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THE CALIFORNIA BEARING RATIO (CBR) VALUE OF ROAD SUB-BASE AGGREGATE MIXED WITH BOTTOM ASH

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Abstract: This paper presents the laboratories results for California Bearing Ratio (CBR) value of road sub-base aggregate mixed with coal bottom ash. The Class-F coal bottom ash used in this study are from Jimah Power Plant, Port Dickson, Negeri Sembilan, Malaysia, meanwhile the road sub-base aggregate used in this study from Hanson Malaysia based on gradation limits from Public Works Department Malaysia (JKR) Standard Specification for Road Works Section 4: Flexible Pavement. The first objective of this study is to determine the CBR value for road sub-base mixed with 3%, 5%, 10%, 15% and 20% of coal bottom ash. The second objective is to determine the optimum concentration percentage of coal bottom ash based on the CBR value for soaked and unsoaked condition. This study involved the California Bearing Ratio (CBR) test for soaked condition and unsoaked condition test to determine the strength of CBR value for road sub-base aggregate. The stabilized of road sub-base aggregate mixed with coal bottom ash results were compared to the control sample of road sub-base aggregate accordingly to Malaysia Public Work Department (JKR) from Standard Specification for Road Works Section 4: Flexible Pavement for road work specification. The laboratory result shows, the optimum concentration of coal bottom ash as additives in road sub-base aggregate is about 9%. The addition of 9% bottom ash to the road sub-base aggregate were improve the CBR value for unsoaked condition and slightly decrease of CBR value for soaked condition. However the result of CBR value for both condition were fulfil the requirement for road sub-base aggregate from Public Works Department Malaysia (JKR) for Standard Specification for Road Works whereas the CBR value for road sub-base more than 30 percent. These study shows, bottom ash more effective used as additives to the road sub-base aggregate to enhance the CBR value.

Keywords: *Bottom ash, California bearing ratio, road sub-base,additives and permeability*

1.0 Introduction

Coal is an option in electric or power generation in many countries. Malaysia promotes coal as a fuel of choice for power generation, to free up more natural gas for export. Since 1988, Malaysia was introduced coal as raw material for power generation. In 2010, coal consumption was expected increase from 10 million tone to 19 million tones. Nowadays, there are four coal power plants in Semenanjung Malaysia namely, Tanjung

Bin (2,100 MW), Jimah (1,400MW), Sultan Salahuddin Abdul Aziz / Kapar (2,420 MW) and Sultan Azlan Shah / Manjung (2,100 MW) power plants. Instead, Sarawak has two coal power plants in Mukah (270MW) and in Sejingkat (100MW and 110MW) (Muhardi, 2010). Increasing in electricity demand has led to increase the coal consumption and thus significant produced more waste products. Consequently, a large volume of coal ash produced is typically disposed of as a waste in utility disposal sites. Coal ash mostly consists of fly ash and bottom ash that considered the most significant waste product produced from coal combustion. Huang (1990) mentioned, about 10% of total weight of coal burned produced fly ash and bottom ash and both of ash disposed as waste material. The problems occur to disposal of ash are limited availability of land and this has a significant to environmental problem. That problem needs to be handling economically in way to reduce that problem. The U.S. Environmental Protection Agency (EPA, 2005) encourage the use of coal combustion products in highway construction projects such as road base, embankments, flowable fill, and other beneficial applications. The increased use of these materials, would be discarded a waste and reduce greenhouse gases in the atmosphere, reduce energy consumption, and conserve natural resources.

Sub-base is the layer of material placed on the subgrade. Sub-base is often the main load-bearing layer of the pavement. Sub-base has three main functions which are to distribute and spread wheel loads from the traffic above it, to provide an adequate thickness of frost resistant material and to provide a working platform on which the roadbase and subsequent surfacing can be laid (Pitman, 2001). The materials used may be either unbound granular, or cement-bound. The quality of subbase is very important for the useful life of the road. Subbase material shall be a natural or prepared aggregate comprising crushed rock, weathered or fragmented rock, gravel or crushed gravel, sand, or a mixture of any of these materials. Based on Malaysia Standard Specification for Road Works, road sub-base shall have a small proportion of plastic or non-plastic fines and shall be essentially free from vegetative and other organic matter, expansive clay.

This study focuses on the alternatives for utilization of bottom ash from coal power plants and their potential as additives to the road sub-base crushed aggregate. This study was limited to the uses of coal bottom ash to enhance the California Bearing Ratio (CBR) value of road sub-base mixed with bottom ash. This study was determined the optimum concentration additives of bottom ash based on the CBR value for soaked condition and unsoaked condition. The laboratory results shows that bottom ash can be usefully used as additives to the road sub-base aggregate and giving high of CBR value and good drainage.

2.0 Materials

2.1 Coal Bottom ash

The coal bottom ash (BA) used in this study considered as main additives were collected from Jimah Power Plant in Port Dickson, Negeri Sembilan, Malaysia. The Jimah coal bottom ash is a waste product produced from combustion of coal for electric power generation. A preliminary of detailed physical properties and chemical composition of the Jimah coal bottom ash from plants was performed and shown in Table 1. Based on the result of particle size in Figure 1, it indicated the Jimah coal bottom ash covered the majoring sand size with the whole range for coarse, medium and fine fraction which mainly the range size from 2mm to 0.06mm. It shows about 97% sand sizes and 3% is fine or silt size, instead from the coefficient of uniformity and coefficient of curvature, the bottom sand can be classified ad poorly graded sand. Based on the result of physical properties, it shows the Jimah coal bottom ash classified as light materials due to the specific gravity is about 2.06. According to Lee (2008) and Muhardi et. al. (2010) the lower specific gravity of bottom ash due to the lower of iron oxide content since the specific gravity related to the chemical composition, the porosity and the shape of bottom ash. Table 2 shows the concentration of chemical compositions results of Jimah coal bottom ash and the Jimah coal bottom ash classified as class-F fly ash accordance to ASTM C618. Jimah coal bottom ash describe as siliceous and aluminous materials that possess little or no cementatious value consisting a little quantity of Calcium Carbonate (CaO) lower than 10%. Based on ASTM C618, the total combination percentage composition of silicon dioxide (SiO_2), aluminina oxide (Al_2O_3) and iron oxide (Fe_2O_3) more than 70 percent. This Jimah coal bottom ash considered as non self-cementing ash because having pozzolanic properties and no or small quantities of self-cementing properties sources of calcium and magnesium ions.

Table 1: Physical properties of Jimah Bottom ash (BA)

Properties	Values of Bottom Ash
Specific gravity, (Gs)	2.06
Particle size distribution:	
Gravel (%)	0
Sand (%)	97
Fine/Silt (%)	3
D_{60}	0.4
D_{30}	0.19
D_{10}	0.09
Coefficient of Uniformity, (C_u)	4.44
Coefficient of Curvature, (C_c)	1.00
Classification	Poorly Graded Sand

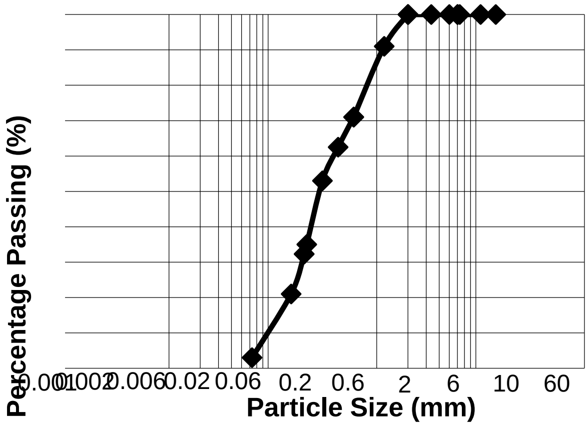


Figure 1: Particle size distribution for Jimah bottom ash

Table 2: Chemical composition of Jimah Bottom ash (BA)

Chemical Constituents	Chemical Composition of Jimah bottom ash (%)
Silicon Dioxide (silica) , SiO_2	46.60
Alumunium trioxide, Al_2O_3	30.30
Iron oxide, Fe_2O_3	6.44
TiO_2	3.31
Calcium Oxides (free lime) CaO	0.68
Potasium oxide , K_2O	0.50
Sodium oxide , Na_2O	0.26
Magnesium oxide, MgO	-
Sulphate, SO_3	0.09
L.O.I	0.64

2.2 *Road sub-base aggregate*

According to ASTM D2940 for Standard Specification for Graded Aggregate Material for Bases or Sub-bases for Highways or Airports, the main material used in highway construction are road sub-base aggregate and its properties are important for the quality of the pavement (ASTM D2940). Instead of to ensure high stability performance of sub-base, the sizes of crushed road sub-base aggregate used in this study was designed based on the gradation limit for road sub-base crushed aggregate size from Malaysia Public Work Department (JKR) from Standard Specification for Road Works Section 4: Flexible Pavement for road work specification and collected in stockpile from Hanson (M) Quarry. The properties of road sub-base aggregate shown in Table 3. Based on the particle size distribution for road sub-base aggregate is shown in Figure 2, the size of road sub-base aggregate ranging from coarse gravel to fine sands sizes and the sizes of aggregate. From the graph, it shows about 76% is gravel and 23% is sand size used as road sub-base aggregate. The road sub-base aggregate sample used in this study is in the range between upper and lower limits from the JKR road work specification for road sub-base aggregate as shown in Figure 2. It can be considered, all the entire sample of road sub-base aggregate comply all the sizes of Malaysia Public Work Department (JKR) specification for road work. The specific gravity of sub-base crushed aggregate is about 2.67 and it can be considered as dense materials. Based on the result for coefficient of uniformity and curvature, the road sub-base aggregate sample can be classified as well graded aggregate.

Table 3: Physical properties of Road Sub-Base Aggregate

Properties	Values
Specific gravity, (Gs)	2.67
Compaction Characteristic:	
Optimum water content, %	7.26
Maximum dry density, (Mg/m^3)	2.07
Particle size distribution:	
Gravel (%)	76
Sand (%)	23
Fine/Silt (%)	1
D_{60}	13
D_{30}	4.5
D_{10}	0.6
Coefficient of Uniformity, (C_u)	21.6
Coefficient of Curvature, (C_c)	2.59
Classification	Well Graded

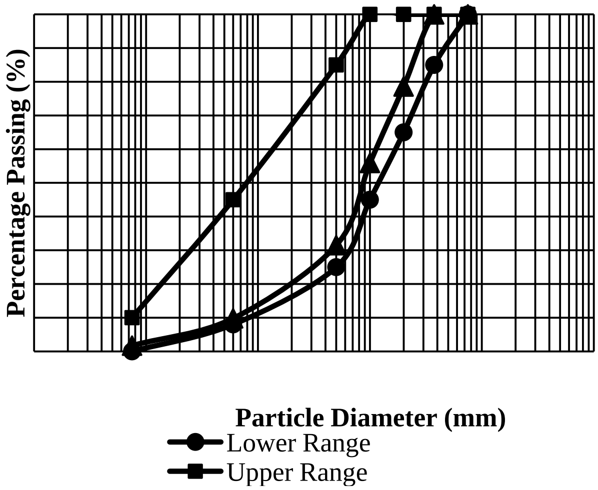


Figure 2: Particle size distribution for road sub-base aggregate based on gradiation limit from Malaysia Public Work Department specification for road work

3.0 Laboratory Testing

3.1 Sample Preparation

Two sets sample were prepared for CBR test. First set sample of road sub-base aggregate considered as control were prepared and second sets samples were mixed with 5 series different percentage of bottom ash at 3%, 5%, 10%, 15% and 20% of dry weight of the sample. The mixtures are compacted at maximum dry density and optimum moisture content and molded into CBR mould for CBR testing based on BS 1377-4:1990. This testing was prepared to determine the optimum concentration of bottom ash as additives at the maximum of CBR index value. Next samples preparation was prepared based on the mixing of road base aggregate with the optimum concentration percentage of bottom ash to determine the CBR index value. The entire tests for CBR testing were performed in unsoaked condition and soaked condition. The last sample was prepared for permeability test for control sample and sub-base aggregate mixed with optimum percentage of bottom ash.

3.2 California Bearing Ratio (CBR) Test

The California Bearing Ratio (CBR) test shown in Figure 2 were carried out to determine the CBR index value and the performance of the samples and the test carried out based on the standard procedure given in BS1377-4: 1990 or ASTM D1883. CBR test method is used to evaluate the potential strength of sub-base course material. CBR defined as the ratio of the load sustained by the specimen at 2.5 or 5.0 mm penetration to the load sustained by standard load aggregates at corresponding penetration level. In this study, the CBR test is used to evaluate the strength of road sub-base aggregate mixed with optimum percentage of bottom ash in unsoaked condition and soaked conditioned. The samples were prepared with its optimum moisture content and were compacted at their maximum dry density.

4.0 Result and Discussion

The California Bearing Ratio (CBR) result for road sub-base aggregate mixed with bottom ash

Figure 3 and Figure 4 shows the laboratories result for CBR value of road sub-base aggregate mixed with 3%, 5%, 10%, 15% and 20% of Jimah coal bottom ash for soaked condition and unsoaked condition respectively compared to control. It can be seen from the results; generally the loads are increase for road subbase aggregate mixed with coal bottom ash at bottom part of sample for unsoaked condition. Meanwhile, the loads are slightly lower for road sub-base aggregate mixed with coal bottom ash at bottom part and top part of sample of CBR for soaked condition. From the laboratories result for unsoaked and soaked condition, it shows that the bottom of sample is able to sustain a higher load compared to top part of sample. Meanwhile Table 4 show the summarized laboratories results of California Bearing Ratio (CBR) value for road sub-base aggregate mixed with various series percentage of Jimah coal bottom ash (3%, 5%, 10%, 15% and 20%) for soaked and unsoaked condition.

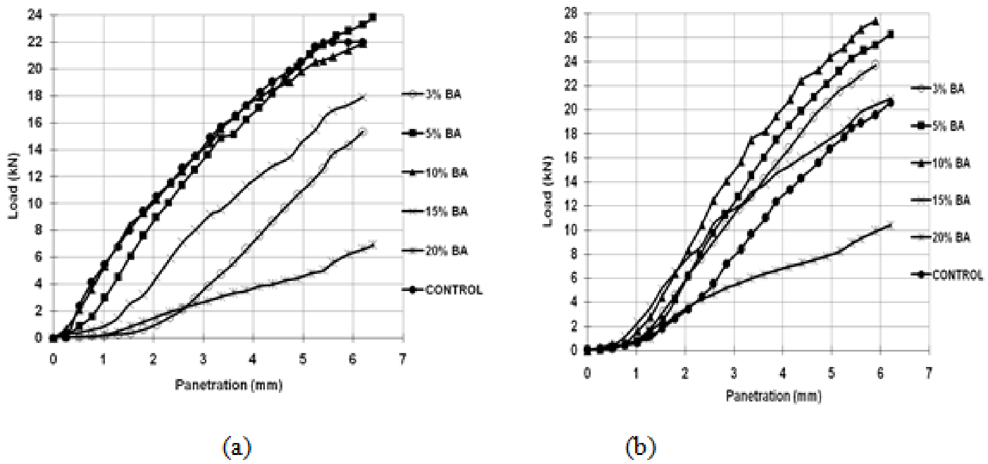
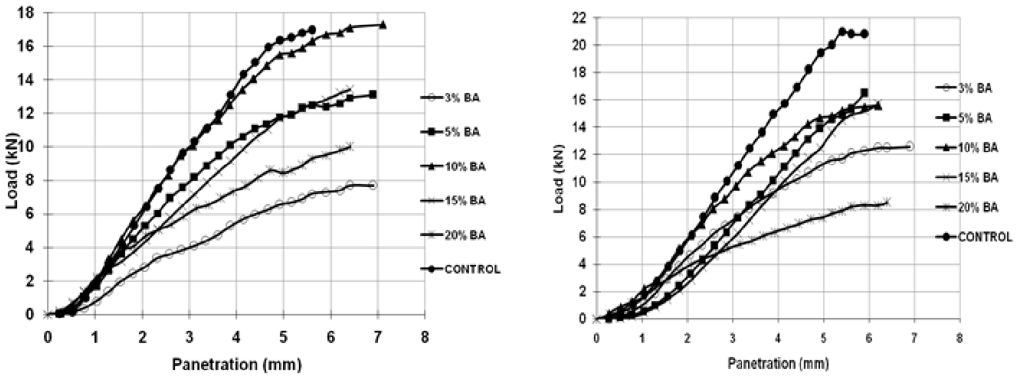


Figure 3: The laboratory result for CBR value for unsoaked condition (a) Top (b) Bottom



(a) (b)

Figure 4: The laboratory result for CBR value for soaked condition (a) Top (b) Bottom

Table 4: The CBR value for soaked condition and unsoaked condition at every percentage of bottom ash

Sample No.	Percentage of Bottom Ash	CBR Value for Unsoaked (%)	CBR Value for Soaked (%)	CBR Value for Soaked (JKR Specification)
1	0% (Control)	94.6	89.4	
2	3%	79.1	44.8	
3	5%	110.2	64.2	Not less 30%
4	10%	111.1	75.7	
5	15%	80.5	60.3	
6	20%	31.2	39.5	

Figure 5 show the graph of CBR value versus various percentage of Jimah coal bottom ash mixed with road sub-base aggragte for soaked condition and unsoaked condition. From the graph, it shows the CBR value for unsoaked condition relatively higher than CBR value for soaked condition due to the saturated condition for soaked condition. Instead, the trend of graph seen similarly for soaked and unsoaked condition. It shows the CBR values are increase from 79.1% to 111.1% for unsoaked condition and increase from 44.8% to 75.7 % for soaked conditioned with the increment of bottom ash from 3% to 10% respectively. However, it was found the CBR value for unsoaked and soaked condition start to decrease with the increment percentage from 10% to 20% of bottom ash. The CBR values start to decrease from 111.1% to 31.2% for unsoaked condition and 75.7% to 39.5% for soaked condition with the increment percentage of bottom ash from 10% to 20%. Form the graph pattern, the optimum percentage of bottom ash used in road sub-base is about 9% were determined at CBR value of 119% for unsoaked condition and CBR value for 77% for soaked condition. This result shows the optimum percentage of 9% bottom ash is suitable and performed in soaked condition and unsoaked condition instead of both conditions are fulfilling the requirement for Public Works Department Malaysia (JKR) road specification for road sub-base is not less than 30%.

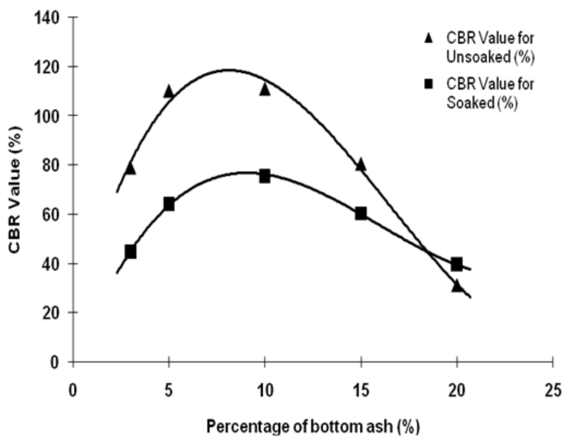


Figure 5: Graph of CBR value versus percentage of bottom ash for soaked and unsoaked condition

5.0 Conclusion

Experimental study has been carried out to determine the effective of coal bottom ash mixed into road sub-base aggregate and it can be concluded that coal bottom ash is suitable material to be used as an additives to the road sub-base aggregate and it was proved by experimental from the laboratory result. The suitable optimum concentration percentage of coal bottom ash used as additives to the road sub-base aggregate was determined about 9%. That percentage is suitable for soaked and unsoaked condition accordingly to the CBR value index. By using the 9% bottom ash as an additives material to the road sub-base aggregate, it was improved by increment of CBR value strength for unsoaked condition. However, slightly decrease in CBR value for soaked condition compared to control due to the saturated condition. Instead the CBR value results for both condition were fulfill the requirement for road sub-base aggregate from Public Works Department Malaysia (JKR) for Standard Specification for Road Works whereas the CBR value for road sub-base should be more than 30 percent. Nevertheless, from this study, it shows that bottom ash more effective as additives and can be used as alternative additives materials to the road base aggregate to enhance and improve the CBR value. Thus this will reduce the construction cost and solving disposal problems.

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References

ASTM C618 (2008). Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolanic for Use as a Mineral Admixture in Portland Cement Concrete. *Annual Book of ASTM Standards*, ASTM, Philadelphia, USA

ASTM D1883 (1994). Standard Specification for CBR (California Bearing Ratio) of laboratory compacted soils. American Society for Testing and Materials, Annual Book of ASTM Standards.

ASTM D2940. (1994). Standard Specification for Graded Aggregate Material for Bases or Subbases for Highways or Airports, American Society for Testing and Materials, *Annual Book of ASTM Standards*, Volume 04.03, West Conshohocken, Pennsylvania.

British Standard Institution, (1990) British Standard Method of Test for Soils for Civil Engineering Purposes. London: (BS 1377).

Head K.H. (1982) Manual of Soil Laboratory Testing Volume 2: permeability, Shear Strength and Compressibility Test. Pentech Press Limited.

Huang H.W. (1990). The Use of Bottom Ashin Highway Embankments, Subgrade and Subbases. Joint Highway Research Project, Final Report, FHWA/IN/JHRP-90/4 Purdue University, W. Lafayette, Indiana.

Joseph, C. Chong. (2005). *Report of the Fourth Meeting of The Asean Forum on Coal (AFOC) Council*. New World Renaissance Hotel, Makati City, Philippines.

Lee Foo Wei (2008) *Morphological, Mineralogical, and Engineering Characteristics of Tanjung Bin Bottom Ash.* Bachelor Degree Thesis, Universiti Teknologi Malaysia, Johor.

Malaysia Standard Specification for Road Works (2008). Section 4: Flexible Pavement. JKR Malaysia. JKR/SPJ/2008-S4.

Muhardi, Aminaton Marto, Khairul Anuar Kassim, et. al. (2010). Engineering Characteristics of Tanjung Bin Coal Ash. Electronic Journal Geotechnical Engineering 15: 1117-1129.

Pitman P., (2001). *External Works, Roads and Drainage,* Spon Press Taylor & Francis Group. 1st Edition, Lib No:TA190.P52 2001. Pp.238-245.

U.S. Environmental Protection Agency (EPA, 2005), Using Coal Ash in Highway Construction - A Guide to Benefits and Impacts, *U.S. Environmental ProtectionAgency (EPA).*