PERFORMANCE PREDICTION OF PREFABRICATED VERTICAL DRAIN IN SOFT SOIL USING FINITE ELEMENT METHOD

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I dedicate this project report to my family especially my parents,

who never stop giving themselves their support and love.

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ABSTRACT

Soft soil ground improvement method by using preloading with prefabricated vertical drain (PVD) had successfully applied in many soft ground construction projects. Due to the complexity of today's construction work, finite element method could assist designers to model very complex subsoil and structural elements. In this study, finite element analysis is performed to verify the effectiveness of modelling of PVD in subsoil using computer software, Plaxis V8. The field settlement data were collected at two particular locations and were analysed using Asaoka's (1978) method to estimate the ultimate settlement and back-calculated the coefficient of horizontal consolidation for these two particular location. Thereafter, by using back-calculated coefficient of horizontal consolidation, finite element analyses were performed to predict the time rate settlement and compared against field settlement results. From the time rate settlement curves generated by FEM, the ultimate settlements were predicted using Asaoka's (1978) method. It was found that the predicted time rate settlement by FEM shows reasonable agreement with the actual field settlement result. The ultimate settlement predicted from FEM is slightly lower compared to actual field settlement monitoring result, but the degree of consolidation settlement achieved were higher. In term of time required to achieve 90% consolidation settlement after surcharge, FEM shows slightly advancement compared to actual field settlement monitored. However, the advancement is only within 5% which is in good agreement with the actual field monitored reading.

ABSTRAK

Saliran tegak pra-fabrikasi (PVD) telah banyak digunapakai di kawasan tapak tanah liat untuk memperkukuhkan tanah liat. Disebabkan kerumitan kerja pembinaan hari ini, kaedah unsur terhingga (FEM) dapat membantu pereka untuk model tanah yang sangat kompleks dan unsur-unsur struktur. Dalam kajian ini, analisis unsur terhingga dilakukan untuk mengesahkan keberkesanan pemodelan PVD dalam tanah dengan menggunakan perisian komputer, Plaxis V8. Rekod enapan di dua lokasi telah dikumpulkan and dianalisis dengan kaedah Asaoka (1978) untuk meramal enapan maksimum serta analisis-kembali nisbah pekali pengukuhan dalam arah mendatar. Dengan nisbah pekali pengukuhan dalam arah mendater yang diperolehi, Plaxis V8 digunakan untuk meramal enapan berlaku dengan masa dan dibandingkan dengan rekod enapan tapak. Dari penyelesaian enapan berlaku dengan kadar masa yang dihasilkan oleh FEM, kaedah Asaoka (1978) digunakan untuk meramalkan enapan maksimum. Perbandingan enapan berlaku dengan masa diantara ramalan FEM dengan rekod enapan di tapak menunjukkan perjanjian yang munasabah. Namun demikian, didapati bahawa enapan maksima yang diramalkan dengan FEM adalah kurang daripada enapan rekod di tapak, tetapi darjah pengukuhan tanah yang diperolehi dengan FEM adalah lebih tinggi. Dalam jangka masa yang diperlukan untuk mencapai 90% pengukuhan tanah selepas surcaj, FEM menunjukkan persingkatan masa berbanding dengan rekod enapan di tapak. Walau bagaimanapun, persingkatan masa yang ditunjukkan oleh FEM hanya dalam likungan 5% yang mana telahpun bersetuju dengan rekod enapan yang sebenar di tapak.

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LIST OF SYMBOLS

Cc	-	Compression index
Cr	-	Recompression index
c_h	-	Coefficient of horizontal consolidation
c_v	-	Coefficient of vertical consolidation
CR	-	Compression ratio
RR	-	Recompression ratio
d_m	-	Equivalent diameter of mandrel
d_w	-	Equivalent diameter of the drain
D_e	-	Diameter of equivalent soil cylinder
e	-	Void ratio
$F(n)$	-	Vertical drain spacing factor
Fr	-	Well resistance factor for vertical drain
Fs	-	Smear effect factor
k_h	-	Soil horizontal permeability
k_s	-	Horizontal permeability of the soil within the smear zone
k_{hax}	-	Horizontal permeability of undisturbed zone in axi-symmetric unit cell
k_{hpl}	-	Horizontal permeability of undisturbed zone plane strain unit cell
k_{sax}	-	Horizontal permeability of smear zone in axi-symmetric unit cell
Pc	-	Preconsolidation pressure
q_w	-	Discharge capacity of PVD
T_h	-	Dimensionless time factor for radial consolidation
U_h	-	Degree of consolidation in horizontal direction
β_1	-	Slope in Asaoka's plot
Δ	-	Difference
φ	-	Friction angle of soil

c	-	Cohesion of soil
E	-	Young Modulus of soil
ψ	-	Angle dilatancy of soil
v	-	Poisson's ratio
λ^*	-	Modified compression index
κ^*	-	Modified swelling index

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Soft soils present the unique challenges to geotechnical professionals due to its poor bearing capacity and exhibit large settlement when subjected to loading. In time of urbanization, rapid growth of population and increasing demand of development such as houses, offices and infrastructures has resulted the construction activities on soft ground which comprises of compressible soil become unavoidable. The construction activities which normally building the platform will create external loading to the soft ground. The additional loading imposes to the soft compressible soil would causes significant magnitude of consolidation settlement over a considerable period of time. Thus for the development projects of building the platform or embankment on top of soft soil, the post construction settlement would be of primary concern.

To minimize the post construction settlement and differential settlement, ground improvement technique by preloading with prefabricated vertical drain are most widely selected technique to resolve this problem. This method is generally used due to its cost effective and fast installation of prefabricated vertical drain.

Preloading on soft soil refers to the process of compressing the soft compressible soil layer under applied vertical stress (preload) prior to the construction and placement of final construction load. Prefabricated vertical drains consist of a flat or cylindrical plastic core wrapped in a geotechnical fabric, and allow water to drain up through the centre of the drain. The main purpose of vertical drain is to shorten the drainage path of soft compressible soil layer and thus increase the rate of consolidation settlement.

Baron (1947) has produced the ‘equal strain hypothesis’ which presume no differential settlement will take place for prefabricated vertical drain treated ground. The ‘equal strain hypothesis’ by Baron (1947) has been extended to include the effect of smear and well resistance by Hansbo (1981). Today, analytical method by Hansbo (1981) is widely used in the design of vertical drains. Field observation of the settlement monitoring results always gives the best understanding of the soft soil behaviour through the settlement trend. The magnitude of final settlement can be estimated based on the field data by Asaoka’s method, hyperbolic method and viscosity method, and thus the degree of consolidation at any time could be assessed. Asaoka’s method (1978) is the most popular method to predict the final settlement as proven in previous study that this method gives good prediction of final settlement compared to actual final settlement at site. Recently, some researchers such as Indraratna and Redana (1997), Lin *et al.* (2000) and Chai *et al.* (2001) had successfully established the derivation of the axisymmetric condition of vertical drain to plane-strain condition to be employed in finite element analysis.

1.2 Problem Statement

Soft soil ground improvement method by using preloading with prefabricated vertical drain had successfully applied in many soft ground construction projects.

Easy and fast installation, properties standardisation, and cost effective compared to other ground improvement method make this method gaining popularity. For a given construction site which comprises of thick layer of soft soil, using the analytical approach by Hansbo (1981), the design of vertical drain would very much depend on the pattern of installation of vertical drain either triangular grid or square grid. Beside the analytical approach, designer could also carry out the design of vertical drain using finite element method or empirical method which depends on the preference and proficiency of the designers.

Due to the complexity of today's construction work, finite element method could assist designers to model very complex subsoil and structural elements and thus finite element method is playing more and more important role in design works. However, the accuracy of field data and laboratory test result is of the major parameter inputs to reflect the real condition of the site which is crucial in design that later could match back the field monitoring results.

The comparison between the field monitoring results and finite element analysis would help designers to get better understanding of the real soil behaviour compared to finite element modelling. Hence, suitable tolerance could be allowed in future design work using finite element method. As such, the effectiveness of modelling of prefabricated vertical drain in soft soil using finite element method must be evaluated.

1.3 Objectives of Study

The objectives of this study are stated in following:

1. To understand the effectiveness of modelling of prefabricated vertical drain in soft soil using finite element method through literature review.

2. To analyses and compare the settlement of embankment in prefabricated vertical drain treated soft ground obtained by finite element analysis and field instrumentation monitoring.

3. To establish an approach for predicting a reliable 90% consolidation settlement by using finite element analysis.

1.4 Scope of Study

This study is based on the project involved building an embankment for a mixed development in soft ground area in Kuala Langat District, Selangor. The field monitoring only limited to settlement monitoring which obtained from rod settlement gauges.

Finite element analysis is carried out using commercial software, Plaxis v8. 2D plane strain modelling using Mohr Coulomb (MC) model and Soft Soil (SS) model are used to model the constitutive subsoil properties. The permeability matching derivation by Lin *et al*. (2000) is used in this study to obtain the equivalence between axisymmetric behaviour of the vertical drain to plane strain condition in Plaxis modelling. Asaoka’s method will be used to predict the final settlement for settlement data obtained from instrumentation and finite element analysis. The time required for 90% consolidation between finite element analysis and field instrumentation monitoring is compared.

1.5 Significant of Study

This study presents the performance prediction of PVD in soft soil using finite element analysis. It is aimed at verifying the effectiveness of modelling of PVD in soft soil by appropriate conversion technique from three dimensional to two dimensional. Comparison between field monitoring settlement result and finite element analysis enabled the designer to predict the time rate settlement in future project, thus the resting period for 90% consolidation settlement could be assessed.

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