CHARACTERIZATION OF KAOLIN CLAY TREATED WITH GROUND GRANULATED BLAST-FURNACE SLAG

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DEDICATION

This project is dedicated to my family

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ABSTRACT

This study was carried out to identify the optimization of GGBS improved the properties of kaolin clay. It is in line with the sustainability approach which concern with the safe reuse, management and disposal of waste material. GGBS collected from local supplier in Johor Bahru was used to improve the geotechnical properties of kaolin clay supplied from a local supplier in Johor Bahru, Malaysia. Treated specimens were prepared at different percentages of GGBS 5%, 10%, 15%, 20%, and 25% and at different curing periods of 7, 14, and 28 days, respectively. Particle size distribution, Atterberg limits, and specific gravity tests were conducted on kaolin clay. Standard proctor test was conducted on both untreated and treated kaolin clay prior preparation of specimen for unconfined compressive strength test (UCS). In addition, consolidated undrained (CU) triaxial tests were conducted for details strength characteristics on development of the treated kaolin clay. It was found that the maximum dry density and the optimum moisture content do not change significantly with the increase of GGBS content. In addition, unconfined compressive strength for the treated kaolin clay shows the highest strength gained after 28 days. Treated kaolin clay with 25% GGBS shows the highest strength gained which shows the highest UCS is 8.75 MPa. At 7 days curing period consolidated undrained (CU) Triaxial test showed that the effective cohesion and friction angle increment of treated kaolin clay with 20% reach up to 417.73%, and 148.17% respectively, of the untreated kaolin clay effective cohesion and friction angle. Overall, the addition of GGBS is very effective in the treatment of kaolin clay due to its promising strength at earlier stages.

ABSTRAK

Kajian ini dijalankan untuk mengenalpasti kadar optimum Ground Granulated Blast-Furnace Slag (GGBS) yang meningkatkan sifat tanah liat kaolin. Ia adalah sejajar dengan pendekatan kemampanan yang berkaitan dengan penggunaan semula, pengurusan dan pembuangan bahan buangan yang selamat. GGBS diperoleh dari pembekal tempatan di Johor Bahru digunakan untuk meningkatkan sifat geoteknik tanah liat kaolin. Spesimen yang dirawat disediakan pada kandungan GGBS yang berbeza iaitu 5%, 10%, 15%, 20%, dan 25% dan pada tempoh pengawetan yang berbeza masing-masing adalah pada 7, 14 dan 28 hari. Pengagihan saiz zarah, had Atterberg, dan ujian graviti spesifik dilakukan pada tanah liat kaolin. Ujian proctor piawai dijalankan pada kedua-dua tanah liat kaolin yang tidak dirawat dan dirawat terlebih dahulu sebelum melaksanakan ujian kekuatan mampatan yang tidak terkandung (UCS). Di samping itu, ujian triaaksial yang tidak dikendalikan (CU) telah dijalankan untuk ciri-ciri kekuatan terperinci mengenai pembangunan tanah liat kaolin yang dirawat. Telah didapati bahawa kepadatan kering maksimum dan kandungan lembapan optimum tidak berubah dengan ketara dengan peningkatan kandungan GGBS. Di samping itu, kekuatan mampatan yang tidak terkandung untuk tanah liat kaolin yang dirawat menunjukkan kekuatan tertinggi yang diperoleh selepas 28 hari. Tanah liat kaolin yang dirawat dengan 25% GGBS menunjukkan kekuatan tertinggi yang diperolehi yang menunjukkan UCS tertinggi ialah 8.75 MPa. Pada 7 hari ujian pengawetan yang tidak dikendalikan (CU) Triaxial menunjukkan bahawa kenaikan sudut perpaduan dan geseran yang berkesan terhadap tanah liat kaolin yang dirawat dengan 20% masing-masing mencapai 417.73% dan 148.17%, dari kaolin tanah liat yang berkesan dan sudut geseran yang tidak dirawat. Secara keseluruhannya, penambahan GGBS sangat berkesan dalam merawat tanah liat kaolin kerana kekuatannya menjanjikan pada peringkat awal.

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LIST OF ABBREVIATIONS

GGBS	Ground Granulated Blast-Furnace Slag
MDD	Maximum Dry Density
OMC	Optimum Moisture Conent
UCS	Unconfined Compressive Strength
CU	Consolidated Undrained

LIST OF SYMBOLS

Al^{3+}	-	Aluminum
c	-	Cohesion
Ca^{2+}	-	Calcium
CaO	-	Calcium Oxide
Fe^{3+}	-	Ferrum
FeO	-	Ferrous Oxide
H^{+}	-	Hydrogen
K^{+}	-	Potassium
kN	-	Kilo Newton
L.O.I	-	Loss On Ignition
m	-	Meter
Mg^{+2}	-	Magnesium
MgO	-	Magnesium Oxide
mm	-	Millimeter
Na^{+}	-	Sodium
Si^{+2}	-	Silicon
TiO_2	-	Titanium Dioxide

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CHAPTER 1

INTROUDUCTION

1.1 Background:

In Malaysia, over 100 million tons of kaolin deposits reserves have been found among the country placed in the states of Perak, Johor, Kelantan, Selangor, Pahang and Sarawak (Baioumy & Ibrahim 2012). Kaolin clay is the weak soil that has the ability to shrinkage when dry and swells when wet. Shrinkage and swelling of subgrade soil may lead to the failure of the structures. Kaolin clay may cause a failure in foundation footings, foundation wall, landslides and roadways. Sometimes these damages can be repaired.

Clayey soils are usually associated with compressibility problems combine with variation of the moisture content due to rainfall and ground water fluctuation. Kaolinite a type of clay is within the soils that are affected by these issues (Abdulhussein *et al.*, 2014). Also, kaolinitic is geochemically and industrially very versatile (Manju *et al.*, 2001) which is used in many industrial products including construction materials and healthcare products. The minerals are formed under tropical weathering conditions in areas where precipitation is relatively high, and where drainage is good, which enables leaching of cations and iron from acidic granitic rocks (Mitchell, 1981).

When a construction is built on this type of soil many problems are expected to take place like severe settlement, heave, and failure of the construction. Considering the high coverage of Malaysia areas with problematic soil effective and attractive soil stabilization methods are required. In Malaysia, the use of chemically stabilized soil is still uncommon practically, assigned to its high cost corresponding to the production cost and environmental uncertainties of bituminous mix and concrete (Eisazadeh *et al.*, 2013).

Previous experiences showed that there are two major problems in constructing in soft clay soft layer and those are the stability of soil deposit and the long term excessive settlement. Those two problem need to be considered in design and construction stages.

Soil stabilization is a technique used to improve soil engineering properties. It is divided in to two types, the first is physical stabilization, which soil is modified to improve mainly its engineering properties, and other type is chemical stabilization, as chemical addictive added to the soil profile to enhance not only its engineering properties but also its chemical characteristics.

Chemical stabilization using Portland cement (PC) is a worldwide method used to improve soil characteristics to provide a workable platform for construction (Brandon *et al.,* 2009). However, the production of Portland cement is responsible for 5% of global CO_2 emissions. The chemical mechanism inherent in Portland cement production generates large amounts of CO_2 and it is excessively energy-intensive as one ton of Portland cement consume around 5000 mega joule of energy and produced around 0.95 ton of CO_2 (Higgins, 2007). alternatively some studies examining uses of Ground granulated blast –furnace slag (GGBS) and found the positive effects of GGBS on Engineering characteristics of clays (Cokca *et al.,* 2009; Sivrikaya *et al.,* 2014). In this study the effect of GGBS as chemical stabilizer on the behaviour of the kaolin clay is investigated in term of the physical and engineering properties.

1.2 Problem statement:

Kaolin clay is problematic soil in term of physical and engineering properties. The fluctuation of water content crucially effect the behavior of kaolin clay caused by rainfall and ground water level's variation. As the volume of the kaolin clay is expected to change significantly with the water content fluctuation. As well as the strength of the kaolin clay is low and don't meet with the most of the engineering structure requirement and may lead to instability and severe defects on the constructed structure. Conventional compaction method is not efficient and ineffective in improving kaolin clay behavior.

.Conventional soil replacement consists of excavating poor or inadequate bearing material and replacing it with stiffer and stronger material. This is commonly used when bearing soil is weak and very compressible. This method is very efficient when the thickness of kaolin clay layer is small otherwise it will reflect on the cost.

Chemical stabilization using Portland cement has been extensively used as binder in soil stabilization, and its effective on stabilizing various types of soil, but as reported that the cement industry have high pollution contribution worldwide including many harmful emissions to the environment a sustainable approach like using Ground granulated blast –furnace slag (GGBS) an industrial steel by product has been encouraged as a novel replacement to PC in many engineering materials. Adding GGBS to Kaolin clay will improve kaolin clay physical and engineering properties and will minimize the need for other chemical stabilizer and reduce the emission of carbon to the atmosphere.

1.3 Significance of Study

This study was carried out to assist the sustainability approach of promoting Ground granulated blast –furnace slag as effective soil stabilizer. This could improve the physical and engineering properties of the soil and reduces the environmental pollution. However, Chemical soil stabilization is the foremost well-known procedure for treatment of soft clay soil with poor engineering characteristics. Cement and lime are the common conventional stabilizers that have been used for improving the soil. Nevertheless, the excessive environmental and economic issues related with cement and lime increases the demand of identifying new more sustainable options. The influence of utilizing GGBS as soil stabilizer is not well defined, as the studies which discussed the characteristics of soils treated with only GGBS have been carried out by few researchers (Cokca *et al.,* 2009; Pathak *et al.,* 2014; Yi *et al.,* 2012; Kumar *et al.,* 2012; Sivrikaya *et al.,* 2014).

However, no studies used GGBS only as stabilizing agent for kaolin clay have been published to date. Thus, the influence of treated soil with GGBS on the consolidated undrained (CU) triaxial parameters have not been discussed in previous studies the only expiation for this is (Pathak *et al.,* 2014) study, but the type of triaxial test which was conducted on his study was not clearly defined. Furthermore the well-defined characteristics of the treated soil using GGBS obviously increase the utilizing of GGBS as alternative of the natural resources and decrease the energy consumption applied for manufacturing of the common soil stabilizers wish includes Portland cement. On the other hand reduce the environmental risks of utilizing manufactured chemical compounds as soil stabilizers.

1.4 Objective of study:

The aim of this study is to identify the optimum proportion of Ground granulated blast –furnace slag (GGBS) in order to improve the geotechnical properties of Kaolin Clay. The objectives of this study are:

1) To determine the physical properties of Ground granulated blast –furnace slag (GGBS) and Kaolin Clay.
2) To identify the effect of various proportions of Ground granulated blast –furnace slag (GGBS) on strength characteristics of kaolin at different curing periods.
3) To verify the changes in the morphology and mineral structure due to strength development of the treated Kaolin clay.

1.5 Scope of the study:

The study investigated the influence of GGGBS as stabilizing agent on kaolin clay engineering characteristics and considered GGBS is the main and only additive for kaolin clay treatment. It further focused on the compaction and strength parameters development. Appropriate research methodological procedures and relevant techniques were adopted. The current research study was limited to the strength characteristics and strength development.

1.5.1 Material:

Soil used in this study is Kaolin Clay supplied by a local factory. Meanwhile Ground granulated blast –furnace slag (GGBS) is obtained from Local source in Johor Bahru, Malaysia.

1.5.2 Testing:

Physical tests to be carried out on Kaolin Clay and GGBS alone are Atterberg limit, Particle Size Analysis, Specific gravity, and standard proctor compaction.

The effect of GGBS content with various curing periods on kaolin is determined by unconfined compression tests (UCS) and standard proctor compaction test. GGBS contents of (5, 10, 15, 20 and 25%) are prepared at different curing periods of 0,7,14 and 28 days, respectively.

In addition triaxial compression consolidated undrained (CU) test will be carried out for the stabilized Kaolin clay at the selected percentages samples at 7 days curing period to determine the development of the effective strength parameters (i.e cohesion and friction angle) of the treated soil.

1.6 Thesis Outline:

Chapter 1: This chapter presented the general introduction of the study. This included the problem statement, the objectives, and the scope of the research.

Chapter 2: This chapter comprised a historical and relevant literature review from previous studies on kaolin clay stabilization with different additives and the improvements on its properties.

Chapter 3: This chapter generally presented and justified the research methodology and material collection techniques. It covered a discussion of the laboratory tests used in this study, and data analysis techniques that will be used.

Chapter 4: This chapter discusses and analysis the tests results in comparison with the previous findings on the subject matter of stabilizing kaolin clay with GGBS.

Chapter 5: This chapter provides the study results summarization which was discussed in the chapter 4, and the recommendation about which proportion is the optimum proportion that can be used to stabilize the Kaolin clay.

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