STUDY ON CHALLENGES APPLICATION GROUND IMPROVEMENT AND SOIL STABILIZATION METHOD IN SABAH CONSTRUCTION INDUSTRY

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ABSTRACT

The practice of ground improvement is commonly characterized as the use of mechanical means to remedy terrible ground conditions. Ground improvement techniques improve the treated soil parameters to satisfy project performance goals. Due to the scarcity of suitable development sites, ground improvement is a fast-developing profession. Engineers are confronted with a challenging problem in constructing structures on insufficient and poor locations. Therefore, it is necessary to investigate the challenges in the application of ground improvement and soil stabilization in Sabah construction industry. Questionnaire surveys with a total of 50 respondents were attained and analysed via BIM SPSS and Microsoft Excel software. The demographic data collected was tested by descriptive statistics frequencies analysis and transformed to bar charts, and pie chart for easy interpretation. The Chi-Square test was used to prove the significance between two variables which is the demographic data such as gender, age, and working period and the method that have been engaged by the respondents. From the analysis, there were significance of the age and working period with the other variables. The familiarity of the respondents was also assessed using the questionnaire survey. The challenges in application of ground improvement and soil stabilization were assessed using the RII analysis where it was found that cost was ranked first as the most significant challenge in the implementation, followed by air pollution, organic content, and stress history. From this research, we can have more knowledge in the implementation of the most used ground improvement method, identified the challenges in implementing the methods in Sabah construction industry and to aid research in geotechnical engineering to develop more method in improving ground that will have less challenges in its implementation.

ABSTRAK

(KAJIAN CABARAN PENAMBAHBAIKAN TANAH DAN KAEDAH PENSTABILAN TANAH DI PEMBINAAN SABAH INDUSTRI)

Amalan pembaikan tanah biasanya dicirikan sebagai penggunaan cara mekanikal untuk memulihkan keadaan tanah yang teruk. Teknik pembaikan tanah menambah baik parameter tanah yang dirawat untuk memenuhi matlamat prestasi projek. Disebabkan kekurangan tapak pembangunan yang sesuai, pembaikan tanah adalah profesion yang pesat membangun. Jurutera berhadapan dengan masalah yang mencabar dalam membina struktur di lokasi yang tidak mencukupi dan miskin. Oleh itu, adalah perlu untuk menyiasat cabaran dalam aplikasi pembaikan tanah dan penstabilan tanah dalam industri pembinaan Sabah. Tinjauan soal selidik dengan sejumlah 50 responden telah dicapai dan dianalisis melalui perisian BIM SPSS dan Microsoft Excel. Data demografi yang dikumpul telah diuji dengan analisis frekuensi statistik deskriptif dan diubah kepada carta bar, dan carta pai untuk tafsiran yang mudah. Ujian Chi-Square digunakan untuk membuktikan kepentingan antara dua pembolehubah iaitu data demografi seperti jantina, umur, dan tempoh bekerja serta kaedah penstabilan yang telah digunakan oleh responden. Daripada analisis, terdapat kepentingan umur dan tempoh bekerja dengan pembolehubah lain. Kebiasaan responden juga dinilai menggunakan tinjauan soal selidik. Cabaran dalam aplikasi pembaikan tanah dan penstabilan tanah dinilai menggunakan analisis RII di mana didapati kos diletakkan pada kedudukan pertama sebagai cabaran paling ketara dalam pelaksanaan, diikuti oleh pencemaran udara, kandungan organik, dan sejarah tekanan. Daripada penyelidikan ini, kita boleh mempunyai lebih banyak pengetahuan dalam pelaksanaan kaedah penambahbaikan tanah yang paling banyak digunakan, mengenal pasti cabaran dalam melaksanakan kaedah dalam industri pembinaan Sabah dan untuk membantu penyelidikan dalam kejuruteraan geoteknik untuk membangunkan lebih banyak kaedah dalam menambah baik tanah yang akan menghadapi sedikit cabaran. dalam pelaksanaannya.

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LIST OF ABBREVIATIONS

PWD	-	Malaysia's Public Works Department
CO_2	-	Carbon Dioxide
UCS	-	Unconfined Compressive Strength
OPC	-	Ordinary Portland Cement
Fe	-	Iron
Mg	-	Magnesium
$2SiO_4$	-	Olivine
MgO	-	Magnesium Oxide
C:N	-	Carbon-Nitrogen
SO	-	Sulfonated Oil
PC-AC	-	Portland Cement – Activated Carbon
HDPE	-	High-Density Polyethylene
CBR	-	California Bearing Ratio
$CaCO_3$	-	Calcium Carbonate
CaO	-	Calcium Oxide
GGBFS	-	Ground Granulated Blast Furnace Slag
RHA	-	Rice Husk Ash
CCR	-	Calcium Carbide Residue
PFA	-	Pulverised Fuel Ash
SF	-	Silica Fume
IBM SPSS	-	IBM Statistical Package for the Social Sciences
RII	-	Relative Importance Index
$CaCl_2$	-	Calcium Chloride
NaCl	-	Sodium Chloride
Na_2SiO_3	-	Sodium Silicates
PVDs	-	Prefabricated Vertical Drains
VCCs	-	Vibro Concrete Columns
VSC	-	Vibro Stone Column

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CHAPTER 1

INTRODUCTION

1.1 Research Background

The practice of ground improvement is commonly characterized as the use of mechanical means to remedy terrible ground conditions. Ground improvement techniques improve the treated soil parameters to satisfy project performance goals. According to Nicholson P.G. (2014), soil can be labelled "poor" if it lacks the bare minimum of engineering qualities and has been determined to perform inadequately for design specifications. It is deemed "marginal" if it meets only a few minimum requirements.

Soft soil is defined as having a low shear strength, extremely compressible, and poor permeability (Huat, 1995, as cited in Mohamad et al., 2016). It has a shear strength of less than 40 kPa and can be easily moulded with just a little touch. Due to the soft soil's high compressibility and low shear strength, poor bearing capacity, a severe post-construction settlement, and instability during excavation and embankment formation are the most common construction issues in this deposit. Thus, numerous failures due to significant settlement and deformation of structures such as embankments have been observed in the past, locally and globally (Mohamad et al., 2016).

When confronted with a challenging or complex geotechnical situation, the engineer must weigh a variety of factors in order to choose the sort of solutions that would provide the desired outcomes. Physical characteristics of the soil and site conditions and social, political, and economic issues all have a role in choosing the suggested course of action. These variables might play a role in identifying the appropriate improvement methods to offer. Each project must be evaluated on its own merits (Nicholson P.G., 2014).

The elements that need to be considered are, firstly the soil type, it is one of the most significant factors to consider when determining which method or materials to use. This is because particular ground improvement procedures are only suitable to certain soil types or grain sizes. Next, the area, depth, and location of treatment required. Many ground improvement techniques have depth restrictions that prevent them from being used on deeper soil strata. Economic and equipment capabilities may also play a factor in determining which procedure is best suited for the project, depending on the project's geographical scope. If there are nearby buildings, noise and vibration problems, or if temperature and water supply are factors, location may play a major influence in the technique selection. The other factors include the required soil, availability of skills, local experience, local preferences, and economics.

It is critical to do research on ground improvement and soil stabilization methods in order to increase soil quality. When "poor" or inadequate soil or site conditions arise, some alternatives could be pursued (Raison, C. A. 2004) such as; (a) The structure could be relocated if the location is abandoned; (b) To transfer the load of the building below to a competent stratum, deep foundations could be utilized; (c) Redesign the structure that could withstand the earth movements, and (d) Prior to construction, the ground's qualities may also be enhanced. It is essential to identify the challenges in implementing any ground improvement methods so that precautions can be made.

1.2 Problem Statement

Geotechnical engineering is concerned with constructing structures on soft ground, and it is a crucial challenge. It is possible that several technical challenges such as slope instability, bearing capacity failure, and excessive settlement may occur during or after the building phase as a result of the inadequate shear strength and high compressibility of this particular soil. Among the most challenging issues in any soft soil, the problem is the reduction of excessive settlement and the increase of bearing capacity in soft soils that have a variable mixed structure for use in building (Moayedi & Nazir, 2018). The issue statement for this research is that there has been little research done on the challenges that the building industry has had in applying ground improvement and soil stabilization methods in the past. Besides, it is essential to enhance the soft and problematic soil deposits through proper stabilising techniques due to the increase in population and the absence of stable ground for the building of civil projects (Rahgozar et al., 2018).

Malaysia's Public Works Department (PWD) has been engaged in several transportation and construction projects on soft soil due to the country's rapid expansion over the last several decades. PWD's role in any development project might be a leading technical agency for the Malaysian government during the construction of forensic inquiry. According to Mohamad et al. (2006), 182 of 252 forensic occurrences (about 72%) are ground settling, while the other 28% are attributable to other factors such as vibration, erosion, and foundation failures. Thus, it is clear that ground settling is the most often encountered technical challenge while constructing on soft ground.

Due to the scarcity of suitable development sites, ground improvement is a fast-developing profession. Engineers are confronted with a challenging problem in constructing structures on insufficient and poor locations (Boobathiraja et al., 2014). Additionally, engineering judgments in determining which soil enhancement work to do is a challenging justification. For example, peat soil is often considered difficult in any building project due to its high compressibility and poor shear strength (Huat, 2004). Infrastructure facilities on peatland have become important as industrialization and population has expanded. Peat soil is one of Malaysia's principal soil types, occupying around 3.0 million hectares or 8% of the country's total geographical area.

There are many methods that could be used to stabilize soil, chemical stabilization is the most extensively used technique of soil stabilization due to its simplicity of application and broad applicability. Lime is the most often-used chemical stabilizer for mitigating the devastating impacts of expanding soils (Zha et al., 2021). However, the widespread use of lime in different building projects significantly increases their costs and increases the use of limestone, a natural resource. Additionally, its manufacture requires a great deal of energy and generates a great deal of greenhouse gas emissions (Seco et al., 2011).

Also, cement is a commonly utilized material in geotechnical engineering projects due to its excellent soil stabilizing properties. However, the primary source of worry is because it produces a significant amount of carbon dioxide (CO2), which adds to the overall amount of CO2 emitted worldwide and is acknowledged as a critical contributor to climate change and the greenhouse gas impact that causes global warming (Fasihnikoutalab et al., 2015).

1.3 Objective

The objective of this research is as follow:

a. to study the implementation of ground improvement in Sabah construction industry.
b. to analyse the challenges of application of ground improvement and soil stabilization method in Sabah construction industry.
c. to assess the awareness of workers in Sabah construction industry on the challenges in implementation of ground improvement and soil stabilization.

1.4 Scope of Study

This study focuses on the challenges of implementation of ground improvement and soil stabilization in the Sabah construction industry and the methods used for ground improvement. Firstly, a review and analysis of previously published publications on past ground improvement and soil stabilization research was done to be used in constructing the survey questionnaire questions. The study utilized a survey questionnaire, and the data collection was conducted to 50 respondents working in construction firm in Sabah mainly from construction firm that specialized in civil engineering construction sector where mostly was located in Kota Kinabalu. The questionnaire surveys were carried out via online survey method as a primary tool for collecting data. WhatsApp application and e-mail were utilized to distribute the survey. By the survey questionnaire method, researchers was able to achieve the objectives stated.

1.5 Significance of Study

Generally, ground improvement refers to modifying the current physical properties of the ground beneath a building site so that permanent or temporary construction can proceed in a safe, effective, and economically viable manner. The typical advantages of a ground improvement include the following: (a) An increase in the shear strength for improved bearing capacity or to provide sufficient support for excavation or tunnelling, (b) A reduction in compressibility to reduce the settlements of buildings or structures, or other deformations in the ground, (c) Reducing permeability to avoid floods, water damage, or to isolate areas of groundwater with contamination, (d) Improvements to deep drainage to support pre-loading or surcharge, (e) Control of ground displacement to prevent differential settlements and ground distortions within a trench, (f) Protecting structures from liquefaction or coastal spreading, by densifying them, replacing them with stronger materials, or deepening their drainage systems.

Choosing the most appropriate ground improvement technique, as well as optimizing it for the specific project demands, requires a thorough understanding of different ground treatment technologies and careful consideration of several factors. Considerations for implementing a quality method include recognizing the method's functions, using a range of selection criteria, ensuring the method's quality, and considering the environment and cost. In this sense, knowing the challenges of implementing any ground improvement method can aid engineers in choosing the best one to use in different soil types. Further, as investigations and field experiences in ground improvement continue to solve these types of difficulties, the discipline is anticipated to maintain its importance as a crucial component of successful geotechnical engineering and construction.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

A variety of terms have been used to describe the action of altering the ground or soil for engineering goals. It entails soil stabilization and ground improvement. Ground improvement and soil stabilization are both processes used to improve the geotechnical qualities and engineering response of a soil or earth substance at a particular location. The methods which could be used to complete the processes, are divided into three categories which are mechanical, biological, and chemical stabilization (Nicholson, P.G., 2014).

Ground improvement is significant for building skyscrapers, dams, oil storage facilities, and highways. Getting things to work better on the ground is a big job for engineers. There is a significant need to develop more reliable, environmentally friendly, and less time-consuming methods to solve the problem (Verma et al., 2021). In the future, improvements will be crucial to geotechnical practice so that cutting-edge materials can be used more efficiently, a lower carbon footprint can be achieved, natural disasters can be better mitigated and prevented, industrial waste can be processed and recycled, brownfield sites can be developed, and existing structures can be maintained and renovated (Simpson and Tatsuoka, 2008). This chapter will discuss the ground improvement method in mechanical, hydraulic, and chemical stabilization method and the challenges of implementation in the factors of environmental impacts, construction works, and geotechnical impacts.

2.2 Ground Improvement Method

2.2.1 Chemical Stabilization

In chemical stabilization, ground improvement is achieved by mixing various chemicals with soil to develop desirable characteristics. Some of the most commonly used chemical methods are uses of inorganic pozzolanic/cementitious binders like fly ash, cement, lime, or some calcium-based chemicals. These methods have shown a long-term change in ground properties; however, some environmental concerns are usually associated with them (Gaafer et al., 2015).

In Malaysia, soft soils are defined as quaternary sediments, which comprise alluvial deposits and organic or peat soils (Kaniraj & Joseph, 2006). Numerous research has been conducted on hardening soft soils, notably the peat soil. The strength of peat soil stabilized with cement and other pozzolanic materials was investigated by Boobathiraja et al., (2014). The soil is stabilized by using binding agents such as lime and cement. 10%, 30%, and 50% of the dry soil mass are put to the peat soil sample, correspondingly. According to tests, lime and cement strengthened the soil. With an increase in the number of additions, the maximum dry density of the soil rises, but the ideal moisture content falls.

The influence of chemical stabilizers on peat shear strength was examined by Moayedi et al., (2013). They study the effects of monovalent, divalent, and trivalent cationic stabilizers on the shear strength enhancement of tropical peat samples. Unconfined compressive strength (UCS) tests were conducted after seven, 21, and 30 days of curing, respectively. It was found that the shear strengths of the peat samples were 8%, 6%, 6%, and 4% sodium silicate, calcium oxide, calcium chloride, and aluminium hydroxide, respectively. The calcium oxide experiment produced the most outstanding UCS value, with treated peat reaching 76 kPa after a 30-day curing period. The strength differences induced by the different cationic stabilizers are best explained by considering the peat's mineral composition and the physical and chemical changes.

Kolay et al., (2011) assessed the efficacy of several stabilizing agents in Sarawak's tropical peat soil. In this experiment, ordinary Portland cement (OPC), quick lime, and class F fly ash were used as stabilizers. The quantities of OPC, quick lime, and fly ash applied to the peat soil sample, represented as a percentage of dry soil mass, were 5-20%, 5-20%, and 2-8%, respectively, for curing durations of seven, 14, and 28 days. The UCS test was conducted on stabilized samples at the stated stabilizer percentages. The findings reveal that the UCS value rises considerably with the addition of all stabilizing agents and curing durations. However, after a 28-day curing period, the UCS values of fly ash and quick lime increase to 15% and 6%, respectively, but rapidly fall beyond this percentage.

Islam and Hashim (2009), stabilized the peat soil using deep mixing. Soil columns were constructed by a deep mixing method using cement, sand, bentonite, and calcium chloride by conducting a field model study. In the first mix design, 100% of high strength cement was used as the binder, 25% well-graded sand was used as the filler, and 4% calcium chloride was used as the binder. In the second mix design, the ordinary Portland cement and bentonite were at 85:15 ratio as the total volume binder, with highly graded sand accounting for 25% of the total volume peat. The bearing capacity of peat soil was shown to increase considerably after stabilization by the deep mixing approach. Compared to conventional Portland cement, sand, and bentonite, the research discovered that high setting cement, sand, and calcium chloride as a binder produced superior results.

Fasihnikoutalab et al. (2015) examine the potential for Olivine to be used as a long-term material for soil stabilization and slope stability, as well as its capacity to help mitigate climate change. With the chemical formula (Fe, Mg) 2SiO4, Olivine is an excellent mineral for CO2 collection. Due to its high magnesium oxide (MgO) content, it may also be a sustainable material for soil stabilization. Due to the chemical makeup of Olivine, it is classed as a pozzolan mineral. Magnesium oxide is an excellent CO2 absorber, and carbonated magnesia provides soil stability, making it an active layer in slope stabilization operations. According to a study of the Tawau geological heritage region, the area's prominent mountainous backbone is formed by volcanic rocks of the andesite-dacite association. This area is situated in the eastern section of the Semporna Peninsula in Sabah, West Malaysia. The rocks include *pyroxene*, *Olivine*, *clinopyroxene*, *hornblende phenocrysts*, and *magnetite microcrystals* (Tahir et al.,2010)

Makinda et al. (2018) investigate the effect of lime-sand-column on the value of the void ratio, coefficient of consolidation, volume compressibility, and compressibility properties of the stabilized soil and the properties of tropical Borneo peat. Lime contributes to the compressibility decrease by serving as a binder between soil particles. Following the evaluation of the peat's engineering characteristics, a consolidation test with lime percentages of three and six was conducted for one and three curing days to determine the effect of the lime-sand column on the peat's engineering properties. Following that, experiments with a varying number of lime-sand columns were conducted. The research discovered that by extending the curing time, increasing the percentage of lime, and increasing the number of sand columns, the compressibility of the peat soil could be decreased.

Ma et al. (2018) analysed the effect of Sulfonated Oil (SO) on the Unconfined Compressive Strength (UCS) values of treated soil samples. SO was added at mass ratios of 0.005 percent, 0.01 percent, 0.02 percent, 0.05 percent, 0.1 percent, and 0.2 percent, respectively. The addition of SO considerably increased the UCS values of Portland cement – Activated carbon (PC-AC) treated soil samples, while soil samples treated with 0.02% SO had UCS values up to 2.2–3.4 times greater than those without SO. PC-AC-SO-treated soils are more resistant to disintegration than PC-AC-SO-treated soils. According to SEM micrograph, the soil compactness was significantly enhanced after Sulfonated Oil treatment.

Fauzi et al. (2013) evaluated the use of high-density polyethylene (HDPE) and glass as stabilizing soil materials in Kuantan's clayey soils. The research investigates the soil engineering properties and strength of different HDPE and glass content clayey soils from various Kelantan sites. To find the optimal mixture design, soil samples were compacted using the Standard Compaction and the California Bearing Ratio methods (CBR). The samples were created by blending soil samples with varying stabilizer levels at an ideal water content. The changes in the stabilizer content were four percent, eight percent, and 12% by total dry weight. According to laboratory testing, introducing stabilizers such as cut High-Density Polyethylene and

Crushed Glass improved the engineering qualities of Kuantan Clayey soil and the California Bearing Ratio.

Cementitious stabilisers, fly ash, furnace slag, salts, chlorides, and silicates are a few examples of chemicals utilised in this category of chemical stabilization techniques. For the majority of granular soils, cement is the most efficient and cost-effective material. Due to high dose requirements and construction (mixing) challenges, however, the use of cement for cohesive soils may be comparatively ineffective or economically inefficient, particularly if the soil is damp and if excessive shrinkage tendencies are a concern. Well-graded, granular soils, such as gravelly soils and sands with only a little proportion of silt or clay, are most suited for cement stabilization. The fact that soil-cement shrinks as a result of hydration and moisture loss is one of the main problems with cement soil stabilization. When shrinkage cracks reflect off of adjacent surfaces or when continuous structural slab action or water tightness are needed, this might have negative consequences.

Fly ash is used in place of or in addition to concrete or simply when the pozzolans in the natural soil are insufficient. Fly ash can be used alone to stabilise soil or improve soil; however, it is frequently combined with other admixtures, such as lime, cement, bitumen, and others, to increase the economics or qualities of each. For instance, adding fly ash as an additive to cement will decrease permeability, raise stiffness, and lessen shrink-swell tendencies. Furnace slag, also known as ground granulated blast furnace slag (GGBFS), is the granular by-product of processing iron blast furnace slag produced during the steelmaking process It is a cementitious substance that can be used in place of equal parts cement and is occasionally referred to as slag cement. For the treatment of clayey soils, GGBFS has been used as a soil additive, occasionally in conjunction with lime, to increase strength and reduce expansion for soils containing considerable sulphates.

For a range of diverse geotechnical applications, a variety of salts have been utilised successfully as stabilising agents. Two salts that are frequently used are calcium chloride (CaCl2) and sodium chloride (NaCl, or regular table salt). Most salts are soluble in water, so if they are not covered, rainwater will soak them away, greatly reducing their brief effects. Calcium chloride can be created directly from limestone or as a by-product of the chemical processing of sodium carbonate. This salt is a calcium-based, inorganic combination that is hygroscopic (attracts water). It has used as a compaction aid, particularly for gravels that struggle to hold moisture. In granular sandy soils, sodium chloride has also been utilised to improve compaction densities and regulate moisture. While sodium silicates (Na_2SiO_3) have been employed to alleviate the effects of dust, they also raise the pH of the soil, which may encourage silicates to dissolve off soil particle surfaces and become available for cementation reactions. This might improve cementitious admixture stability.

2.2.2 Hydraulic Stabilization

Hydraulic stabilization is a term that refers to a set of soil and ground improvement procedures that involve altering the flow, presence, and pressures of water in the ground. Any change in the earth's surface related to drainage, dewatering, seepage, or groundwater flow might be included. Some of the most severe engineering impacts caused by the presence, introduction, or change in concentration of water in the ground include foundation collapse, slope failure, excessive volume change, liquefaction, pipe failure, and full or differential settlement. Construction dewatering is a frequent application in which the water table is lowered to facilitate excavation in a dry environment (Nicholson P.G., 2014).

A primary strategy to improving ground engineering is to change the hydraulic characteristics of the ground. This may be accomplished by altering the permeability of earth materials by physical or chemical manipulation, or by dewatering specified soil masses. Improvement tactics may vary depending on the intended objective, which might range from enhanced flow capacity for "free drainage" to producing a practically "impermeable" barrier or boundary condition. ground improvement strategy.

Modifying hydraulic characteristics in the earth has many major goals such as:

- The water table is temporarily lowered over a given area (construction dewatering)
- Lowering of the water table on a long-term basis (for permanent subsurface structures)