COMPARISON BETWEEN PREDICTED AND ACTUAL GROUND SETTLEMENT IMPROVED USING STONE COLUMNS

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I dedicate this project report to

All my family, the symbol of love and giving,

My friends who encourage and support me,

All the people in my life who touch my heart,

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ABSTRACT

Ground improvement is an important requirement in today's construction industry. One of the ground improvement techniques is stone column which reinforces the ground with compacted stone. It is a very efficient method of improving the strength parameters of soils like shear strength, bearing capacity and reducing the consolidation settlement. It offers a much economical and sustainable alternative to piling and deep foundation solutions. Many methods have been developed by past researchers to predict the ground settlement improved with stone columns. However, the predicted ground settlement is complicated and remains a problem for practical applications. The main purpose of the study is to outline and recommend the appropriate method to predict the ground settlement improved using stone columns. In this study, ground settlement improved using stone columns will be analyzed in both analytical and numerical methods. For analytical analysis, the settlement calculation will focus on two conventional methods which are Equilibrium Method and Priebe Method. For numerical analysis, the settlement of ground treated with stone columns will be modelled in finite element software (PLAXIS 2D V8), in the plane strain method, the behaviour of the ground settlement can be simulated with consolidation process. Then a comparison between field monitored settlement and predicted settlement mentioned above had been carried out. Based on this study, Priebe Method was proved to be reliable even though it does not capture all the fundamental soil parameters and stress changes that take place during stone columns installation and subsequent loading during embankment construction.

ABSTRAK

Kaedah pembaikan tanah merupakan keperluan penting dalam industri pembinaan pada hari ini. Tiang batu atau “Stone Column” adalah salah satu teknik pembaikan tanah yang memperkukuhkan tanah dengan batu dipadatkan di bawah tanah. Kaedah tiang batu adalah satu teknik yang berkesan untuk meningkatkan parameter-parameter tanah yang berkaitan dengan kekuatan tanah seperti kekuatan ricih dan keupayaan galas serta mengurangkan enapan tanah. Kaedah ini telah menjadi alternatif yang lebih murah dan berkekalan ketika dibandingkan dengan cerucuk dan penyelesaian asas dalam yang lain. Banyak kaedah anggaran untuk meramalkan enapan tanah bagi tanah yang telah ditambahbaikkan dengan tiang batu telah dikaji. Walau bagaimanapun, ramalan enapan tanah yang telah ditambahbaik dengan tiang batu adalah rumit dan aplikasi praktikal masih perlu diperbaikkan. Tujuan utama kajian ini adalah untuk mengetahui kaedah yang sesuai untuk meramalkan enapan tanah yang telah ditambahbaikkan dengan menggunakan teknik tiang batu. Dalam kajian ini, enapan tanah bagi tanah yang telah ditambahbaikkan dengan tiang batu akan dikaji dengan analisis analitikal dan analisis berangka. Dalam analisis analitikal, ramalan enapan tanah akan fokus kepada Kaedah Equilibrium dan Kaedah Priebe. Manakala, ramalan enapan tanah dengan analisis berangka akan dikaji dengan program komputer yang memiliki kaedah unsur terhingga (Plaxis 2D V8). Kaedah satah terikan dan proses enapan telah disimulasikan dalam model komputer. Selepas itu, enapan yang sebenar berlaku di tapak dan enapan yang diramalkan telah dibandingkan. Berdasarkan kajian ini, Kaedah Priebe telah terbukti boleh dipercayai walaupun ia tidak mempertimbangkan semua parameter tanah dan perubahan tekanan yang berlaku ketika pemasangan tiang batu dan pembinaan tambak.

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LIST OF SYMBOLS

A	-	Tributary Area
A_c	-	Area of stone column
a_s	-	Area replacement ratio
b_c	-	Radius of stone columns model in Plaxis
C_c	-	Compression index
C_r	-	Recompression index
c	-	Cohesion
D	-	Stone column diameter
D_c	-	Constrained modulus of stone column
D_e	-	Equivalent diameter
D_s	-	Constrained modulus of soils
d	-	Depth of stone column
E	-	Young Modulus
e_0	-	Initial void ratio
f_d	-	Depth factor
H	-	Vertical distance of the ground which settlements are being calculate
K_{aC}	-	Coefficient of active earth pressure
K_{oC}	-	Coefficient of earth pressure at rest
k_h	-	Permeability in horizontal direction
k_v	-	Permeability in vertical direction
n	-	Stress concentration factor
n_0	-	Basic improvement factor
n_1	-	Reduced improvement factor
n_2	-	Final improvement factor

n_{max}	-	Maximum value of improvement factor
P	-	Total applied load
P_c	-	Load applied on stone column
P_s	-	Load applied on soils
p'_c	-	Preconsolidation effective stress
R_e	-	Equivalent radius
r_c	-	Radius of stone columns at field
S	-	Settlement of untreated soil
S_n	-	Settlement at time t_n
S_{n-1}	-	Settlement at time t_{n-1}
S_{ult}	-	Ultimate settlement
S_t	-	Total settlement for ground improved using stone columns
s	-	Spacing between stone column
W_c	-	Weight of stones
W_s	-	Weight of soils
β	-	Settlement reduction ratio for stone columns treatment
β_0	-	Intercept of the fitted straight line with S_n axis
β_1	-	Gradient or slope of the fitted straight line
$\delta\sigma'$	-	Increase in effective stress due to applied load
φ	-	Angle of friction
φ_c	-	Friction angle of stone columns
γ_c	-	Unit weight of stone columns
γ_s	-	Unit weight of soils
ρc_1	-	Settlement of soil within depth of stone columns treatment
ρc_2	-	Settlement of untreated soil below stone columns
μ_c	-	Ratio of stresses acting on the stone column
μ_s	-	Ratio of stresses acting on the soft soil
ν_s	-	Poisson’s ratio of soil
σ'_0	-	Average initial effective stress
σ_c	-	Vertical stress acting on the stone column
σ_s	-	Vertical stress acting on the surrounding soft soil

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CHAPTER 1

INTRODUCTION

1.1 Background

Soft ground improvement technique is a method to improve the mechanical behavior of soft soil in order to speed up construction. The purposes of ground improvement are to increase the bearing capacity, reduce the magnitude of deformations and differential settlements, accelerate the consolidation by reducing the excess pore water pressures and increase the soil shear strength in order to reduce the construction cost and shorten the construction time. Basically, ground improvement can be classified into two categories namely as techniques involving works on soil such as dewatering and compaction and methods that require foreign materials such as use of chemical admixtures or utilization of various reinforcement.

With the ever-growing economical activities in Malaysia, infrastructure development such as highway and railway interlinking between Northern and Southern region of Peninsular Malaysia, ground improvement technique is gradually becoming a vital aspect in the construction industry. However, the construction of such infrastructure projects requires different foundations and ground improvement techniques for different geological formations and ground conditions. The existing soil for a given site might not be suitable for supporting the desired facilities as the safe bearing capacity of soil might not be adequate to support the given loads. Therefore, as a geotechnical engineer, it is necessary to ensure the soil properties within the influence zone to be improved in order to make them suitable to support the required loads.

Although there are variety soil improvement techniques available in the market, “stone column” is still one of the most popular and effective technique in practice around the world. Installation of stone columns into soft soil helps to improve the shear strength, reduce the excessive settlement and speed up the consolidation process by shortening the horizontal drainage paths for pore water flow. Hence, stone columns have been successfully used for the construction of highway embankment, industrial and residential structures, airport runways and also railway tracks.

1.2 Problem Statement

Stone column is used as one form of ground improvement in cohesive soils to meet specific bearing capacity, settlement magnitude and settlement rate requirements. There are many methods established that can be used for settlement prediction after the soft ground is treated with stone columns. However, the predicted settlement normally difficult to match the actual settlement recorded using settlement gauges at site.

If the actual settlement is higher than the predicted settlement, it will create havoc especially for infrastructure project and foundation of the structures. However, if the predicted settlement is too much higher than the actual settlement, the structures or building designed above the treated ground will be safe, but the design is not cost effective. Remedial works on ground treated with stone column will incur higher cost to the particular project. Therefore the method to obtain accurate predicted settlement to match with actual field settlement is crucial.

1.3 Objectives of the Study

The main purpose of this study is to determine the suitable method to use in predicting the ground settlement improved using stone columns at Kodiang, Kedah. In order to achieve the aim of the study, the following objectives are set forth:

a) To understand the mechanism of settlement for ground treated with stone columns using Priebe Method and Equilibrium Method.
b) To acquire and analyze field data for ground treated with stone columns.
c) To simulate ground settlement, compare between predicted and actual ground settlement and suggest the most improvisation method to predict ground settlement improved using stone columns.

1.4 Scope and Limitation of the Study

This study focuses specifically on the ground improvement for soft clay located in Kodiang, Kedah. A test embankment was constructed at Kodiang on May 2018 to evaluate the performance of stone column foundation for Electrified Double Track Project between Ipoh to Padang Besar. The test embankment consists of two zones namely Zone 1 (3.0m fill + 1.0m surcharge) and Zone 2 (2.0m fill). Only subsurface investigation data and settlement monitoring records for Zone 1 test embankment were analyzed. Comparison between field monitored settlement with few conventional methods in predicting the settlements had been carried out to identify the most accurate and reliable method in predicting the settlement. In addition, the settlement of ground treated with stone column might be affected by design parameter selection, installation effects and stress distribution. In this study, the settlement prediction will purely focus on 3 main components, which are Equilibrium method, Priebe Method and Numerical modelling using finite element software, PLAXIS 2D V8 with plane strain model suggested by Tan *et al.* (2008).

1.5 Significance of the Study

This study is mainly to identify the ground behavior around Kodiang, Kedah after treating with stone columns. With complete monitoring data and ground investigation records, the ground settlement improved using stone columns can be predicted especially for stringent settlement criteria for rail project. This study will eventually suggest the most appropriate method to predict ground settlement improved using stone columns.

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