GROUND IMPROVEMENT FOR RING BEAM TANK FOUNDATION COMPARED BETWEEN VIBRO REPLACEMENT AGAINST COMBINATION OF DYNAMIC TECHNIQUES WITH NUMERICAL MODELS

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DEDICATION

This thesis is dedicated to my father, who taught me that the best kind of knowledge to have is that which is learned for its own sake. It is also dedicated to my mother, who taught me that even the largest task can be accomplished if it is done one step at a time.

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ABSTRACT

Construction of large tanks are often carried out implementing a ring beam foundation. Majority of the load is transferred the ground, therefore, in areas of poor ground conditions, additional measures are taken to avoid geotechnical failure. Various methods exist for ground improvement, however, techniques such as piling and Vibro-Replacement are commonly implemented, due to their deep depth of improvement and flexibility of applicability for a wide range of soil profiles. However, alternative techniques may be implemented which could prove more efficient and even cost effective. Dynamic techniques, due to their fast rate of production, reduced operation costs and impressive efficiency prove as viable options. But since dynamic techniques have limitations with soil type and depth of improvement, for stratified geotechnical profiles, they may only be carried out in a combination with one another, which may deter engineers for opting to implement them. In the current study, the efficiency of ground improvement for a ring beam tank foundation shall be compared between Vibro-Replacement against combination of dynamic techniques with numerical models, to provide an insight between their capabilities and preliminary cost estimations shall also be carried out to a lesser extent to get an idea of the economic factors that affect decision making for ground improvement operations.

ABSTRAK

Pembinaan tangki besar adalah berkait rapat dengan pelaksanaan asas alang cincin. Oleh sebab kebanyakan bebanan akan disalurkan ke permukaan tanah, pada permukaan tanah yang berkeadaan tidak baik, langkah keselamatan tambahan akan diambil bagi mengelakkan dari berlakunya kegagalan secara geoteknikal. Terdapat banyak kaedah bagi pembaikpulihan tanah, akan tetapi, teknik pencerucukan (piling) dan Vibro-Replacement adalah teknik yang biasanya dilakukan disebabkan kedalaman pembaikpulihannya yang tinggi dan flesibiliti kebolehgunaannya untuk pelbagai jenis profil tanah. Walau bagaimanapun, teknik alternatif lain juga boleh digunapakai memandang terbuktinya lebih efisien dan lebih kos efektif. Teknik dynamic menjadi pilihan yang baik kerana ia memberi kesan kepada kadar produksi yang lebih tinggi, pengurangan kos operasi dan bukti kecekapan yang mengagumkan. Akan tetapi, memandangkan teknik dynamic mempunyai kelemahan pada jenis tanah dan kedalaman pembaikpulihan, bagi profil geoteknikal berstrata, ianya hanya dilakukan dengan gabungan teknik lain, menyebabkan ahli jurutera tidak memilih untuk menggunakan teknik ini. Dalam penyelidikan semasa, kadar kecekapan bagi pembaikpulihan tanah dengan pelaksanaan asas alang cincin perlu dibandingkan antara Vibro-Replacement dan kombinasi teknik dynamic serta model berangka untuk memberi gambaran tentang kebolehan dan anggaran kos permulaan perlu dilaksanakan bagi memberi idea akan faktor ekonomikal yang memberi impak untuk membuat keputusan dalam operasi pembaikpulihan tanah.

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LIST OF ABBREVIATIONS

E.G.L.	-	Existing Ground Level
F.B.L.	-	Foundation Base Level
V.R.	-	Vibro-Replacement
D.R.	-	Dynamic Replacement
D.C.	-	Dynamic Compaction

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CHAPTER 1

INTRODUCTION

1.1 Overview

In countries with abundance of soft/compressible soil profiles, a great demand for ground improvement exists. Prior to any construction work, geotechnical properties of the ground are assessed to verify it's capability of sustaining loads after construction. In the case of a storage tank, however, the geotechnical properties are critical during different stages of storage and operation which shall be discussed in upcoming chapters. The crucial aspect is that the ground should sustain the tanks during these stages and if geotechnical properties are deemed insufficient or poor, ground improvement must be carried out. Many improvement techniques of different types exist and it is not uncommon to opt for a combination of improvement techniques. A prominent method of improvement is stone columns or Vibro-Replacement, as will be detailed in further chapters, it can be implemented on almost all soil types which makes it a commonly chosen technique over others. Alternative techniques such as Dynamic Compaction, Rapid Dynamic Compaction and Dynamic Replacement, have limitations with either depth or soil type, but, in a combination these dynamic techniques can carry out the improvement as well (Han, 2015). In the current study, improvement implementing Vibro-Replacement shall be compared against a combination of dynamic techniques for the rehabilitation of a ground where a storage tank placed on a ring beam foundation shall rest. Detailed aspects of all techniques involved, such as operation parameters and expected improvement, shall be deduced with viable justifications. Improvement efficiency for both strategies shall be analyzed primarily and economic factors (in terms of overall project cost and duration) shall be discussed lightly.

1.2 Background

Large storage of liquids in fields such as petrochemical, oil and gas industry or reverse osmosis sewage treatment plants, prompt the construction of large tanks. Apart from the load of the structure, the foundation design should take into consideration the tank liquid load, wind and seismic loads. Only a fraction of the load (approximately 10% of the tank shell load), is received by the foundation and the majority of the bearing pressure is directly transferred to the ground and therefore, the ground must be competent enough to sustain the load. The total settlement, differential settlement and edge settlement are common criteria that should be assessed by the geotechnical engineer to ensure constructability and avoid failure (Nagesh and Sasidhar, 2017).

To improve the engineering properties of the ground, many methods and techniques exist, depending on the soil type, economic factors or just personal preference. For the purpose of the current study, ground improvement implementing a single technique i.e. Vibro-Replacement shall be compared against a combination of dynamic techniques, in terms of efficiency and economic factors for the improvement of a ground on which a ring beam foundation shall be constructed.

Realistic geometry are well represented implementing Finite Element Method (FEM). With the ability to work with general boundary conditions and account for heterogeneous and anisotropic material properties, it increases the reliability and accuracy of the method. This implies that arbitrary shapes (which are more representative of real world geometry) can be made up of combined continuum of different material property regions i.e. property of inter-connected elements would vary with spatial location similar to what would be found in a natural setting (Akin, 2005). Owing to the attractive qualities of FEM, numerical models shall be used to perform deformation analysis and estimate settlements more accurately, using the software PLAXIS.

1.3 Problem Statement

Failure of large tanks due to settlement are dictated by the ground, as it takes the load that is transmitted to it (Nagesh and Sasidhar, 2017). In an attempt to avoid failure, ground improvement proves a cost-effective method, as opposed to deep foundation or conventional excavation and replacement, especially if the thickness of soft soil is substantial (Braiek, 2017). Vibro-Replacement, due to being compatible with a large range of soils and deep improvement depth is a commonly chosen improvement technique. As shall be detailed in later chapters, improvement can be carried out in multiple ways implementing multiple techniques, but it is difficult to find a technique as material flexible and deep improvement as Vibro-Replacement. However, a combination of other techniques, like dynamic techniques, may be carried out in multiple stages and due to their low cost, cheap operations (no requirement of electricity or water), ease to use and higher energy implemented (Han, 2015; Hussin, 2006), may actually prove more efficient and cost effective compared to Vibro-Replacement technique. In the current study a comparative analysis shall be drawn.

1.4 Aims and Objectives of the Study

The aim of current study is to assess and compare the performance of Vibro-Replacement against a combination of dynamic techniques in improvement of a ground for a large tank with ring beam foundation. Thus, the objectives of current study shall be as given below.

a) Design ground improvement operations for both Vibro-Replacement and combination of dynamic techniques for ground improvement for a large tank with a ring beam foundation.

b) Compare the efficiency of both operations in achieving the design criteria.

c) Assess the economic factors and compare approximate cost estimates for carrying out both operations.

1.5 Scope of the Study

To achieve the aim and objectives mentioned in Section 1.4, the scope of the study shall involve the tasks mentioned below.

a) Defining improvement parameters which involve, grid spacing, number of pillars to construct (for ground reinforcement techniques) and energy parameters (more prominent in dynamic techniques which involve height of drop, weight of drop, etc.).

b) Preliminary assessment using empirical methods to assess technique suitability.

c) Numerical Models made using PLAXIS to verify design criteria.

d) Comparison between both operations in terms of efficiency in reducing settlement and discussion regarding economic factors with rough estimated costs of both operations.

1.6 Hypothesis of the Study

An analysis of the performance of ground improvement carried out by Vibro-Replacement and combination of dynamic techniques will aid in understanding the efficiency of both techniques when implemented for a large tank ring beam foundation. With results from both operations, a comparison can be drawn and acquiring data regarding costs will also enhance existing knowledge regarding economic factors and cost effect from carrying out both operations for a similar scenario which can aid in understanding decision making for choosing techniques implemented in ground improvement operations.

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