COMPARISON OF PREDICTED SETTLEMENT BEHAVIOUR TO THE FIELD MEASUREMENT OF STONE COLUMN IMPROVED GROUND

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Dedicated to my mother and late father

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I would like to extend my greatest thanks to my mother who is the pillar of my strength and existence. I would like to present this to my late father whom always would want me to be someone great. I would like to present my effort to the lotus feet of god for whom has made myself into who I am now. Special thanks and love goes to the one whom had discovered the softest side in my heart.

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ABSTRACT

Stone columns form one of the accepted methods of ground improvement at which large size columns of coarse stones are installed into the ground by means of special vibrators. It is found that, stone columns increase shear strength of the ground, thus increasing bearing capacity and stability of the ground as well as to reduce settlement. The stone column design using Priebe's method has gained much widespread use due to its simplicity. However it was found that the settlement computed using Priebe's method has always been higher than the field settlement obtained. A comparison study was carried out between design settlement and field settlement. Based on the comparison and back analysis it is found that the improvement ratio of stone column increases with the increase of soil strength. This inherently implies to that of larger corresponding stone column spacing. Based on the findings, charts has been made to obtain a settlement reduction factor to be used in calculating the settlement of the improved ground, resulting in increase in the spacing and reducing the number of stone columns utilised. The time rate settlement was back calculated using Asaoka's method to assess actual coefficient of vertical and horizontal consolidation. With this, the back calculated spacing together with the coefficient of consolidation parameters were used to simulate back the field settlement to validify the findings. Based on the simulation, it was found that the back calculated improvement ratio and spacing are corresponding well with the actual field settlement. Therefore a relationship was established for basic soil parameters and the parameters related to stone column settlement details.

ABSTRAK

Tiang batu adalah salah satu cara pemulihan tanah yang diterima secara umum di mana batu-batu dimasukkan ke dalam tanah dengan mengunakan pengetar khas. Tidak dapat dinafikan bahawa tiang batu menambahkan kekuatan ricih tanah dan secara langsung menigkatkan keupayaan galas dan kestabilan tanah dan juga mengurangkan enapan. Rekabentuk tiang batu mengunakan kaedah Priebe telah mendapat kegunaan meluas kerana ia adalah satu kaedah yang mudah untuk digunapakai. Walaubagaimanapun Secara amnya enapan yang dikira mengunakan kaedah Priebe selalunya lebih tinggi daripada enapan sebenar di tapak. Satu perbandingan telah dilakukan diantara magnitud enapan yang dikira menggunakan kaedah Priebe dan enapan sebenar di tapak. Melalui perbandingan dan pengiraan balik yang dibuat, didapati bahawa nisbah pembaikan tiang batu meningkat dengan meningkatnya kekuatan tanah. Ini secara tidak langsung berkait dengan peningkatan jarak antara tiang batu. Daripada perbandingan dan pegiraan balik, sebuah carta telah di sediakan untuk mendapatkan faktor pengurangan enapan dimana carta itu boleh digunakan dalam pengiraan enapan yang secara tak langsung dapat menambahkan jarak antara tiang batu dan seterusnya mengurangkan bilangan tiang batu yang diperlukan untuk mencapai enapan yang sama. Kadar enapan juga dikira balik mengunakan kaedah Asaoka untuk mendapatkan pekali pengukuhan tegak dan ufuk. Dengan mengunakan data pengiraan balik ini, enapan sebenar di kira balik untuk mengetahui samaada data-data pengiraan balik itu benar ataupun tidak. Daripada pengiraan balik, telah didapati bahawa, jarak antara tiang batu dan nisbah pembaikan tiang batu berhubung rapat. Maka satu hubungan telah dicapai untuk parameter asal tanah dan parameter enapan tiang batu.

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A	Grid area
A_c	Stone Column Area
c	Cohesion
c_h	Coefficient of horizontal consolidation
c_v	Coefficient of vertical consolidation
d	Depth of subsoil layer from ground
D_c	Constrained modulus of stone column material
D_s	Constrained modulus of subsoil
f_d	Depth factor
H	Thickness of subsoil
K_{aC}	Coefficient of active earth pressure of column material
m_v	Coefficient of volume change
n	Settlement improvement ratio
N_k	Cone factor
P_c	Pressure within stone column along the depth
P_s	Pressure within soil in tributary area
q_c	Cone friction
R	Settlement reduction factor
S_u	Undrained shear strength
U_r	Degree of consolidation (radial only)
U_{rv}	Degree of consolidation (both radial and vertical)
U_v	Degree of consolidation (vertical only)
α	Coefficient of constrained modulus
δ_{ig}	Settlement of improved ground
δ_{og}	Settlement of unimproved ground
ϕ_c	Friction angle of stone column material
ϕ_s	Friction angle of subsoil

γ_s	Bulk density of subsoil
μ_s	Poisson's ratio of stone column material
σ_{vo}	Insitu overburden stress

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CHAPTER 1

INTRODUCTION

1.1 Introduction

In quest of knowledge and demand, there is ever increasing awareness of new technologies created or found by man. The field of geotechnical engineering is not new to this phenomenon. Over the last century, the field of geotechnical engineering has achieved many milestones with brilliant ideas and advancements. The ground improvement techniques is one of the area which has attained lots of interest and improvements due to an interesting fact that 'anything can be constructed anywhere if only proper foundation is laid'.

Many methods for ground modification and improvement are available around the world now, including dewatering, compaction, preloading with and without vertical drains, grouting, deep mixing, deep densification and soil reinforcement are among those. Many of these techniques, such as dewatering, compaction, preloading and grouting, have been used for many years. However, there have been rapid advances in the areas of deep densification (vibro-compaction, deep dynamic compaction, compaction piles, and explosive densification), jet and compaction grouting, deep mixing, and vibro-replacement and vibro-displacement in recent years. These methods have become practical and economical alternatives for many ground improvement applications.

While most of these technologies were originally developed for uses other than seismic risk mitigation, many of the recent advances in the areas of deep densification, jet and compaction grouting, and deep mixing methods have been spurred on by the need for practical and cost effective means for mitigating seismic risks. Many of these methods have also been applied to increase the liquefaction resistance of loose, saturated, cohesionless soils.

Ground improvement techniques basically utilize the effects of increasing adhesion between soil particles, densification and reinforcement to attain on or more of the following:

(1) increased strength to improve stability,
(2) reduced deformation due to distortion or compressibility of the soil mass,
(3) reduced susceptibility to liquefaction, and
(4) reduced natural variability of soils.

Of many techniques of ground improvements, stone column has gained lots of popularity since it has been properly documented in the middle of the last century. As in most new ground improvement techniques that were developed in foreign countries, experience has preceded the development of theory and comprehensive guidelines. Potential applications of stone column include the following :

(1) stabilizing foundation soils,
(2) supporting structures,
(3) landslide stabilization, and
(4) reducing liquefaction potential of clean sands.

The high potential for beneficial use of stone columns is mainly as a ground improvement technique to strengthen weak and soft soil. This includes the area of highway, railway and also airfield applications prompted a comprehensive investigation to determine how and why the system works so well, and to develop appropriate design and construction guidelines. This has resulted in many empirical design concepts to be published for the purpose of designing the stone column.

1.2 Background of Study

Vibro replacement or stone column has been adapted and utilized as one of the effective ground improvement method since early 1980's. This can be referred back to the ground improvement carried out at certain parts of North South Expressway, Keretapi Tanah Melayu (KTM) double tracking between Seremban and Rawang and many more locations throughout the country.

The stone column technology is not new as far as Malaysia is concern, simply because of the history and the number of contractors engaged in this business. The major players who were also pioneers in stone column construction in Malaysia are Keller (M) Sdn. Bhd. and Bauer (M) Sdn. Bhd. There are many other local stone column contractors now in the market besides these two foreign companies.

Even though the design of stone column is broadly based on empirical methods, there are a lot of studies being carried out to date to improvise the design and detailing of the stone columns to match the following details:

(1) local subsoil condition and
(2) local construction methodology.

Most of the cases, there are instrumentations carried out at those areas improved by stone column but those data have never been utilized fully for the purpose of improvising the design methodologies adopted. Thus it is appalling that we, Malaysians have to rely heavily on the foreign research and approach to solve our own problems.

Therefore, an attempt is being made to understand the major principle behind the stone column ground improvement which is to reduce the total settlement, in local geotechnical context.

The design works has been carried out based on certain subsoil parameters derived from the soil investigation carried out at site. This design has been carried out based on one of the empirical methods available. While the method is predicted to provide relatively good assessment of the details needed, there is much to be done to improvise the design approach by comparing the results with the field instrumentation results. By doing so, it is assumed, at this stage that there could be some improvement in the context of the detailing such as spacing and number of stone columns.

1.3 Objectives of Study

The main objectives of the study are as follows:

(1) to predict the settlement behaviour of stone column improved ground using Priebe's Method (Priebe H. J., 1995),
(2) to compare the predicted settlement with the field settlement.
(3) to suggest improvisation in the design method adopted based on results obtained in the comparison study.

1.4 Scope of Study

This study is confined to the following scopes:

(1) This study is to focus on the writer's own design work carried out using Priebe's Method (Priebe H. J., 1995) only.

(2) The construction of stone column was carried out based on top feed vibro replacement method (wet method).
(3) The data collected for the areas or locations of stone column ground improvement in Malaysia only.
(4) The minimum number of data set is limited to 5 numbers.
(5) The study focuses only on the settlement behaviour of the stone columns.

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