STRENGTH AND COMPRESSIBILITY CHARACTRISITCS OF KAOLIN MIXED WITH BOTTOM ASH

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ABSTRACT

Coal is one of the world's most important sources of energy, fuelling almost 40% of electricity worldwide. The burning of coal produced coal ash that mostly consists of Fly Ash and Bottom Ash. Bottom Ash (normally recognized as coal combustion residues from pulverized fuel power stations) has been categorized as solid garbage. However, the utilization of Bottom Ash in construction-related applications has received some attention within the last decade. This project aimed at determining the strength and compressibility of Kaolin, mixed with 25 %, 50% and 60% of bottom ash. Kaolin, in powdered forms, was mixed with Bottom Ash and compacted at optimum moisture content. The strength and compressibility of the compacted samples were determined from direct shear test, unconsolidated undrained triaxial tests, and one-dimensional consolidation test, besides the California Bearing Ratio and permeability tests. It was observed that the granular nature of Bottom Ash increased the friction angle of Kaolin, increased the permeability and expedite the consolidation rate. However, the addition of 25% Bottom Ash gives the highest shear strength of Kaolin while the addition of 60% Bottom Ash gives the highest permeability and coefficient of consolidation. This results show that Bottom Ash can be used to increase the strength of soil, in particular the soft soil and also could expedite the consolidation of the soil. This is due to the granular nature of the materials that could increase the voids in the mixtures and also contribute to increase in friction angles.

ABSTRAK

Arang batu merupakan salah satu sumber tenaga dunia yang paling penting yang dapat memberikan hampir 40% dari kuasa elektrik seluruh dunia. Pembakaran arang batu yang dihasilkan oleh abu batubara adalah sebahagian besarnya terdiri daripada abu terbang dan abu bawah. Abu bawah (biasanya dikenali sebagai residu pembakaran arang batu dari loji kuasa bahan api serbuk) telah dikategorikan sebagai sampah padat. Namun, penggunaan abu bawah dalam aplikasi yang berkaitan dengan pembinaan telah mendapat beberapa perhatian sejak sedekad yang lalu. Projek ini bertujuan untuk menentukan kekuatan dan kebolehmampatan Kaolin, dicampur dengan 25%, 50% dan 60% dari arang batu. Kaolin, dalam bentuk serbuk, dicampur dengan abu bawah dan dipadat pada kandungan lembapan optimum. Kekuatan dan kebolehmampatan sampel terpadat ditentukan dari ujian ricih terus, ujian tiga paksi tak terkukuh tak tersalir dan ujian pengukuhan satu dimensi, selain "California Bearing Ratio" dan ujian kebolehtelapan. Didapati bahawa sifat berbijian abu bawah meningkatkan sudut geseran Kaolin, meningkatkan kebolehtelapan dan mempercepatkan kadar pengukuhan. Namun, penambahan abu bawah sebanyak 25% memberikan kekuatan ricih Kaolin yang tertinggi sedangkan penambahan abu bawah sebanyak 60% memberikan nilai pekali kebolehtelapan dan pekali pengukuhan Kaolin yang paling tinggi. Keputusan ini menunjukan bahawa abu bawah boleh digunakan untuk meningkatkan kekuatan tanah, khususnya tanah lembut dan dapat mempercepatkan pengukuhan tanah. Ini disebabkan oleh sifat berbijian bahan yang dapat meningkatkan rongga dalam campuran dan juga menyumbang terhadap peningkatan sudut geseran.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AASHTO-	-	American Association of State Highway and Transportation Officials
ACAA	-	American Coal Ash Association
ASTM	-	American Society of Testing and Materials
BS	-	British Standard
CBR	-	California bearing ratio
CCRs	-	Coal combustion residues
CD	-	Consolidated drained
CU	-	Consolidated undrained
FGD	-	Flue gas desulfurization
USCS	-	Unified Soil Classification System

LIST OF SYMBOLS

ρ_d	Dry density
ρ	Bulk density
w	Moisture content of soil
G_s	Specified gravity
D	Diameter
S	Shear strength
c	Cohesion intercept
ϕ	Angle of internal friction
σ_1	Major principle stress
σ_2	Intermediate principle stress
σ_3	Minor principle stress
λ	Wavelength
d	Inter planner spacing
θ	Angle of incidence of X-ray to the Cu target element
C_u	Coefficient of uniformity
C_c	Coefficient of curvature
γ_d	Compacted dry density
γ_n	Normalized density
γ_w	Water density
σ_d	Deviator stress
ε_v	Volumetric strain
ε_a	Axial strain
C_C	Compression index

e	Void ratio
σ'	Effective pressure

LIST OF APPENDICES

CHAPTER I

INTRODUCTION

1.1 Introduction

Soft clays are widely found throughout the coastal plains of Malaysia, central plain of Thailand and East of Sumatra, Indonesia. Soft or poor unstable ground generally means subsoil, which has shear strength of less than 40 kPa. Soft soil can be physically moulded by light finger pressure. For very soft soil, the shear strength is less than 20 kPa and the soil can be extruded between fingers when squeezed. Soft soils are also generally referred to as weak compressible soils such as coastal alluvial soil or marine clay, and slime in examining pond areas (Neoh, 2000).

Besides the common use of surcharge with vertical drains, there are many others methods to stabilize soft soil, such as the use of floating piles, stone columns, replacement method, etc. (Broms, 1977; Raju, 2000). However, cost is the main concern for considering these stabilization methods. Generally the stabilization of soft clay usually involves expensive soil improvement methods to enhance stability and reduce uneven settlement. In construction of road structures, especially road embankments, bridge approaches and slopes, they require an extensive stabilization of wider foundation base. Consequently, requirement for land area is increasing. In most cases, imported backfill materials are also required and will further increase the overall cost of the project (Loke, 2000).

The solutions of many geotechnical issues for construction are very much directly or indirectly related to the understanding of the problematic soils. Soft clay is one of the problematic soils which are commonly found along the coastal areas at West Malaysia. In Klang area, the thickness of the soft marine clay may vary from 20 to 40m (Cheung, 2008).

Coal is one of the world's most important sources of energy, fuelling almost 40% of electricity worldwide. In many countries this figures much higher: Poland relies on coal for over 97% of its electricity; South Africa for 92%; China for 77%; and Australia for 76% (Joseph, 2005). Coal was introduced as a raw material for power generation since 1988 in Malaysia. The existing coal-fired power plants in Malaysia are Kapar (1,600 MW) commissioned in 1988, TNB Janamanjung (2,100 MW) commissioned in 2003 and Tanjung Bin (2,100 MW) commissioned in 2004. Looking at the electricity generation mix, the percentage of coal remains stable at an average of 8.6 percent from 1993-2000 and increased slightly to 12 and 14.1 percent in 2001 and 2002 respectively. However, in 2003, the percentage increased tremendously from 14.1 percent to 24.6 percent of coal in the electricity generation mix due to the commissioning of Janamanjung power plant. According to Joseph (2005), with the two more new constructed coal-fired power plants, Jimah and Tanjung Bin, coal consumption is expected to increase from 10 million ton to 19 million ton in year 2010. Malaysia imports about 70 percent of its total coal requirements from Indonesia, other will be imported through bulk carriers from mines in China, Australia, South Africa, and elsewhere as the need arises.

Coal ash mostly consists of fly ash and bottom ash, according to the American Coal Ash Association (ACAA, 2003), in the US, the general production ration of fly ash and Bottom Ash is approximately 80:20. The heavier ash that drops through the bottom of the furnace where it is collected in a funnel is called as bottom ash. It is classified as wet or dry Bottom Ash depending on the type of furnace used and relatively coarse material. The lighter fly ash is carried through the boiler with the exhaust gases and is collected by ash precipitators (Huang, 1990). Fly ash accounts for 70 to 80 percent of the coal ash produced by most electric power plants while Bottom Ash constitutes about 10% - 18% of the overall ash.

Bottom Ash [normally recognized as coal combustion residues (CCRs) from pulverized fuel power stations] has been categorized as solid garbage. But, CCRs are increasingly being regarded as a useful substitute material resource. They had an appearance similar to dark grey coarse sand, and its particles are clusters of micron sized granules, up to 10 mm in diameter (60% - 70% smaller than 2mm. 10% - 20% smaller than 75 microns) (ACAA, 1998).

1.2 Problem Statement

The growing demand for electricity resulted in the construction of many coal fired power plants. As the consumption of coal by power plants increases, so does the production of coal ash. While the use of coal increases, waste issues associated with coal production are tempted more and more thoughtfulness (Joseph, 2005). Even though there is no report about the producing of coal ash annually in Malaysia, but basically about 10% of total weight of the coal burned produces ash (Huang, 1990). Disposal of unused coal ash is costly and places a considerable burden on the power industry and finally transferred to the electricity consumer. In addition, the disposing of ash contributes to the ongoing problem of diminishing landfill space pose an environmental hazard. Previously, most researches had been focussing on the properties of fly ash (ACAA, 1998).

Nevertheless, some of the studies showed that the engineering properties of most Bottom Ash were more favourable than those of traditional highway material and has the capability to improve asphalt pavement performance when used to substitute a portion of the aggregate in asphalt mixes. Changeability of coal Bottom Ash is a latency problem because of the variability in type and origin of coal burned, boiler types, degree of coal pulverization, firing conditions in the furnace and ash handling practice (Huang, 1990). There is a requirement for a systematic manner to estimate locally available bottom ashes for potential construction utilization because even Bottom Ash produced from unitary source can be entirely difference depending on the operating conditions and procedures.

Kapar power plant consumed enormous quantities of coal each year. This produces a substantial amount of unused coal ash. The majority of ash is disposed in mines prior to their reclamation. Besides, there are many areas of the Malaysia faced with a shortage of conventional construction materials. In city areas where demands of construction materials are high, deficiency in the supply of conventional materials aggregates. In addition, zoning restrictions and environmental regulations often remove accept Table materials from availability. Normally these same city areas are served by power stations that produce large quantities of ash. Obviously, a favourable combination of circumstances is created for utilization of power plant ash as a partial or full substitute for conventional aggregates in various applications. The successful use of Bottom Ash in civil engineering construction would provide significant economic savings.

The advancement of works in bearing capacity studies have led to further works on the use of reinforcement in soft soils or clays. Soft clays have been known to cover vast coastal areas of Malaysia (Neoh, 2000). As development progresses, more construction areas have occupied these compounds. The problem with soft clay is large settlement and low bearing capacity. With more research being conducted, various techniques are available to reduce the settlement and increase the bearing capacity of soft clays.

1.3 Objectives

This master project is aimed at improvement in the strength and compressibility characteristics of Kaolin, representing as soft clay, by mixing with Bottom Ash so that Bottom Ash as waste material could be used in improvement of soft soils. Hence, the objectives of this project are as follow:

i. To determine changes in basic properties of Kaolin mixed with various percentage of Bottom Ash. These percentages are 25%, 50% and 60% by weight of bottom ash.

ii. To evaluate the strength characteristics of Kaolin mixed with bottom ash at maximum compaction.

iii. To determine the compressibility characteristics of Kaolin mixed with bottom ash at maximum compaction.

1.4 Scope of Study

In this project, only the Bottom Ash from Sultan Salahuddin Abdul Aziz Shah power plant (Kapar, Selangor) is concerned (Figure 1.1, Figure 1.2). Sultan Salahuddin Abdul Aziz Shah power plant is located at the west coast of Peninsular Malaysia, approximately 50 km to the west of capital city of Malaysia, Kuala Lumpur. It is normally known as Kapar Power Station. The power station lies between the mouths of the Kapar Besar and the Serdang Kecil Rivers. Totalling 2420

MW, this station consists of steam plants firing oil, gas and coal as well as open cycle Frame 9 gas turbines.

Kapar Energy Ventures Sdn. Bhd owns, operates and maintains Sultan Salahuddin Abdul Aziz Power Station since 9th July 2004, after successful acquisition of the power plant from Tenaga Nasional Berhad.

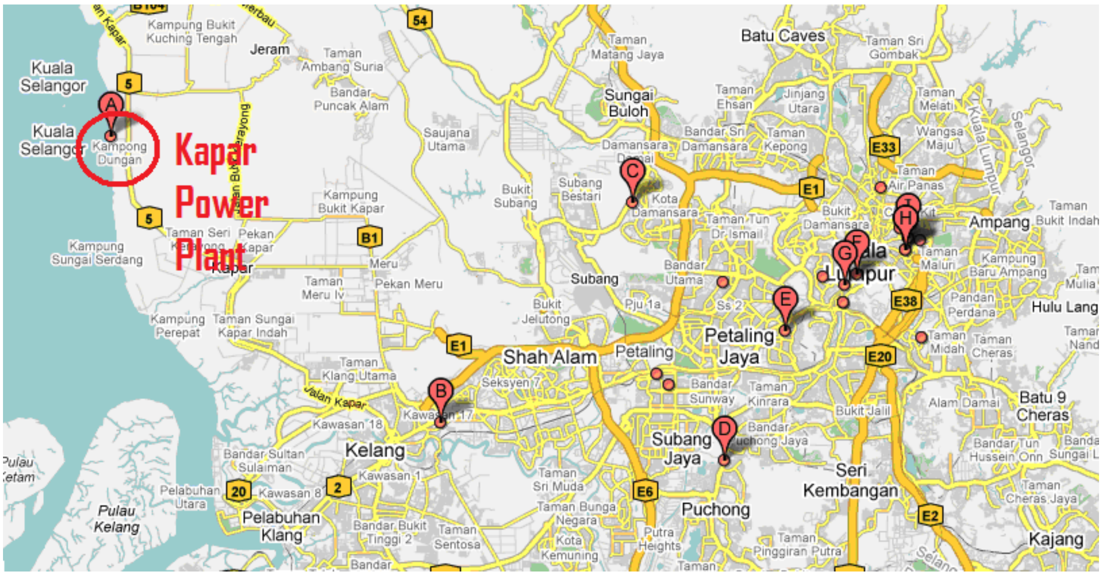

Figure 1.1: The Location of Sultan Salahuddin Abdul Aziz power plant (www.maps.google.com, 2010).

Figure 1.2: Salahuddin Abdul Aziz Shah power plant in Kapar Selangor.

The study focuses on the strength and compressibility of Kaolin mixed with Bottom Ash. Kaolin had been used to represent the clay soil. The engineering properties of the materials had been tested using the standard method such as the British Standard 1377, 1996 or the American Society for Testing and Materials (ASTM), depending upon the suitability or the availability of the equipment in the laboratory within Universiti Teknologi Malaysia (UTM).

1.5 Importance of study

Since construction is inevitable in many areas of Malaysia and of course some other parts of the world that have the problem in strength and compressibility of soft clay, basic knowledge and understanding of soft clay and Bottom Ash properties are of great importance to improve the strength and compressibility of soft clay mixed with Bottom Ash. Using this mixture, increase in strength that leads to increase in ultimate bearing capacity of soil, decrease in coefficient of volume compressibility and decrease in coefficient of consolidation that lead to smaller settlement are expected. Relatively, smaller settlement cause better compressibility.

This allows the engineers to use the results obtained for preliminary design purposes involving construction of the soft soil that could be improved by adding certain percentages of Bottom Ash.