THE EFFECT OF BOTTOM ASH ON CRUSHABLE SANDY SOIL

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SUPERVISOR'S DECLARATION

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I hereby declare that the work in this 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 Universiti Malaysia Pahang or any other institutions.

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ABSTRAK

Di dalam proses pembinaan, pecahan zarah-zarah pasir berlaku di bawah beban hentakan. Sebagai contohnya, ketika kerja memacu cerucuk ke dalam pasir. Pecahan pasir ini akan menyebabkan pengurangan dalam saiz pasir dan mengubah ciri-ciri kejuruteraan pasir seperti pengedaran taburan zarah, bentuk pasir, nisbah lompang dan aspek lain.

Objektif untuk projek penyelidikan ini adalah untuk mengkaji kesan abu bawah terhadap tanah pasir yang hancur. Pelbagai eksperimens akan dijalankan untuk mengkaji keberkesanan abu bawah dalam meningkatkan sifat kejuruteraan tanah pasir yang telah hancur. Abu bawah akan dicampur ke dalam pasir dengan peratusan 5%, 10%, 15% dan 20% dan menjalani 500 dan 1000 kali pukulan di bawah Mesin Hentakan. Ciri-ciri kejuruteraan untuk campuran abu bawah dengan pasir akan diuji bagi situasi sebelum dihancurkan dan situasi selepas dihancurkan dengan 500 dan 1000 kali pukulan. Ciri-ciri kejuruteraan yang telah diuji termasuk analisis ayakan, spesifik graviti, ketumpatan relatif, ujian kebolehtelapan, ujian standard proctor dan ujian nisbah galas California.

Berdasarkan keputusan eksperimens yang telah dianalisa, penambahan abu bawah ke dalam pasir yang hancur telah menunjukkan peningkatan dalam galas beban pasir. Antara peningkatan terhadap pasir termasuk sifat-sifat kejuruteraan seperti indeks kehancuran, keupayaan galas dan kebolehtelapan.

ABSTRACT

In construction, the breakage of sand particles are often occur under crushing load, for instance, during the pile driven process into the sand. The breakage of sand particle will result in the reduction of size of the sand and alter it engineering properties such as particle size distribution, particle shape, void ratio and many others properties.

The objective of this research project is to study the effect of bottom ash on crushable sand soil. The effectiveness of bottom ash in improving the engineering properties of crushed sandy soil was studied. The bottom ash with 5%, 10%, 15% and 20% was added into the sand and crushed with 500 and 1000 blows under Automatic Compactor. The engineering properties of different proportion of bottom ash mixture before crushing and after crushing with 500 and 1000 blows were tested. The engineering properties which were tested including the sieve analysis, specific gravity, relative density, permeability test, standard proctor test and California bearing ratio test.

Based on the result, the adding of bottom ash into the crushable sand showed improvement to the load bearing capacity of the crushable sand. The improvement includes the engineering properties such as crushability indices, bearing capacity and permeability.

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LIST OF SYMBOLS

%	Percentage
Cu	Coefficient of uniformity
Cc	Coefficient of curvature
N_L	Number of layers
N_B	Number of blows
W_h	Weight of hammer
D	Distance between hammer and sample
V_m	Volume of mould
D_{10}	Value of the particle diameter at 10% in the cumulative distribution
D_{30}	Value of the particle diameter at 30% in the cumulative distribution
D_{50}	Value of the particle diameter at 50% in the cumulative distribution
D_{60}	Value of the particle diameter at 60% in the cumulative distribution
Br_{50}	Breakage Index at 50% in the cumulative distribution
D_{50i}	Value of the particle diameter at 50% in the cumulative distribution at initial gradation
D_{50f}	Value of the particle diameter at 50% in the cumulative distribution at final gradation
Cr_c	Crushing Coefficient
FI	Fouling Index
$P_{0.075}$	Percentage by weight of material sample passing 0.075mm sieve
$P_{4.75}$	Percentage by weight of material sample passing 4.75mm sieve
FI_D	Percentage of fouling
$P_{9.5}$	Percentage by weight of material sample passing 9.5mm sieve
W_d	Dry weight of the sample
k	Coefficient of permeability
L	Length of specimen
A	Cross sectional area of permeameter
t	Time for discharge
h	Hydraulic difference of water
G_s	Specific gravity
W_1	Weight of bottle and stopper
W_2	Weight of bottle, stopper and dry soil
W_3	Weight of bottle, stopper, water and soil
W_4	Weight of bottle, stopper and water
P_{min}	Minimum density
M_1	Mass of soil
V_c	Volume of mould
P_{max}	Maximum density
M_2	Mass of soil
V_s	Volume of tested soil
e_{min}	Void ratio of coarse grained soil in densest state
e_{max}	Void ratio of coarse grained soil in loosest state
R_d	Relative density
e	Void ratio of coarse grained soil in its natural existing state
P_T	Test load corresponding to the chosen penetration from the load penetration curve
P_s	Standard load for the same penetration

LIST OF ABBREVIATIONS

OPC	Ordinary Portland Cement
CBR	California Bearing Ratio
UMP	Universiti Malaysia Pahang
ASTM	American Society for Testing and Material
USCS	Unified Soil Classification System
PSD	Particle Size Distribution
USBR	US Bureau of Reclamation

CHAPTER 1

INTRODUCTION

1.1 Introduction and Background

Sand is naturally granular and porous construction material which is formed by the weathering of rocks. Due to its high accessibility, sand has been widely used in construction industry for centuries. During construction, breakage of sand particles and reduction in size of particles may occur under crushing load. For instance, when the piles are driven into the sand, the sand will experience stresses which are high enough to break the sand particles. The breakage of sand particles will result in the increase of percentage of fine particles and broaden the particles size grading (Kikumoto, Wood, & Russell, 2010).

The designs in geotechnical engineering related to foundation are usually analysed using the soil parameters obtained from in situ or the laboratory test. The calculations were done assuming that the soil parameters will always remained unchanged after post design work. However, in reality the sand will experience crushing and the size of sand may be reduced during and post construction work. The changes in size of sand will alter the mechanical behaviour and engineering properties of the granular material such as strength behaviour, volume change, pore pressure developments and permeability (Emidio, Flores, & Impe, 2009). These changes are depends on the amount of sand particle crushed due to the applied crushing load.

The occurrence of the changes of gradation of sand is uncontrollable and irreversible. These changes indicate that the sand which exists at the end of the piles driven activity will be different from the sand that exists initially. The changes in mechanical behaviour may result in the failure of the construction due to the decreasing

of bearing capacity. Therefore it is vital to determine the crushability of granular sand that is used for geotechnical applications and predict the bearing capacity accurately.

Over the past decades, researchers have done many researches on how to reduce the impact and improve the quality of crushable sand and one of the possible solutions would be adding bottom ash as partial replacement of the sand filler. Studies of engineering properties of the physical and chemical characteristic of bottom ash had shown that the engineering behaviour of the bottom ash is almost similar with natural granular sand. More extensive research has to be carried out to investigate the specific usage and benefits of bottom ash as an alternative material in construction industry.

An experiment had been carried out on the standard proctor compaction test and one dimensional compression test on West Virginia bottom ash (Da Fonseca, Cruz, & Consoli, 2009). The laboratory data showed that at low stress levels, the compressibility of bottom ash was comparable to natural granular soils at similar relative densities. Besides that, there are study about the possibility of coal bottom ash to replace sand in embankments and the result showed that the bottom ash had acceptable environmental properties related to its leachate (Da Fonseca et al., 2009). These tests have shown the possibility of bottom ash to be used as the replacement of sand.

In this research, the possible effect of the bottom ash to act as the partial sand replacement will be studied. A series of tests will be conducted to determine the effect of bottom ash in improving the crushability and permeability of the crushable sandy soil as well as improving the bearing capacity of the crushable sand.

1.2 Problem Statement

During driving of piles, the low hardness sand often results in lower shear behaviour where a laboratory tests show higher shear strength for sands. This is because some of the sand particle had experience change of gradation due to particle breakage. These sands have shown some problems during constructions. The crushing of sand particle in construction is almost inevitable. The change in particle size will influence the engineering properties of sandy soil such as the lowering bearing capacity and permeability and the insufficient bearing capacity to support the load will cause a failure to the construction above it. In order to improve the crushability of the granular sand, the bottom ash was suggested to be added as partial replacement of sandy soil. The benefits of using bottom ash as partial sand replacement is able to solve the disposal problem of bottom ash.

Today, with the heavy growth of industrialization in the country, the amount of coal power plants waste has increased tremendously. For example, Tanjung Bin power station which is located at Johor had produced 180 tonnes of bottom ash per day from the burning of 18,000 tonnes coal per day (Abubakar & Baharudin, 2012). Hence the disposal of the coal waste such as fly ash and bottom ash has become a main concern for many countries including Malaysia. This is because the large amount of coal waste generated requires high cost for operating landfill, and there are potential health and environmental hazard from the landfill of coal wastes. The coal wastes consist of two types, fly ash and bottom ash. The potential use of fly ash in concrete has been known for decades and has been widely used in cement industry for atrial cement replacement and mineral additive in cement reduction. However, the use of bottom ash is not largely utilise due to its relatively high unburned carbon content (Kurama & Kaya, 2008). Hence the new application of bottom ash will be the main concern of this research. This issue will be resolved if only when the suggested use of bottom ash as the partial replacement in sandy soil to reduce the crushability is achieved.

The success of this research will have two beneficial effects, which are to reduce the amount of residue of coal combustion to be landfilled, and to reduce crushability

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