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NONLINEAR SOIL-STRUCTURE INTERACTION ANALYSIS OF MULTISTOREY BULDING

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NONLINEAR SOIL-STRUCTURE INTERACTION ANALYSIS OF MULTISTOREY BULDING

BY

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GS14101

A Project Report Submitted in Partial Fulfillment of the Requirements of the Degree of Master of Science in Structural Engineering and Construction in the Department of Civil Engineering

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2005

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APPROVAL FORM

The project attached hereto entitled," NONLINEAR SOIL-STRUCTURE INTERACTION ANALYSIS OF MULTISTOREY BULDINGS " prepared and submitted by HESHAM S. H. ALDAIKH in partial fulfillment of the requirements for the Degree of Master of Science in Structural Engineering and Construction is hereby approved.

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

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HESHAM S. H. ALDAIKH.

DATE:

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Dedicated to

My beloved Father"Salem"& Mother"Rebeh"

Your prayers and encouragement that made me whom I am today is very much acknowledged.

MY dear brothers "Wesam", "Abdullfatah", "Edreis", "Khaled" and to my little sister "Safa"

Your motivation, sacrifice and support during the period of my academic mission is appreciated.

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ABSTRACT

The interaction among structures, their foundations and the soil medium below the foundations alter the actual behaviour of the structure considerably than what is obtained from the consideration of the structure alone. Conventionally, superstructures are usually analyzed by assuming the structure to be fixed at the foundation level. Such an analysis neglects the flexibility of foundation and compressibility of soil mass. It is also assumed, conventionally, that the soil is behaving linearly neglecting that fact that it is nonlinear in nature.

In this study an attempt has been made to carry out a two dimensional linear and nonlinear analysis of the problem of a multistory building incorporating soil-structure interaction with respect to nonhomogenous soil properties in Malaysia. Two techniques of analysis have been carried out, in the first, linear stress strain relationship is assumed for the soil where finite element method has been employed in modelling the superstructure members and foundation beam while Winkler's springs have been attached to the foundation beam to represent the soil layer below foundation, and then a linear coupled finite infinite element modelling is done. Three noded isoparametric beam bending element with three degrees of freedom that takes into account of the transverse shear forces and axial flexural interaction, this element is used to represent the frame members in all types of analyses. Eight noded isoparametric quadrilateral finite element is used to represent the near filed of soil while the far field is represented by using five noded isoparametric infinite element.

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In the second analysis, the same coupled finite-infinite element modelling is used, the difference is that, the soil is considered to behave nonlinear and a hyperbolic model is used to take this nonlinearity into account.

The result showed the importance of taking soil structure interaction into account, results obtained from each analysis have been obtained and comparison among various analyses has been stated.

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ABSTRAK

Sifat sebenar struktur berubah disebabkan oleh tindak balas dan di antara struktur , asas struktur dan medium tanah yang berada di bawah asas tersfut.

Secara konvensionalnya superstruktur biasanya di analisis dengan mengamdiakan bahawa struktur binaan tersebut di bina pada level asas. Analisis tersebut mengenepikan keanjalan asas dan kemampatan jisim tanah. Secara tradisonalnya, di andaikan bahawa tanah adalah bersifat linear dan ini menyangkal kenyataan bahawa tanah pada semulajadinya bersifat tidak-linear.

Dalam kajian ini, percubaan telah dialkukan untuk mendapatkan analisis 2-dimensi linear dan tidak-linear permasalahan pembinaan bangunan bertingkat yang berkiatan interaksi antara dan struktur dengan mengambli kira ketidaksamaan jenis tanah di Malaysia .

Dua jenis teknik telah di gunakan .Pertama, di andaikan bahwa terdapat perkaitan di antara tekanan dan regangan linear pada tanah di mana kaedah unsur. Terhingga diagunakan dalam model superstruktur dan cerucuk untuk tiang. Spring Winkler pula di pasangkan pada fungsi tiang untuk menggantikan lapisan asas bawah tanah dan kemudiannya model unsur terhingga, tidak terhingga di buat.

Tiga nod tiang isoparametrik yang bengkok tiga darjah dengan mengambil kira tindak balas tekanan regangan melintang dan paksi boleh ubah di gunakan dalam semua

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bentuk analisis. Lepan nod tiang isoparametrik sisi empat unsure terhingga di perlukan untuk lapangan yang lebih dekat manakala lima nod tiang isoparametrik unsure tidak terhingga diperlukan untuk lapangan yang lebih jauh.

Dalam analisis kedua, model unsure terhingga, tidak terhingga yang sama digunakan. Perbezaannya (alah tanah di anggap bersifat linear dan ketidakselarian nonlinearity ini di ukur dengan menggunakan model hiperbolik.

Hasil yang di perolehi daripada semua analisis yang telah digunakan menunfukkan bahawa kepentingan interaksi/ tindak balas antara tanah dengan struktur perlu di ambil kira dan perbandingan diantara pelbagai analisis telah diuyatakan.

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CHAPTER I

INTRODUCTION

1.0 General

There are number of complex problems that face designers and analysts in the field of civil engineering in general and structural engineering in particular, one the top of these complicated problems those of structural elements in direct contact with the surrounding soil and rock including underground conduits such as tunnels and culverts, also foundations, embankments, retaining walls, pavements and railways track systems. When such structural elements exposed to externally applied forces and/or internally developed forces within the ground, both structural element and ground must be treated as one integral and compatible unit, this is because neither the element nor the ground is independent of each other as a result of their intimate physical contact, these phenomena are commonly referred to as *Soil Structure Interaction problems.*

The analysis of soil structure interaction problems is a vast field of interest in the area of civil engineering .During the last quarter of the 20^{th} century the importance of either static or dynamic soil structure interaction for several structures found on soils was well recognized .The interaction among structures , their foundation and the soil medium below the foundation is found to be altering the actual behaviour of the structure considerably than what is obtained from consideration of the structure alone , thus it is important to understand how a structure will interact with the surrounding soil medium in addition to the necessity for a reasonable accurate model for the soil-foundation-

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structure system with computational validity ,efficiency and accuracy is certainly needed .

1.1 Why Soil Structure Interaction.

The response of any system comprising more than one component is always interdependent, due to the high concentration of load over any part of a structure such as one of the supports , the soil below tends to settle more , with the differential settlement among various parts of the structure , both the axial forces and the moments in the structural members may change , hence the force quantities and the settlement at the finally adjusted condition can only be obtained through the analysis of the soil-structure- foundation system , this explains the importance of considering soil structure interaction studies.

1.2. Problem Components

For any common application of SSI problems where a foundation supports a superstructure of some type of building, there are three principle components of the problem which are Foundation (raft), soil medium (subgrade) and superstructure.

These components are conceptually illustrated in Figure.1 next page.

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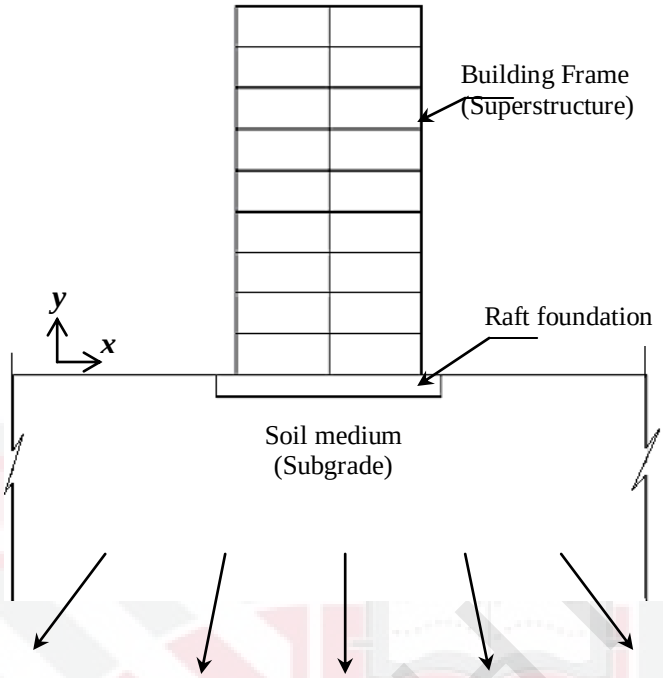

Figure 1.1. Problem components

1.3 Problem Solution

More than any other type of foundation, a mat supported structure represents a situation where SSI is important and should always be considered. The reason is that the load-displacement behavior of any one component (mat, subgrade or superstructure) is physically linked, and thus dependent on the behavior of, the other two, this means that ideally, the mat-subgrade-superstructure system shown in Figure 1.1 should always be analyzed as a single problem to achieve maximum accuracy of results.

The combined mat and superstructure together are actually a single structural system or (megastructure) that is in contact with the ground. As a result of some system of applied

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loads to the megastructure, there will be displacements, including vertical downward displacement (settlement) at foundation level into the ground.

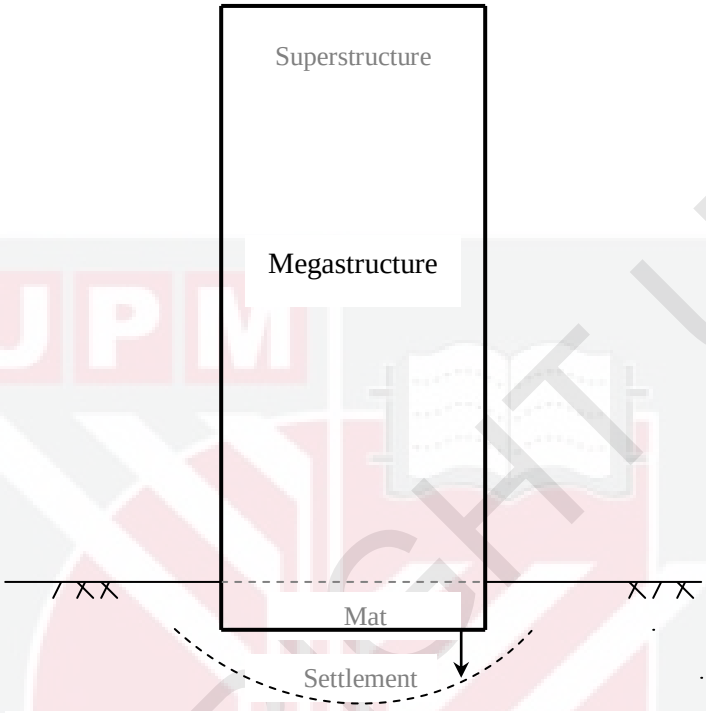

Figure.1.2 Problem components: Ideal Analysis

The ideal solution shown Figure1.2 above is technically achievable at the present time using some type of numerical methods such as Finite-element Method.

In chapter two alternative solutions to the problem have been discussed such as the conventional solution which has its origins in pr-computer days and some alternative modern solutions.

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1.4 Objectives

Objectives of this project can be written as follows:

i) To obtain how a plane frame-raft-soil system would be modeled (physical and material modeling) incorporating the effect of soil structure interaction, with respect to Malaysian soil properties taking into account the nonhomogenousity, linear and nonlinear behaviour of soil.

ii) To study the structural response of the plane frame-raft-soil system using nonlinear elastic soil model and to find the nonlinear elastic soil parameter.

iii) To carry out a comparative study among various types of analyses.

1.5 Scope of study

To achieve the objectives of the present study stated above, a comprehensive review on the literature regarding the field of soil structure interaction, including books, journals and through the international network.

Two load cases, with partial factors of safety in accordance with British Standards BS8110 Part 1:1997, and BS6399 Part2:1997, have bee considered, the first load case considers the gravity loads to be acting on the structural members of frame and the foundation beam while the second load case is considering the gravity loads in addition to the wind load .

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Finite element method, by the means of an existing finite element program written in FORTRAN programming language, has been utilized in idealizing the system of soil structure interaction.

Linear analysis is conducted first where Winkler's analogy and linear finite element modelling are considered and then a nonlinear finite element is used. Plane strain conditions

The current study is focusing on the study of vertical and lateral displacements in different structural members of frame and the settlement of foundation in addition to bending moments in beams, columns and the raft foundation, axial forces in columns and contact pressure below the foundation and also vertical stresses in the soil media.

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