PERFORMANCE ON COAL BOTTOM ASH IN HOT MIX ASPHALT

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Abstract

The research conducted is Performance on Coal Bottom Ash in Hot Mix Asphalt. The purpose of this research is to Performance on Coal Bottom Ash applications as aggregates in road bases, sub-bases and pavement. This study focused in three parts objectives in determining the stability of asphalt mixture that is mixed with a certain percentage of bottom ash using Marshall Method, determining physical properties of bottom ash when mixed with asphalt and determining the quality improvement of the Marshall cube in terms of appearance and texture. This study is basically conducted by experimental work and finally resulted in graphical plots. Coal Bottom Ash is obtained from Tanjung Bin Power Plant and laboratory test for this research is conducted at IKRAM Pavement laboratory. Coal Bottom Ash content specimen has high stability and has a good surface texture. Further research can be conducted to identify pavement with coal bottom ash under Tropical weathering and to increase the design life span of pavements. Of waste materials which are industrial wastes like coal ash policies Coal Bottom Ash span stone used by plants in the country to generate of electricity coal combustion is the result of coal ash policies are not used and discarded without producing any harm. The result of Marshall Test and Resilient Modulus was compared between samples. From the experimental results, the use of coal bottom ash meets the specification as stated in SPJ/JKR/rev2008 even though there is a slight difference in the parameter value. From the results obtain in this research , bottom ash can be considered as one of the alternatives to modify HMA properties but further research on the ability and reaction in mix need to be clearly determined.

Index Terms: *Coal Bottom Ash, Hot Mix Asphalt , and Materials*

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1. INTRODUCTION

Bottom ash is agglomerated ash particles, formed in pulverized coal furnaces that are too large to be carried in the flue gases and impinge on the furnace walls or fall through open grates to an ash hopper at the bottom of the furnace. Physically, bottom ash is typically grey to black in color, is quite angular, and has a porous surface structure. These incombustible byproducts that are collected from the bottom of furnaces can burn coal for the generation of steam, the production of electric power, or both. The majority of these coal by-products is produced at coal-fired electric utility generating stations, although considerable bottom ash is also produced from many smaller industrial or institutional coal-fired boilers and from coal-burning independent power production facilities. The type of by-product which is either bottom ash or boiler slag produced depends on the type of furnace used to burn the coal.

The most common type of coal-burning furnace in the electric utility industry is the dry, bottom pulverized coal boiler. When pulverized coal is burned in a dry, bottom boiler, about 80 percent of the inbound material or ash is entrained in the flue gas and is captured and recovered as fly ash. The remaining 20 percent of the ash is dry bottom ash, a dark gray, granular, porous, predominantly sand size minus 12.7mm material that is collected in a water-filled hopper at the bottom of the furnace. When a sufficient amount of bottom ash drops into the hopper, it is removed by means of high-pressure water jets and conveyed by sluiceways either to a disposal pond or to a decant basin for dewatering, crushing, and stockpiling for disposal or use.

In road based construction, asphalt concrete is an important material to be used for construction of highways, pavements and parking lots. As for current road users are increasing in using the highways and roads, maximum maintenance of the road is necessary. Government has to allocate a big amount of money for this maintenance of roads and highways. There are no exact methods found in improving the quality of road construction in improving and reducing the out going currency. In the current highway engineering practices there are no proven long lasting roads, highways and pavements that resist deformation from imposed loads, skid resistant or can withstand the weathering forces.

As has been seen often, the roads get easily damaged due to heavy loads and impacts. In considering to these factors, this study could help to improve the quality and the strength of asphalt used in pavement construction. So, how much research has been done for the benefit of coal ash policies to reduce or replace the normal hydrated lime is used as filler material in concrete hot mix pavement asphalt. Mixture basically of three main ingredients of bitumen, aggregate and act as filler .Bitumen adhesive agent between aggregate. Filler serves to fill the cavity between the voids, small voids that exist due to discrepancies in the aggregate and bitumen surface at once thicken the bitumen.

Hence coal Bottom Ash as a filler policy are expected to produce a quality pavement equal to or better than the use of hydrated lime as filler .Besides that addition to the use of this material is expected that the waste problem in the environment can be overcome and the road construction costs can be reduced

2. LITERATURE REVIEW

Various types of pavement used in the construction of road street pavement are dependent on the load to be borne ole road and classified according to ability road. Between is a capable road from things, from things capable of roads which are widely used in the road network in the world. Bituminous pavement to be the preferred choice in the construction of the road because it has a design life long .Pavement high quality plays an important role to ensure quality and long life of the pavement still depends on the quality. Multipressure tests were still being carried out to ensure the bituminous pavement is able to bear the burden of traffic growing.

Traffic load is constantly changing and increasing from time to time require structures that can accommodate heavy loads or changed and the serviceability of the road structure and serviceability high . Durability to endure high traffic load also depends on the strength, stiffness and stability pavement .Pavement a strong way is dependent on the materials used in the mixture bitumen. Mix according specification material is very important to ensure a long life span for a good road pavement and it's also important for the comfort of road users.

2.1 Material Properties of Coal Bottom Ash

2.1.1 Physical Properties

Coal bottom ash physically has a porous surface texture and is edged particles. Size range of coal bottom ash is the fine stone to sand. Size is coarser than fly ash coal. Coal Ash policies typically sized coal as sand with 50 to 90 percent passing size 4.75mm (No. 4), to 10 to 60 percent passing 0.42mm (No 40), and 0 to 10 percent passing 0.075mm sieve size (No. .200). The size range is from 19mm to 38.1mm.Figure 2.0 compares the grain size distribution curves of few bottom ash samples (RMRC User Guidelines 2007).

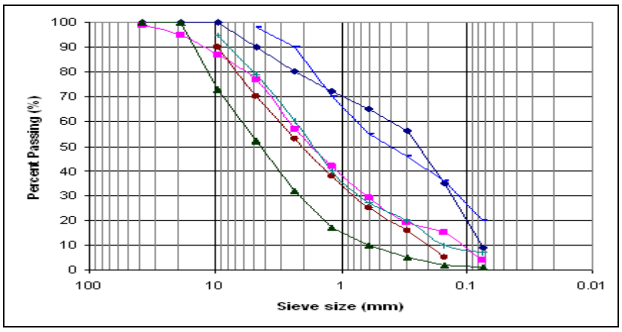

Figure 2.0: Grain size distribution curves of several bottom ash samples

Source: RMRC User Guidelines 2007

Typical physical properties of coal bottom ash are shown in Table 2.1. Coal bottom ash with a high carbon content specific gravity lower. Coal ash produces policy with a low specific gravity has a porous texture, particle nature 'popcorn' that fell under the load or compaction.

Table 2.1: Typical physical properties of bottom ash (Moulton,Seals,dan Anderson,1973)

Property	Bottom Ash
Specific Gravity	2.1 -2.7
Dry Unit Weight	7.07 - 15.72 kN/m3 (45 - 100 lb/ft3)
Plasticity	None
Absorption	0.8 - 2.0%

2.1.2 Chemical properties of CBA

The chemical composition of coal bottom ash this material consists of silica, alumina and iron with small a number of calcium, magnesium, sulfate and calcium other. Content composition is very low at less than one percent and total silica, alumina and iron (siO2+Al2O3+Fe2O3) reached 88.5 percent.

The salt content or in some cases, the pH of the coal bottom ash is low, this . This material may pose the nature eroding ,when coal bottom ash used subbase or base layer, it has the potential to cause corrosion on metallic structures in contact with said yet so, coal bottom ash in this study used the road surface layer, therefore no erosion problems should be considered.

2.1.3 Chemical properties of cement

Portland cements can be characterized by their chemical composition although they rarely are for pavement applications. However, it is a Portland cement's chemical properties that determine its physical properties and how it cures. Therefore, a basic understanding of Portland cement chemistry can help to understand the behavior.

2.3 Mechanical properties of coal bottom ash

Table 2.2 shows a list of typical mechanical properties of bottom ash coal through the compression characteristics of maximum dry density and optimum moisture, resistance characteristics through Los Angeles and sodium abrasiveness, its shear strength and bearing strength through friction angle and the permeability. The maximum dry density value of coal bottom ash is usually 10 to 25 percent lower than the granular material nature. Otherwise optimum moisture content was higher than the natural granular materials

Table 2.2: Typical characteristics of the mechanical properties of coal bottom ash (Moulton,Seals,dan Anderson,1973)

Typical characteristics	Coal bottom ash
Maximum dry density (kg/m3)	1210 - 1620
Optimum moisture content (%)	< 20 or in the range 12-14
Abrasiveness of Los Angeles (%)	30 -50
Loss in the sodium sulfate (%)	1.5 - 10
Friction angle	38 -42 °
California bearing ratio , CBR	40 - 70
Permeability coefficient	10-2 – 10-3

2. 4 Sustainability of CBA material

CBA is a non-hazardous material which does not emit carbon dioxide into the atmosphere. Bottom ash emphasizes in reducing carbon dioxide emission. Since bottom ash is the waste products of coal fired power plant, this research can lead to the awareness of sustainable development of the society. This is very advisable in sustainable developments to reduce carbon dioxide emission and to recycle the waste materials.

At the present time, there is limited information on the influence of parameters using CBA in construction materials, especially HMA with bottom ash as the fine aggregate

As the test conducted by SIRIM it shows that CBA were related in 3 different factors which is:

i. Physical hazards such as explosiveness, ignitability and flammability are not inherent properties of the components in the waste sample.
ii. No toxic chemicals were identified in the compositions as major constituents.
iii. The ash sample is not harmful to the environment and does not contain infectious microorganisms (SIRIM).

2.5 Factors of Degration of Asphalt pavements and HMA

Deterioration or loss of pavement performance is in the form of rutting. Fatigue cracking due to repeated dynamic heavy vehicle loading, moisture damage-related distresses in the bituminous layers, surface wear in countries where studded tires being used are due to deformations in one or several layers.

Environmental conditions such as temperature and water can have a significant effect on the performance of asphalt concrete pavements as well. Moisture is the major climatic condition that adversely affects the quality of asphalt concrete.

The infiltration of moisture into HMA pavements is one of the most common causes of degradation in pavement structures. When moisture enters the pavement structure, it can find its way between the aggregate and the asphalt cement, leading to a loss of cohesion within the pavement.

Moisture may damage asphalt concrete in three ways. The moisture may combine with the asphalt resulting in a loss of cohesion of the asphalt film. The water may also cause failure of the bond at the asphalt aggregate interface. Finally, degradation of the aggregate may result as the moisture in the asphalt concrete freezes. The loss of cohesion and the failure of the asphalt bond with the aggregate are defined as stripping.

Factors affecting moisture sensitivity of HMA have been identified as the type and use of the mix, the characteristics of the asphalt binder as well as the aggregate and environmental effects during and after construction, and the use of anti-stripping additives. Many factors are involved in moisture sensitivity of HMA, so the test method should closely simulate the real field condition to reflect these variables (Warren, Jim).

3. METHODOLOGY

For the purpose of the study, the test that's being used is for IKRAM pavement laboratory. This chapter describes about the procedures and test methods used according to JKR/SPJ/1988 specification. A typical evaluation for use with Marshall Mix methods includes three basic steps.

3.1 Review Process

The research process is divided into two phases, which first obtain optimum bitumen content and the second phase to obtain optimum ash content suitable policy and Marshall test specification. Optimum bitumen content obtained from the first phase of the study will be used in the samples in the second phase.

3.2 The First Phase of the Review Process

- Provide materials to mix AC 14
- Do Sieve Analysis
- Combined aggregate grading appropriate to determine and meet the grading limits.
- Determine the specific gravity of aggregate
- Conventional mix design with use 4.0%, 4.5%, 5.0%, 5.5% and 6.0% bitumen content.
- Resilient modulus test performed on each sample.
- Obtain its optimum bitumen content and Marshall identified
- A set of samples using the conventional bitumen content and features designed
- Analyze data

3.3 The Second Phase of the Review Process

- Provide materials to mix AC 14
- Do Sieve Analysis
- Combined aggregate grading appropriate to determine and meet the grading limits.
- Determine the theoretical maximum density
- Conventional mix design with use coal bottom ash 1.0%, 2%, 3.0%, 4.0%, 5.0% and 6.0% with bitumen content.
- Resilient modulus test performed on each sample.
- Obtain its optimum bitumen content and Marshall identified
- A set of samples using the conventional bitumen content and features designed
- Analyze data

4. RESULT

This chapter provides all the results and data obtained from the experimental test conducted by IKRAM pavement Laboratory. All the results are discussed and analyzed. This includes the material tests and density, stability and flow test on the Marshall specimens. To provide a clear description of the data and results, the values are described in the form of tables, graphs and figures. All the tables and graphs shown in this chapter are shown by using Microsoft Excel program.

4.1 Aggregate Gradation Results

In this study, the sieves were made to isolate the aggregate by size sieve aggregate hot mix asphalt needs to be in a certain range of sizes and have a ratio indicates certain . Table 4.1 shows AC14 grading used in this study.

Table 4.1: Gradation of the aggregate limit for mix AC14 (PWD, 2008)

Sieve Size	Grading Limit		Percent Retained (%)	Percent Passing (%)
	Upper	Lower		
20	100	100	100	0
14	90	100	95	5
10	76	86	81	14
5	50	62	56	25
3.35	40	54	47	9
1.18	18	34	26	21
0.425	12	24	18	8
0.15	6	14	10	8
0.075	4	8	6	4

4.2 Theoretical Maximum Density

Table 4.2: Result for the Theoretical maximum density for samples containing different Coal bottom ash percent

Theoretical maximum density with CBA Percentages	Asphalt Content of Mix (%)	SG of Asphalt, Gb	Effective SG of aggregate , Gse
0%	5.1	1.03	2.594
1%			2.619
2%			2.625
3%			2.625
4%			2.644
5%			2.624
6%			2.62

The theoretical maximum density value shown in table 4.2 . This test is using the optimum bitumen content of 5.1% in each the sample. The specific gravity of asphalt is 1.03 and the rate of the density is different as a Percentage of coal bottom ash. The values of the theoretical maximum density are Marshall will be used in the analysis of the specific gravity of aggregate. From this value voids in the mixture can be analysis.

4.3 Determination of Characteristics of Marshall

Marshall Tests performed on all samples that are designed. The first phase involves determining the optimum bitumen content of the mixture AC14.All sample shows the relationship between percentage of bitumen with the density, air voids, voids filled with bitumen, stability, flow, and resilient modulus. Bitumen content obtained shall be used to design the control samples and samples containing modification coal bottom ash

In the second phase shows the relationship between the percentage of basic coal Bottom ash with a dense, air voids, voids filled with bitumen, stability, flow, and resilient modulus. Next, data from tests carried out in the analysis of Obtain optimum coal bottom ash content

4.3.1 Density

Figure 4.1 shows a graph of density versus the percentage of coal bottom ash. Density indicates the density of the mixture increased by decreasing the volume of space, but maintains the weight of material

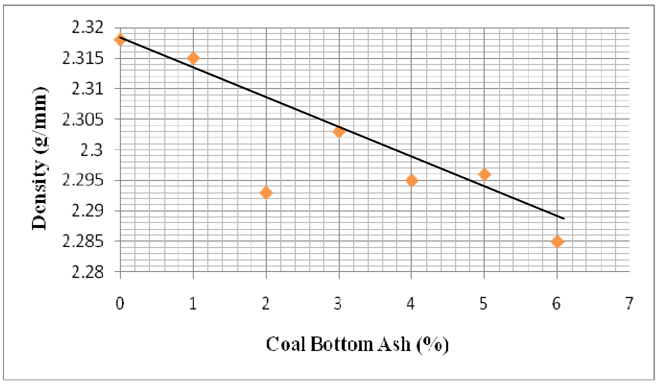

Figure 4.1: The graph density versus coal bottom ash

Based on the graph, coal bottom ash content at a minimum density is 6%. The graph shows the increasing coal bottom ash content, the density is decreasing. This is because the coal bottom ash is a porous particle. Therefore, when mixed with bitumen, it will be absorbed by the coal bottom ash and cause bitumen decreases (Anderson, Usmen, and Moulton, 1976). Bitumen is less, not to satisfy the air void in the sample and causes the density of the sample decreases

4.3.2 Voids in Total Mix (VTM)

Figure 4.2 below shows a graph of the percentage of air voids versus coal bottom ash. Air voids are small air volume between the coated aggregate in a bituminous mixture. Unit expressed as a percentage of the bulk volume of a compacted specimen (Che Ros and Mohd Rosli, 2008).

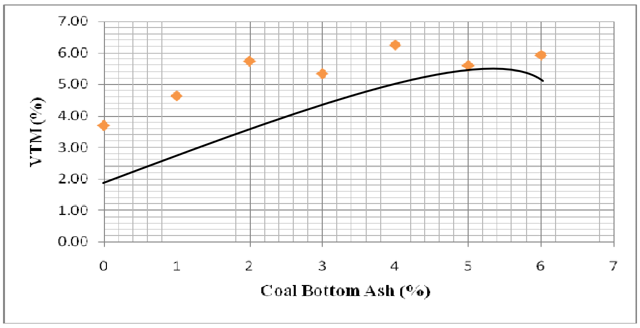

Figure 4.2: The graph voids in total mix versus coal bottom ash

An upward curve when the bottom ash content of coal is due to increasing air voids are not filled with coal bottom ash bitumen. More bottom has absorbed as much bitumen and cause air voids can not be met and therefore improve air void content in the mixture. Air voids and density has direct relevance for the higher air voids, the lower the density.

Air voids that are allowed according to the specifications JKR/SPJ/rev2008 is 3-5%. This range aims to make room for the bitumen to expand and trap air in hot weather. The presence of basic coal bottom ash has increased air voids content and its value has out of specification requirements.

4.3.3 Voids Filled Bitumen (VFB)

The percentage of voids filled bitumen volume of void spaces between the aggregate in a compacted specimen containing air voids and the volume of bitumen that is not absorbed in the aggregate (Mohd Rosli Che Ros, 2008). Figure 4.3 below shows a graph of versus percent voids filled bitumen with coal bottom ash.

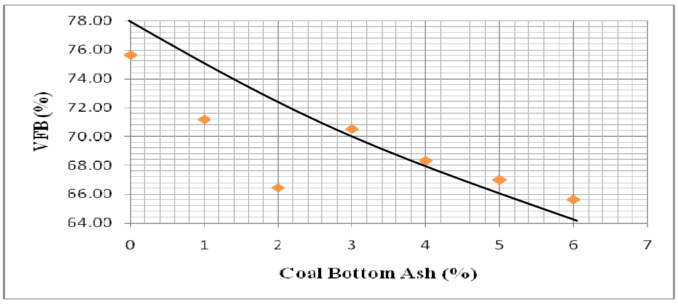

Figure 4.3: The graph voids filled bitumen versus coal bottom ash

Curve obtained from the graph above shows that there lower bitumen content when coal bottom ash content increases. This shows the lack of a binding layer of bitumen aggregate in which air voids in between and in the aggregate cannot be met by the bitumen. This situation is a result of the reaction between the bitumen with the coal bottom ash capacity to absorb the bitumen, causing voids content filled with bitumen decreases.

4.3.4 Flow

Figure 4.4. Shows a graph of flow versus percent coal bottom ash. The flow is the height difference before and after the test specimens with the maximum load (and Mohd Rosli Che Ros, 2008).

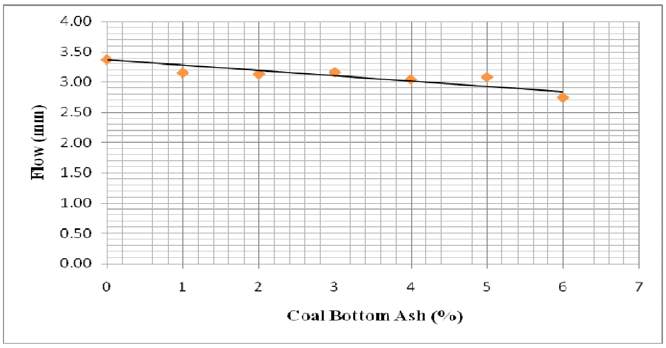

Figure 4.4: The graph flow versus coal bottom ash

From the graph, the flow rate is still within the range of specifications allowed by JKR/SPJ/rev2008 the 2-4%. Based on the graph, the flow decreases with increasing percent of coal bottom ash in the mixture. This indicates that a stronger pavement under maximum load the presence of coal bottom ash as a filler for angular coal bottom ash particles provide interlocking nature and repairing the internal friction between particles of coal bottom ash aggregate and aggregate with an aggregate

4.3.5 Stability

The stability of the sample shows the maximum load that can be borne by the sample before failure (Che Ros and Mohd Rosli, 2008). Figure 4.5 below shows a graph of the stability of the samples versus the percentage of coal bottom ash.

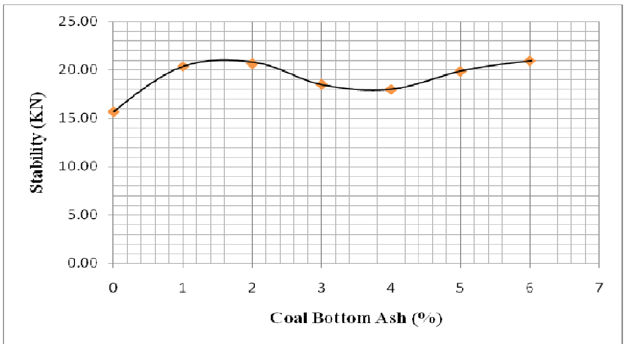

Figure 4.5: The graph stability versus coal bottom ash

The graph shows an upward curve, the higher the coal bottom ash content, the higher the stability of the sample. Stability is a measure of the viscosity of bitumen samples are controlled by the internal friction angle of aggregates. The presence of particles of coal bottom ash has strong angular aggregate bond network and thus increase the angle of internal friction between aggregates. Therefore, the stability increases with the increase of coal bottom ash content.

4.3.6 Resilient Modulus

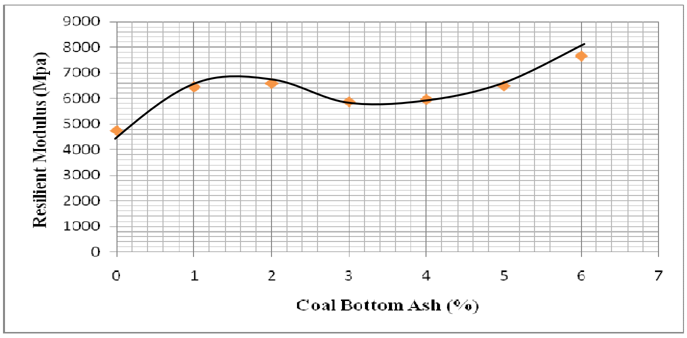

Figure 4.6: The graph resilient modulus versus coal bottom ash

Figure 4.6 shows a graph of resilient modulus versus coal bottom ash. The resilient modulus of the sample shows the strength of the pavement applications level as the road wearing course. Increase the strength of the sample stability and flow demonstrate that the lower the percentage of coal bottom ash increases. The coal bottom ash 3% resilient modulus reduction occurs and suddenly rises from the coal bottom ash 4% to 6%. This is because it is a problem use the tools are not in good condition.

4.4 Determination of Optimum bitumen content

The mean optimum bitumen content shall be determined by averaging five optimum bitumen contents so determined as a fellow

4.4.1 Density

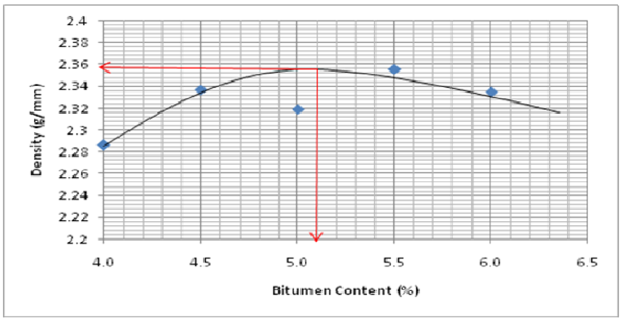

Figure 4.7: Density vs. Bitumen Content

Figure 4.7 shows the analysis of the results density versus bitumen content at 5.1 % value density is 2.36 g/mm. It means with highly absorbent aggregates, some difficulty in determining density may occur. In such cases , the bitumen content at which the increase in density shoes a marked falling off shall be adopted,

4.4.2 Voids in aggregate filled with bitumen (VFA)

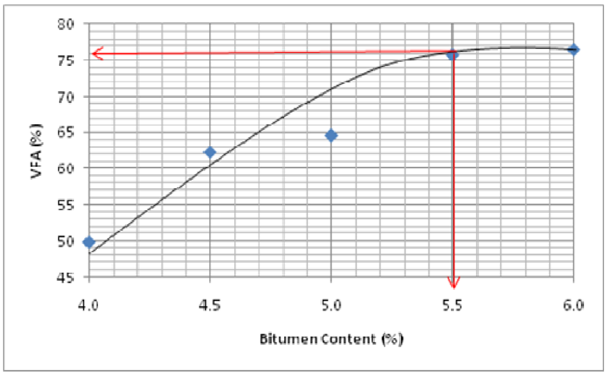

Figure 4.8: VFA vs. Bitumen Content

Figure 4.8 shows the analysis of the results VFA versus bitumen content at 5.5 %, value VFA is 76%. The voids filled with asphalt is the percentage of the intergranular void space between the aggregate particles that is filled with asphalt. Therefore, the is calculated by subtracting the air voids from the VMA and dividing by the VMA and expressing the value as a percentage.

4.4.3 Voids in Mix (VTM)

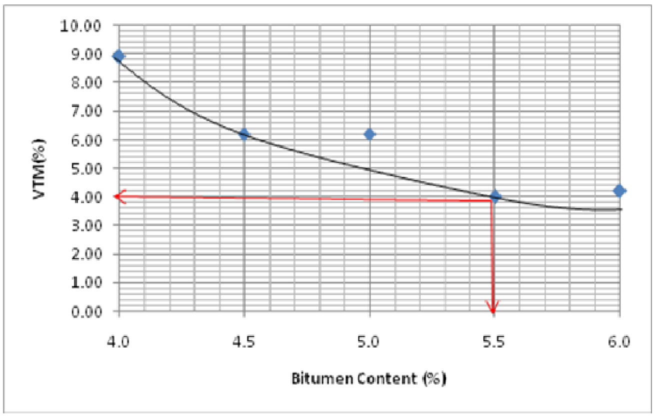

Figure 4.9: VTM vs. Bitumen Content

Figure 4.8 shows the analysis of the results VTM versus bitumen content at 5.5 %, value VTM is 4 % the total volume of the small pockets of air between the coated aggregate particles throughout a compacted paving mixture, expressed as a percent of the bulk volume of the compacted paving mixture. The percentage of air voids decrease with increasing asphalt content.

4.4.4 Stability

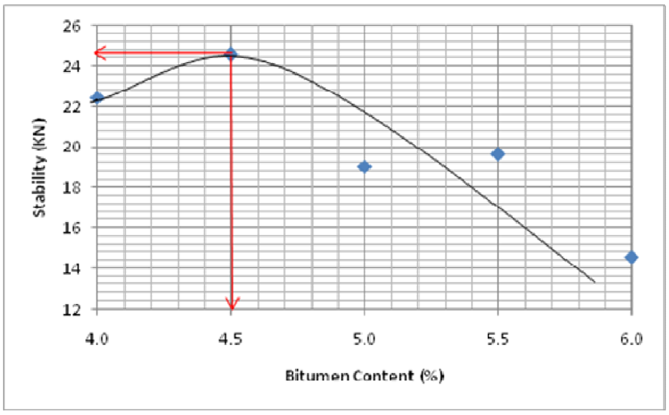

Figure 4.10: Stability vs. Bitumen Content

Figure 4.10 shows the analysis of the results stability versus bitumen content at 4.5 %, value stability is 25 KN. Stability value generally increases as asphalt content increases and then beyond a certain percentage of asphalt in the mixture stability decreases .

4.4.5 Flow

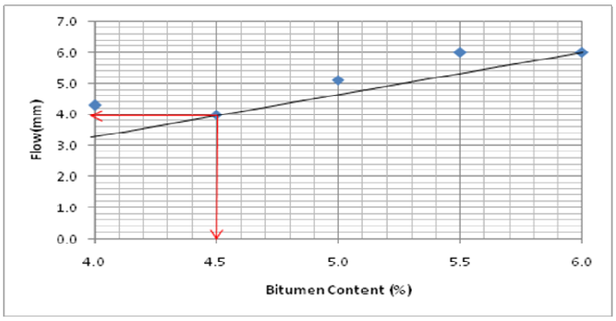

Figure 4.11: Flow vs. Bitumen Content

Figure 4.11 shows the analysis of the results Flow versus bitumen content at 4.5 %, value flow is 4mm. If flow value increase with increasing asphalt content. Flow equals to the median of the range given in JKR/SPJ is 2.0 – 4.0 mm.

4.5 Comparison of the results with the specification (JKR/SPJ)

Table 4.3: Optimum Asphalt Content Value

Property	Selected Asphalt Content (%)
4% VTM	**5.5**

Maximum Value of Bulk Density	**5.2**
Maximum value of stability	**4.5**
Maximum Value of VFA	**5.5**
Average	**5.1**

Table 4.3 shows Marshall Test results and calculations to obtain the optimum bitumen content. Obtained the optimum bitumen content was average 5.1%. Once the optimum content is known, the conventional sample set is designed to use 5.1% bitumen. These samples will be made where the control sample characteristics will Marshall compared with samples containing coal bottom ash.

4.6 NAPA Method

Table 4.4: Comparison of specifications and standards

Properties	Specification	Result	Status
VTM	3.0% - 5.0%	4%	Accepted
VFA	70% - 80%	76%	Accepted
Stability	> 8kN	25 kN	Accepted
Flow	2 - 4mm	4 mm	Accepted

Table 4.4 show comparisons of specifications by using NAPA Procedure, optimum asphalt content are determined by the median air void content of the specification. Based on the specification that stated in the project requirement, 4% is the median air void.

1. Optimum asphalt content 5.5% asphalt VTM is 4%.
2. Optimum asphalt content 5.5% asphalt, % VMA is 16.82%.
3. Optimum asphalt content 5.4% asphalt, % VFA is 75%.
4. Optimum asphalt content 4.5% asphalt, stability is 25kN.
5. Optimum asphalt content 4.5% asphalt, flow is 4mm.

4.7 Comparison between the Conventional Samples and coal bottom ash Samples Optimal

Once the optimum ash content of coal bottom ash is obtained, the three-sample design and the use of coal bottom ash are at the optimum content of 1%. Marshall Characteristics of the sample set is then compared with conventional sample.

Table 4.7: Marshall features conversational samples and samples of coal bottom ash optimal

% Coal Bottom Ash	Bitumen (%)	Density (g/mm)	VTM (%)	VFB (%)	Stability (KN)	Flow (N/mm)	Resilient Modulus (Mpa)
0	**5.1**	**2.318**	**3.70**	**75.62**	**15.69**	**3.37**	**4741**
1	**5.1**	**2.315**	**4.64**	**71.17**	**20.39**	**3.15**	**5498**

Based on the Table 4.7, the conventional sample shows the voids filled bitumen high and low values of air voids than samples with the optimum content of coal bottom ash with porous particles causes the bitumen having holes. Particles thus could not complete filling of air voids present in the mixture as part large mixed bituminous coal has been absorbed by the bottom ash, and some used to bind the aggregate particles

Due to air voids directly proportional to the density, the higher air voids because reduces .This density indicates that the bitumen does not respond well when there is coal bottom ash in mixture. Spread bitumen to the aggregate grain is not uniform because the bitumen content was reduced.

However, the stability of the samples containing coal bottom ash is higher than conventional. This sample showed that the presence of coal bottom ash can increase the internal friction between aggregate and make a stronger and stability .Flow mixture of diminishing is consistent with the stability of the increase samples. Shows a sample of reduced flow is not easy to deform under load maximum sample this modification is necessary to create a stronger pavement and strong

4.8 Modulus Resilient

Resilient modulus tests conducted for each sample to evaluate the effectiveness of pavement performance under load traffic .Load moving traffic will be transferred to the pavement and this causes tension to pavement. Modulus test is the relationship between applied pressure and the tension resulting from the pressure.

4.8.1 Modification of the Sample

Figure 4.12 shows the modulus values obtained from tests conducted on samples containing coal bottom ash as a filler material

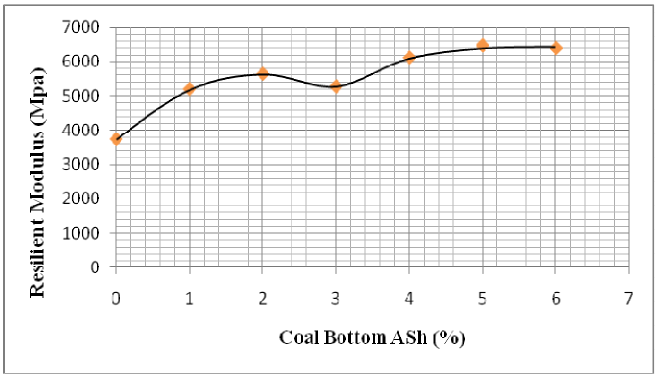

Figure 4.12: Resilient modulus of the sample graph modification

The graph represents an increase in the modulus of the coal bottom ash content increase .It means that more coal bottom ash is used, the stronger the pavement as a high value indicates tensile modulus experienced by the pavement is a pavement means lower tension vehement very good and able to bear the burden caused traffic. Therefore it can be said that the use of coal bottom ash as a filler to reduce tension caused by the pavement.

4.8.2 Comparison between Resilient Modulus the Samples of Conventional and Coal Bottom Ash sample Optimal

Table 4.8: Resilient Modulus of the sample conventional and coal bottom ash sample Optimal

Coal Bottom Ash (%)	Bitumen (%)	Resilient Modulus (Mpa)
0	5.1	3732
1	5.1	5192

Table 4.8 shown a comparison value of the modulus of the conventional samples and samples containing a coal bottom ash percentage of the optimal. It can be seen that the value of the modulus of the samples containing optimum coal bottom ash content is higher than the conventional samples. This shows that the mixture containing coal bottom ash has a lower voltage when under load.

4.9 Optimum Asphalt Content Value with Coal Bottom ash

The Table 4.9 show is the comparison of the results with the specification when asphalt content mixed with coal bottom ash.

Table 4.9: Comparison of results with the specification

Figure	Properties	Specification	Result	Status
4.2	VTM (%)	3 – 5	4.64	Accepted
4.3	VFB (%)	70% - 80%	71.17	Accepted
4.4	FLOW (mm)	2 - 4	3.15	Accepted
4.5	STABILITY (kN)	> 8	20.39	Accepted
4.6	RESILIENT MODULUS (Mpa)	3000	5498	Accepted

From the results above the final result may alter if such value is taken into account. In the calculation, it is assumed that the effective specific gravity of aggregate is 1.76 and the specific gravity of asphalt is 1.03.

When calculating the value of bulk specific gravity and theoretical specific gravity for a compacted mixture percentage of VFB, VTM, Flow, Stability and Resilient Modulus as accepted requirement with the specification.

CONCLUSIONS

The use of coal ash as a base material in road construction is no longer limited to only subgred layer. This study has given new dimension to the use of coal bottom ash as a filler material in the HMA. The optimum content of coal bottom ash obtained from this study is 1%. Coal bottom ash cannot replace the use of conventional filler material as a whole. The use of hydrated lime is still required with coal bottom ash.

Based on the results obtained, the sample containing the coal bottom ash is better in terms of strength, stiffness, and the sample flow than conventional samples. Consequently, the pavement will become stronger and able to reduce the deformation of the pavement if loaded high traffic load. However, there are weaknesses in the use of coal bottom ash as filler where the air void content increased while reducing the density of the mixture. This has due to the chemical properties of bottom ash coal of high ash content silica a great effect on bonding bitumen and aggregates. Consequently, the three characteristics of the Marshall air voids, voids filled with bitumen and low density compared to the performance of the conventional samples even exceeded the prescribed specifications.

Although coal bottom ash cannot replace the use of hydrated lime as a whole, but believed that if the bitumen content of higher is used, it will be able to improve the performance of air voids, voids filled with bitumen and density. Balancing between the coal bottom ash content of the bitumen content is very important to get a quality pavement. Thus it can be concluded that the use of coal bottom ash can increase the strength of the pavement, but some modifications must be done to overcome the lack of use. If the coal bottom ash can be used in large quantities, this means that this waste can be recycled at a maximum and this will impact the environment .Study more carefully and deeply to be done to maximize the use of coal bottom ash in the HMA.

Recommendations for Future Research

Based on recent research studied and experimented relating to Performance Coal Bottom Ash in Hot Mix Asphalt has indicated the need of further research and studies. Accordingly are proposed future recommendations for research and studies that can be related to these studies.

i. To conduct further research in various proportions of CBA content in HMA.
ii. Using different types of bitumen, such as PG grade bitumen to test the effect of using coal bottom ash on the pavement
iii. To conduct further research by using blended CBA in the form of dust replacing Portland cement.
iv. Conduct research on pavement using proportion of CBA under tropical weather.
v. Investigate the characteristics of Marshall on the use of coal bottom ash to binder layer

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