AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
STRUCTURAL ENGINEERING DEPARTMENT

SOIL IMPROVEMENT USING STONE COLUMNS

Thesis
Submitted in Partial Fulfillment of the
Requirements for the Degree of

MASTER OF SCIENCE
In
CIVIL ENGINEERING (STRUCTURES)

By

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STATEMENT

This thesis is submitted to Ain Shams University for the degree of M.Sc. in Civil Engineering.

The work included in this thesis was carried out by the author at the Department of Structural Engineering, Faculty of Engineering, Ain Shams University, Cairo, Egypt.

No part of this thesis has been submitted for a degree or a qualification at any other University or Institution.

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ABSTRACT

The special nature of soft soil deposits makes it one of the most complicated soil types to work with from a geotechnical engineering point of view. There are two main problems encountered when undertaking construction projects on soft soil deposits, excessive settlement and low shear strength. Stone columns are considered one of the most effective techniques used to improve soft soil deposits. Using stone columns to reinforce soft soil deposits increases the bearing capacity, reduces the settlement and accelerates the consolidation and construction time.

Different analytical methods used to calculate and study the improvement of the soft soil deposits when reinforced with stone columns represent the final behavior of the reinforced soil, i.e. after consolidation process takes place. Finite element analysis programs can be used to study the behavior of the soft soil deposits reinforced with stone columns both during and after the consolidation process. In order to represent the problem accurately a three dimensional finite element analysis is required. However, due to the fact that two dimensional finite element analysis programs are common in practical application, a need to convert the three dimensional problem to a two dimensional configuration is needed.

One of the main objectives of this research is to investigate the different possible two dimensional configurations that can be used to model the problem of soft soil deposits reinforced with stone columns, and to recommend the configuration whose behavior is nearest to the actual behavior of the reinforced soft soil.

A case study of an embankment construction for Penchala Toll Plaza project at New Pantai Expressway, Malaysia is undertaken (Tan et al., 2008). A three dimensional finite element analysis of this case history using PLAXIS 3D is performed. A comparison between the numerically

predicted behavior and the documented actual behavior of the embankment showed a good agreement between them.

A Comparison is then done between the results of the three dimensional numerical model and different configurations for a two dimensional numerical model of the same case study. An Axisymmetric configuration, a Plane strain configuration using an equivalent width for the column and a Plane strain configuration using equivalent parameters for the column are used to numerically model the case. The results show that the axisymmetric configuration shows the best agreement with the three dimensional analysis. Also, the plane strain with equivalent parameters configuration shows more reliability by giving more accurate results than the plane strain configuration using equivalent column parameters.

A study for the performance of the stone columns is conducted. The effect of various parameters such as the embankment height, column spacing and modulus of elasticity of the column on the stress concentration factor and column load share ratio as well as settlement and time reduction factors is studied through a parametric study. The findings of this parametric study are then compared to some of the other analytical approaches used to estimate the behavior of the reinforced soft soil and a recommendation is done for the appropriate analytical methods to be used.

Keywords: Stone columns, soil improvement, embankments, soft soil

SUMMARY

Stone columns are considered one of the most effective techniques used to improve soft soil deposits. Using stone columns as reinforcement for soft soil deposits provides the advantages of reduced settlement as well as reduction in the consolidation and hence construction time. The main objective of this research is to investigate the behavior of the soft soil reinforced using stone columns and the interaction between the soft soil and the stone columns. The research presents a numerical study using finite element analysis method using three dimensional modelling and different possible two dimensional configurations that can be used to model the problem of soft soil deposits reinforced with stone columns. A case study reported by Tan et al. (2008) of an embankment construction for Penchala Toll Plaza project at New Pantai Expressway, Malaysia, in 2003 is undertaken, and the behavior of the different models is compared to readings taken from field during and after construction. Finally, a parametric study is performed to study the effect of different factors affecting the behavior of the stone columns and its efficiency in the reduction of the settlement of the soft soil deposits and improving the soft soil behavior.

The thesis consists of seven chapters

Chapter (1) is the introduction to this research; it discusses the importance, the scope and the main objectives of the research.

Chapter (2) is a literature review which briefly discusses through the past researches the behavior of soft soil deposits reinforced with stone columns.

Chapter (3) presents a brief discussion about finite element method including analysis sequence and different types of elements that may be used in the analysis. Also, the finite element analysis program which is used during this research is briefly discussed.

Chapter (4) presents the case study description. Also, it illustrates all the three dimensional and two dimensional numerical models conducted to investigate the behavior of soft soil reinforced with stone columns under an embankment. Finally, a comparison between the numerically predicted response of different models and the monitored response is presented.

Chapter (5) is a parametric study performed to investigate the effect of different parameters on the behavior and performance of stone columns.

Chapter (6) presents a comparison between the findings of the numerically performed parametric study with some of the analytical methods used to estimate the behavior of the soft soil reinforced via stone columns

Chapter (7) presents the summary and the conclusions of the research. It ends up with the suggestions for future studies and research topics relevant to the subject.

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