembinaan yang akan dibangunkan. Kajian ini juga menganalisis kaedah mendapan menggunakan 'One-Dimensional Consolidation Theory' oleh Terzaghi (1984) berdasarkan beban yang akan ditanggung oleh tanah lembut tersebut. Kajian ini juga memberi tumpuan untuk menghapuskan mendapan yang berlebihan disebabkan oleh beban tambakan tanah yang besar dan keupayaan galas tanah yang tinggi. Jumlah mendapan pada 8.0m tambakan tanah yang kekal sebanyak 473.4mm menunjukkan mendapan yang akan berlaku di kawasan projek ini adalah mendapan yang sangat berlebihan. Kaedah R & R adalah tidak sesuai dilaksanakan untuk kajian ini kerana lapisan tanah lembut yang mempunyai ketebalan 15.0m perlu dikeluarkan dan perlu ditambak dengan 8.0m tanah yang lebih baik untuk mencapai aras formasi yang diperlukan. Kaedah (PVD) juga tidak sesuai digunakan sebagai kaedah pembaikan tanah lembut di kawasan ini kerana PVD digunakan untuk memendekkan tempoh surcaj dan mempercepatkan mendapan tetapi tidak mengurangkannya. PVD juga tidak boleh menanggung keupayaan galas yang tinggi iaitu sebanyak 160 kN/m2 beban yang akan ditanggung untuk menanggung tanah yang ditambak. Oleh itu, kajian ini telah menggunakan kaedah 'Pile Embankment' untuk penambahbaikan tanah lembut bagi menanggung beban tambakan tanah yang besar dan untuk menghapuskan mendapan yang berlebihan.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

PWD	-	Public Work Department
R&R	-	Remove and Replace
PVD	-	Prefabricated Vertical Drain
DSM	-	Deep Soil Mixing
SI	-	Soil Investigation
EGL	-	Existing Ground Level
BGL	-	Below Groun Level
BH	-	Bore Hole
RL	-	Ground Level
FL	-	Finish Level
RC	-	Reinforcement Concrete
LL	-	Live Load
IL	-	Imposed Load
SPT-N	-	The sum of the number of blows require for the second and third 150mm to a depth of 450mm in Standard Penetration Test
FOS	-	Factor of Safety

LIST OF SYMBOLS

C_c	-	Compression Index
C_s	-	Recompression Index
H	-	Thickness of soft layer
P_c	-	Preconsolidation Pressure
OCR	-	Over consolidation ratio
H_d	-	Drainage length
γ_{bulkpf}	-	Surcharge Fill
γ_{bulk}	-	Unit weight of soft ground
e_o	-	Initial Void Ratio
CR	-	Compression Ratio
f_y	-	Grade Of Steel
σ_t	-	Total vertical stress
U_w	-	Pore Water Pressure
σ' / P'_o	-	Initial vertical effective stress
Δ_q	-	Change in stress
S_{cp}	-	Primary consolidation settlement
f_{cu}	-	Concrete Grade
Q_k	-	Live Load
G_k	-	Imposed Load
D	-	Effective Depth
Z	-	lever arm
A_s	-	reinforcement area
v	-	Allowable Shear

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background of The Study

Geotechnical Engineer has always been a challenge of weak foundation especially on soft soils. Soft soils are defined as soils with large amount of fine particles such as clayey and silty soils with high moisture content, peat or loose sand deposition and located near or below the water table (Kamon, M. and Bergado, 1991, p.526). Soft soil is non-homogeneous with particles of highly variable and complex properties unlike other construction materials (Rohayu Che Omar and Rashid Jaafar, 2000, p. 316). The typical characteristic of soft soils such as low shear strength, low permeability and high compressibility will make them inadequate to support additional load of infrastructure built on them (N O Mohamad et. Al, 2002, p.1).

The problem with soft soil in engineering construction always occurs even during pre or post construction. This is because the soft soil cannot meet the specification required for construction such as bearing capacity of soft soil is too weak to support structure above. Construction problems normally reported on soft soils area are low bearing capacity, excessive long term constructions settlement and instability in excavation and embankment construction (N O Mohamad et. Al, 2002, p.1). The characteristics and engineering properties of the soft soils was determined to improve understanding of the problems. Normally, the original soil s at a construction site are not always suitable to support structure such as dams, bridges, highways and buildings. Therefore, if the structure constructed on the soft soil, problems will occur after the construction completed. The structure will have high settlement and crack will occur because of this settlement.

Normally, the deformation of soil due to applied stresses is a one of the settlement problem. As a result of this deformation, the load geometry carrying system will have changed, a part of the fill material under the high ground water level will become buoyancy which will affected the soil stability of the soil and total surcharge loading (Balasubramaniam A S and Brenner R P, 1981, p.481). The settlement of structure usually happens by the movement of the soft soil deal to the change of ground water table and surcharge. If the settlement is unrest, the crack of the structure will become bigger and the structure will start exhibit movement without any reason. Settlement problems can be preventing with the understanding of the characteristics of the soil using bore log, recognizes the variety of soil types and finding the right solution for the soils that carries the structure loads and finding potential problems.

The suitable soil improvement techniques are required to overcome soft soils problems which can increase the bearing capacity, reduce post construction settlements and reduce liquefaction risk. The engineering characteristic of soft soil is well studied and recorded through researches and field trials.

1.2 Problem Statement

Excessive settlement along bridge approach is a one of geotechnical engineering problem found in the lower region of Sabah. The mechanism of excessive settlement is due to the soft soil condition because the project is located near to the river and expected high loads applied on the soft soil. To overcome the excessive settlement problem, engineers have developed different type of soft ground improvement. The settlement of foundation on soft soil construction has become one of the key problems for foundation design because of the less suitable land for development of civil engineering construction. The problem could be minimized by many techniques such as Remove and Replace (R&R), Preloading technique with or without Prefabricated Vertical Drain and Pile Embankment. Therefore, the selection of most suitable method for soft soil treatment need to be choose base on the soft soil condition on site and the settlement value due to the heavy fill embankment.

Removal and replacement of soil is the simplest and oldest methods which improve the soil bearing conditions. By replace the poor soils such as medium or soft clay and organic soil with more suitable materials such as crushed stone, sand or gravel as well, nearly any soil can be used in fills will improve the foundation condition. However, some soils are not suitable to use as a replacement layer if there are hard to compact than others material when used as a replacement layer (Sherif Abdel Salam, 2007). The use of removable and replacement of soil for shallow foundation treatment can effectively increase the bearing capacity and reduce settlement of soil. The success of this method depends on the good workmanship for replacement of suitable material. The effectiveness of using various types and thickness of replacement material can increase the bearing capacity and reducing consolidation settlement of soft soil. Gnerally concluded with increasing the thickness of the replacement layer, the vertical settlement decreased (Marwa Abdel Fatah, p. 12).

If the removal and replacement method is not suitable, preloading or pre compression method where just easilyy to place a surcharge fill as loading on top of the soil that need large settlement to happen before construction of the structure. The fill can be removed after the desired consolidation settlement achieved. In general, this method is effective and adequate in clayey soil. Since clayey soils have low permeability, so the desire consolidation in clayey soils takes too long time to happen even with very high of surcharge load. Hence, preloading may not be a possible solution with tight construction schedule. Hence, the prefabricated vertical drains (PVD) may be used to reduce the surcharge time but not to accelerate settlement. Pore water will flow laterally to the nearest vertical drain instead of travel vertically to the permeable drain layer. Hence, the drainage distance decreased. Therefore, this can decrease the distance of the drainage flow. The surcharging time will decrease whenever distance between the vertical drain become closer (Won Pyo Hong & Seongwon Hong, 2017). The temporary surcharge is developed by putting the embankment material to the height in excess of the final design height, normally are used to expedite the pre compression rate. If the temporary load is bigger, the rate of pre compression may become faster. Besides, surcharge is also controlled by stability

consolidation and the availability of sufficient fill. The cost of earthwork will increase if more placement and subsequent removal of a temporary surcharge is needed. In some condition, the slope of the embankment may need to be flattened or supported by or install toe berms to maintain stability of the foundation of the embankment which will also increase the construction cost.

To provide an economical solution to the problem of constructing embankments solution on the soft soils, the piled embankments may be used for the alternative. A pile embankment is an embankment supported by driven into in the soft soil. A pile embankment constructed by driving piles with a grid formation layout in a soft soil through a required depth to reach a hard stratum of firm soil or bedrock. The piles can overcome the uneven surface settlements problem that sometimes may happen in embankment supported by pile without reinforcement. Piles embankment has been used to transfer large embankment loads through soft clay deposits to a firm layer. The embankment load may be transferred directly to the pile through a slab. Lateral flows of the soft soil affected by the embankment loads are effectively prevented through the soil arching mobilize in pile-supported embankments.

There three types of pile supported embankment these being slab, cap beams and isolated caps placed on heads of the piles. In case of the pile slab method, the pile is uniformly and appropriately installed in several rows in soft soils, a concrete slab covers the head of the piles, and embankment materials are filled on the concrete slab (Won Pyo Hong & Seongwon Hong, 2017). The reduction of approach embankment settlement is cited as a specific application of embankment piles. In this method, the influence factor such as height of embankment, depth of soft ground, elastic modulus of soft ground and stress concentration are investigated. At the end, both the differential and total settlements of the embankment can be eliminated (Low, B.K., Tang, S.K., Choa, V., 1994).

1.3 Objectives of the Study

In general, this study will be carried out to understand the behaviour of soft soil. In more specific terms the objectives of this study are as follows:

a. To interpret bore log due to the soil profile and properties on site.

b. To calculate the settlement of soft soil base on the expected loading on site.

c. To design the most suitable method to improve soft ground on site due to heavy fill embankment applied on the soft ground.

1.4 Scope of the study

The scope of this study is a development of bridge constructions in an area in Lahad Datu, Sabah. This study involves only the soil improvement for approaching lane connected to the bridge which is located near to the river. Boreholes were carried out to obtain the subsoil information and necessary soil parameters for planning and assessment of the soil treatment design. The selection of soils treatment based on the settlement value calculated on the expected loading on site. Therefore, the pile embankment design is the most suitable method to treat the soft soil due to high load applied on the soft soil.

1.5 Significance of the Study

In engineering construction, many methods are applied for the ground improvement of the soft soils. Mostly in Malaysia, soft ground usually has coastal alluvial soil which extremely soft and easy to find at costal area. Many problems can be happened on the soft ground soil in construction area especially at road and building construction. if not treated properly, settlement will be occurring at the soft

ground. The weak and compressible of soft ground leads to embankment failure and collapse. Hence, the suitable method to improve the soft soils is the pile embankment. The pile embankments are applied on soft soils and have various advantages. Such as the piled embankment can be constructed rather fast and has a small settlement after construction or is even settlement-free. Another advantage is that a pile embankment can be built next to sensitive constructions.

REFERENCE

Annon., 1988. *Designing for soil reinforcement*. Technical publication, 1st Edition, Exxon Chemicals Geopolymers Ltd, UK.

Britton, E. & Naughton, P.J. 2008a. *The arching mechanism in piled embankments under road and rail*

Balasubramaniam A S and Brenner R P, 1981 *Consolidation and Settlement of Soft Clay, Soft Clay Engineering* (Development in Geotechnical Engineering), Elsevier Scientific Publishing Company, **20** 481 – 527.

Huat B B K, Othman K and Jaafar A A, 1995 *Geotechnical Properties of Malaysia Marine Clays*, Journal – Institution of Engineers Malaysia.

Huat B B K, Maail S and Mohamed T A, 2005 *Effect of Chemical on the Engineering Properties Of Tropical Peat Soil,* American Journal of Applied Sciences, Science Publication.

Low, B.K., Tang, S.K., Choa, V., 1994. *Arching in Piled Embankments.* Journal of Geotechnical Engineering 120 (11), 1917–1938.

Indraratna, B., Rujikiatkamjorn, C., Wijeyakulasuriya, V., McIntosh, G., and Kelly, R. 2010. *Soft Soils Improved By Prefabricated Vertical Drains: Performance and Prediction*. Symposium on New Techniques for Design and Construction in Soft Clays, 227-246.

Jabatan Mineral and Geosains Malaysia, 2010 *Garispanduan Pemetaan Geologi Kejuruteraan Kawasan Tanah Gambut dan Tanih Lembut*, Kementerian Sumber Asli dan Alam Sekitar.

Han, J. and Gabr, M.A. (2002). *A numerical study of load transfer mechanisms in geosynthetic reinforced and pile supported embankments over soft soil.* Journal of Geotechnical and Geoenvironmental Engineering, ASCE, 128(1), pp. 44-53

Kamon, M. And Bergado, D.T. 1991. *Ground ImprovementTechniques*. Proc. 91h Asian Regional Conf.Soil Mech.Found.Eng'g., Bangkok, Thailand, 2. 526-546.

Kaniraj S R and Josept R R, 2006 *Geotechnical Behavior of Organic Soils of Sarawak*, 4th International Conference Soft Soil Engineering, Vancouver, Canada.

Lawson, C.R., 2001. *Performance Related Issues Affecting Reinforced Soil Structures In Asia.* Keynote lecture, Proceeding of the International Symposium on Earth reinforcement, Fukuoka, Kyushu, Japan, pp 831 – 868.

Marwa Abdel Fatah, "*Improvement Of Bearing Capacity Of Soft Clay Soil Beneath Shallow Foundation Using Cohesionless Soil Replacement,"* Menoufiya University, Egypt, 2014.

Martin G. Taube, "Prefabricated Vertical Drains- the squeeze is on," Geo-Strata,Geo institute of ASCE, vol. 9, pp. 12,14,16, march/april 2008.

N O Mohamad, C E Razali1, A A A Hadi, P P Som, B C Eng, M B Rusli1 and F R Mohamad, 2002. *Challenges in Construction Over Soft Soil.* Case Studies in Malaysia Geotechnical Engineering Branch, Public Work Department of Malaysia, Kuala Lumpur

N O Mohamad, C E Razali1, A A A Hadi, P P Som, B C Eng, M B Rusli1 and F R Mohamad, 2015 *Challenges in Construction Over Soft Soil.* Case Studies in Malaysia Geotechnical Engineering Branch, Public Work Department of Malaysia, Kuala Lumpur

Reid W.M and Buchanan (1983), *Bridge Approach Support Piling, Proc. Conf. on Advance in Piling and Ground Treatment*, ICE London.

Rohayu Che Omar and Rashid Jaafar, 2000. *The Characteristics and Engineering Properties of Soft Soil at Cyberjaya, lnstitut Alam Sekitar Dan Pembangunan (LESTARI),* UKM Soil Centralab Sdn. Bhd, p. 316-317, Geological Society of Malaysia Annual Geological Conference 2000 September 8-9 2000, Pulau Pinang, Malaysia

Rojanathara, 1985, Rungarunanotai, 2003, Vardahanbuthi et. Al, 2010). *Settlement Observation along Bridge Approach Structure*, Sorasak Seawsirikul, Korchoke Chantawarangul and Barames Vardhanabhuti Department of Civil Engineering, Rajamangala University of Technology Isan, Khonkaen, Thailand.

T.Schweckendiek et al. (Eds.), 2015 *Evaluation of Differential Settlement Along Bridge Approach Structure on Soft Bangkok Clay*

Sherif Abdel Salam, "*The Effect Of Replacement Soil On Reducing Settlement Of Footing On Deep Soft Clay Using Numerical Approach*," Cairo University, Giza, Egypt, Thesis 2007.

Tan Y C and Gue S S, 2000 *Design and Construction Control of Embankment over Soft Cohesive Soils*, Seminar on Ground Improvement – Soft Clay, Kuala Lumpur, Malaysia.

Won Pyo Hong & Seongwon Hong (2017) *Piled Embankment To Prevent Damage To Pipe Buried In Soft Grounds Undergoing Lateral Flow,* Marine Georesources & Geotechnology