Progress in Engineering Application and Technology Vol. 2 No. 2 (2021) 018-024

PEAT

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/peat
e-ISSN : 2773-5303

A Potential Review Use of Coal Bottom Ash as Fine Aggregate Replacement on Road Construction

Wann Sharfrina Abdul Halim[1], Abd Sukor Sarif[1]*

[1]Department of Civil Engineering Technology, Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, Pagoh, 84600, Johor, MALAYSIA

*Corresponding Author Designation

DOI: https://doi.org/10.30880/peat.2021.02.02.003
Received 13 January 2021; Accepted 01 March 2021; Available online 02 December 2021

Abstract: The most common pavement used in the Malaysian roadway is flexible pavement which is a mixture of asphalt and bitumen. Bitumen is used as a binder to bind the aggregates, fillers, and binders which is used for road building and repair is asphalt. Asphalt sustainability could be increased by replacing the aggregates with waste material such as coal bottom ash. Coal bottom ash produced from coal combustion is used to replace fine aggregate in asphalt pavement mixture and compare with a standard mixture. Due to the increasing quantity of coal combustion waste, there is needed to search for another alternative way to reduce the residues by recycling the coal bottom ash. This study aims to control the review on Marshall properties of the asphalt mixture and determine the range of optimum percentage of bottom ash by comparing data from the previous study. Lab tests that are used by researcher in this study are the Marshall Stability Test. All researchers using optimum of bottom ash (6.00 %-25.00 %) which resulting the Marshall stability ranges from 15.60 kN to 22.00 kN. Accordingly, it is complying with the JKR Standard value which is higher than 8.00 kN. From this study, the cost to dispose of the ash can be reduced and the sustainability of the environment can be maintained, hence improving the engineering properties of asphalt.

Keywords: Coal Bottom Ash; Fine Aggregate; Coal Combustion; Asphalt Pavement

1. Introduction

Road construction in Malaysia has been started before independence in 1957. Road in Malaysia is mostly paved using flexible and rigid pavement. Flexible pavement is a mixture of asphalt and bitumen. Bitumen is used as a binder to bind all the aggregates. A combination of aggregates, fillers, and binders used for road building and repair is asphalt.

The aggregates used for mixtures of asphalt consist of crushed gravel, sand, slag, or dirt. Waste and by-products such as coal bottom ash are usually used as sources for aggregates as the raw materials in

*Corresponding author: sukor@uthm.edu.my

the concrete mix through regulated low-strength content [1]. Instead of crushed rock in the sub-base layer of a road, coal bottom ash may well be a possible road construction material, contributing to reduced energy consumption and less pollution generated from energy. Bottom ash can also be an additive material for stabilizing expansive soil [2].

1.1 Problem Statement

Waste material from the combustion of coal will be produced. From the previous study [3], it has been reported that Tanjung Bin power plant needs about 18,000 tons/day of coal to generate electricity, and it will result in the produce a large quantity of coal ash disposal. The storage space needed to store the ash will be a concern due to the increase of ash from days to days [3].

The cost to manage the disposal of ash will be increased and give affect company expenses. The disposal process of coal combustion can pollute the environment, and it is a significant contributor to emissions and landfills.

The recycling of bottom ash is a potential idea to fix the disposal problem of coal ash. This study introduced the waste materials produced by coal combustion as a replacement for fine aggregates to reduce pollution and maintain the environment's sustainability.

1.2 Project Objective

The main objectives of this study are as follows:

- To control the review on Marshall properties of the asphalt mixture.
- To determine the range optimum percentage of bottom ash by comparing data from the previous study

1.3 Project Scope

This study is mainly focused on the previous research paper. In finding the Marshall properties of the asphalt pavement, focused on stability and flow of the Marshall Stability Test data from the previous study are collected.

This study required the replacement of fine aggregate with coal bottom ash. Samples that are used by the researchers with a CBA mix from range 0.00 % to 30.00 %, and the top portion of bottom ash that achieves the strength are determined to compare with a standard mix of asphalt pavement. The performance of the asphalt pavement with coal bottom ash are evaluate throughout this study.

1.4 Significance of the Study

The basic interest to the environment is the management of waste, and it is gaining importance in the production of industrial waste. A strategy and solution should be appropriately planned to ensure the industrial waste is managed. The study's significance is to ensure sustainable development by re-use waste material, which is coal bottom ash. Fine aggregate that is commonly used is through natural sand. The cost of the pavement construction can be minimized by using recycled products.

2. Materials and Methods

This chapter provides the method and procedure that are used by the researchers as a guideline for completing this study report. The result of previous research using the Marshall Stability Test was recorded to have sufficient data.

2.1 Materials

In this research, the materials used that are mentioned in the previous study to construct the pavement are aggregate, natural sand, bitumen, and coal bottom ash. Aggregates that are used for this research are divided into two types, which are fine aggregates and coarse aggregate. Bitumen, known

as asphalt, are a mixture of dense, sticky, viscous organic liquids, mainly composed of polycyclic aromatic hydrocarbons, naturally occurring or obtained by crude oil distillation. Bottom ash is used to replace fine aggregate used in pavement construction.

2.2 Methods

The mixture's Marshall stability is defined as the maximum load carried by the sample at the average test temperature of 60 °C. The flow value is the deformation that the sample undergoes during the loading up to the full load. The Marshall Stability Test result from the previous study compares each researcher's optimum percentage with a conventional mixture. Figure 1 illustrated the flow of research methodology.

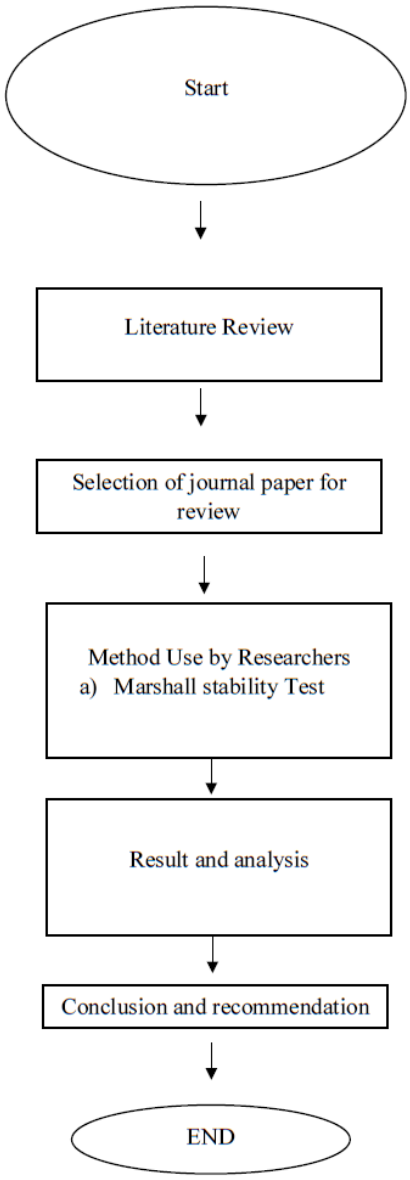

Figure 1: Research Methodology Flowchart

3. Results and Discussion

This chapter provides the result of this project obtained from the previous study. The Marshall Stability Test that has been carried out was used to determine the asphalt mixture's mechanical properties and the pavement's performance with coal bottom ash. Table 1 below show the standard

specification that is provided from Jabatan Kerja Raya (JKR) that are focused on the Marshall Stability and Flow.

Table 1: Test and Analysis Parameter (JKR Standard Specification for Road Works)

Parameter	Wearing Course	Binder Course
Stability, S	>8000 N	>8000 N
Flow, F	2.0-4.0 mm	2.0-4.0 mm

3.1 Results

Table 2: Summary of Permissible Parameter of Marshall Stability value

Author	Bottom Ash Content (%)	Marshall Stability (kN)	JKR Permissible Parameter	Results
Vasudevan, G. (2013)	0	15.69	>8kN	Pass
Mohammed, H. *et al.*. (2020)	25	17.50	>8kN	Pass
Yoo, B. S. *et al.* (2016)	10	17.20	>8kN	Pass
Vasudevan, G. (2013)	6	22.00	>8kN	Pass
An, J. *et al.* (2015)	20	15.60	>8kN	Pass

Table 2 shows a summary of the permissible parameter of the Marshall Stability value parallels to the JKR standardization. The Marshall Stability value is higher than the standard value which higher than 8 kN. The highest Marshall Stability accomplishes by the previous study is 22.00 kN while the lowest is 15.60 kN. The stability is derived from cohesion and internal friction. The pavement is necessary to have good stability to transmit the load severely from time to time.

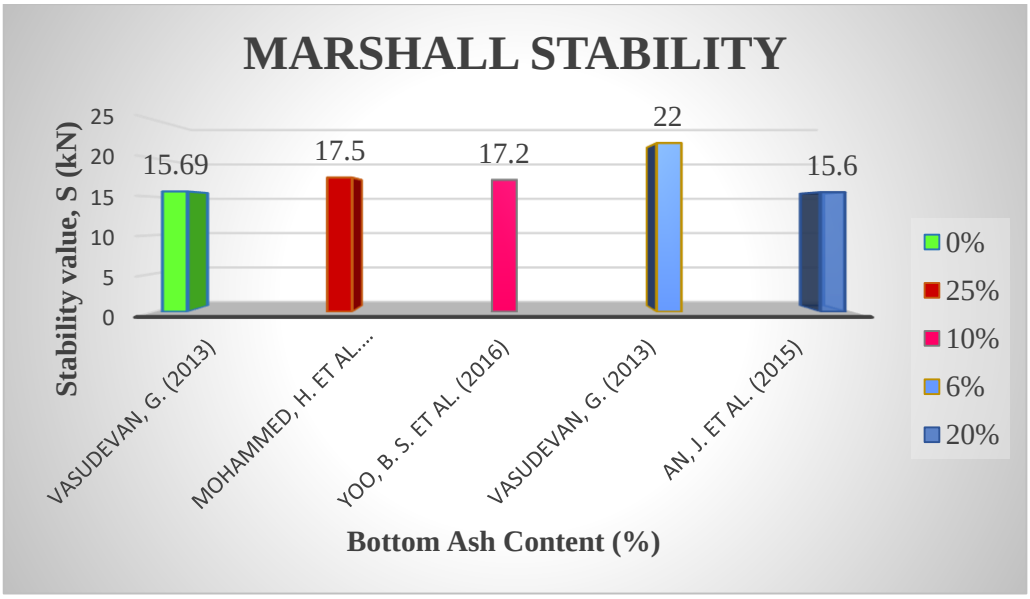

Figure 2: Graph of Marshall Stability Result

Figure 2 shows the graph of the Marshall Stability Test result. The optimum percentage of bottom ash for the first study needed was 25.00 %, which is above the control mix [4]. As the bottom ash is increased in quantity, the flow also increases. The implementation of bottom ash from coal decreased the aggregate's voids, regardless of its necessity gravity, which is high. This leads to an improvement in bitumen flow in the mix, thus improving asphalt concrete's flexibility.

For the second previous paper, [5] discuss that the optimum percentage of bottom ash was 10.00 %, and the number of Marshall Stability Result is higher than the control mix. Optimal asphalt content and other asphalt mixture properties are not significantly impacted by the 10 to 30 percent change in BA content.

[6] respectively stated that 6.00 % of bottom ash is needed to achieve the Marshall Stability Test's optimum value. The fine aggregate is replaced by 20.00 % of the bottom ash to achieve the optimum value of stability, as mentioned by [7]. The Marshall stability decrease when 30.00-40.00 % of bottom ash was replaced. On the other hand, with increased BA content, the flow values appear to increase, significantly increasing flow values after 30 percent of replacement.

Table 3: Summary of Permissible Parameter of Marshall Flow value

Author	Bottom Ash Content (%)	Marshall Flow (mm)	JKR Permissible Parameter	Results
Vasudevan, G. (2013)	0	3.37	2.0-4.0mm	Pass
Mohammed, H. *et al.*. (2020)	25	3.90	2.0-4.0mm	Pass
Yoo, B. S. *et al.* (2016)	10	3.50	2.0-4.0mm	Pass
Vasudevan, G. (2013)	6	2.80	2.0-4.0mm	Pass
An, J. *et al.* (2015)	20	3.60	2.0-4.0mm	Pass

The summary of the permissible parameter for the Marshall Flow value is shown in Table 3, which pass the JKR standard. The standard parameter for JKR is in the range of 2.00-4.00 mm. The flow values can be defined as the vertical deformation when the maximum load is reached.

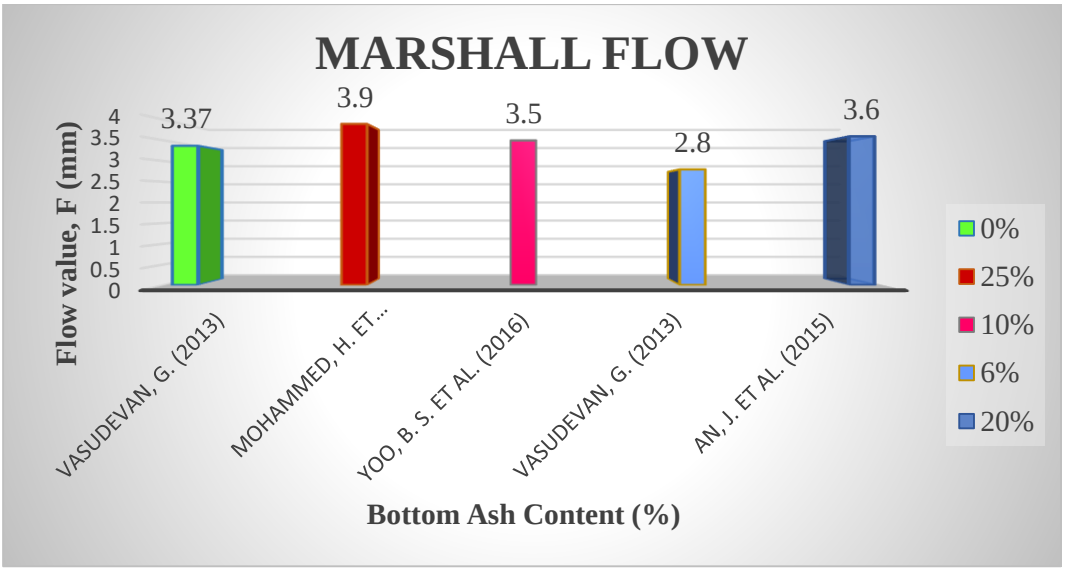

Figure 3: Graph of Marshall Flow Result

The relationship between bottom ash content and flow are shown in the Figure 3. The conventional samples obtained are 3.37 mm as stated by [6]. From the graph shown on Figure 3, [4] stated that the Marshall Flow that are obtained from the testing with 25.00 % of bottom ash replacement is the highest with 3.90 mm. Bottom ash that are used by [5] is 10.00 % and the Marshall Flow result is 3.50 mm. For the bottom ash content with 20.00 % from [6], the Marshall Flow that are resulted is 2.80 mm. [7] acquired 3.60 mm for the Marshall Flow by replacing 20.00 % of bottom ash content in the Marshall Stability Test.

4. Conclusion

Based on the review of previous research, the substitution of bottom ash in fine aggregate can increase the asphalt's stability. The proportion of asphalt mixes with bottom ash indicates that all samples were containing coal bottom ash present values within the prescription for all Marshall Stability parameters in the mix based on the Marshall Analysis result. The finding also demonstrated that coal bottom ash could strengthen its Marshall parameters as a partial substitution of fine aggregate in asphalt pavement.

Maintaining the bitumen content between the coal bottom ash content is vital for achieving a better roadway. It is also logical to argue that using bottom ash from coal would improve pavement quality. However, suppose it is possible to manufacture large quantities of coal bottom ash. In that case, specific changes must be made to cover the lack of use, ensuring that this material is recycled to the fullest, affecting the loss of environment use.

All researchers using the range of optimum of bottom ash (6.00 %-25.00 %) which resulting the Marshall stability ranges from 15.60 kN to 22.00 kN. Accordingly, it is complying with the JKR Standard value which is higher than 8.00 kN. From this previous paper, it had been observed that when 30.00 % and the upper value of bottom ash being a substitute, the stability and flow decreases proportionally.

4.1 Recommendations

The recommendations for this study are as follow:

- In future experiments, various forms of ash can be used to enhance stability and flow values.
- Conduct pavement research using the proportion of CBA in tropical weather.
- Discuss Marshall's functionality in the application of the bottom ash of coal to the binder layer.
- Checking performance ensures that the improved pavements are durable and have a long lifespan in impact resistance, mechanical properties and toughness.
- New guidelines must be provided that include new design requirements based on the blend's consistency to facilitate the use of this recycled content.

Acknowledgement

The authors would like to thank the Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia for its support.

References

[1] D. Y. S Yan, et al., “Development of Controlled Low-Strength Material Derived from Beneficial Reuse of Bottom Ash and Sediment for Green Construction,” 2014, http://dx.doi.org/10.1016/j.conbuildmat.2014.04.087.

[2] C.R. Devi, “Bottom Ash as an Additive Material for Stabilization of Expansive Soil,” International Journal of Engineering and Techniques - Volume 4 Issue 2, Mar-Apr 2018. ISSN: 2395-1303. 2018

[3] A. Marto, et al.,"Engineering characteristics of Tanjung Bin coal ash," Electronic Journal of Geotechnical Engineering, 15. 1117 -1129. ISSN 1089-3032. 2010

[4] H. Mohammed, et al., "Coal Bottom Ash as Partial Replacement of Fine Aggregate in Asphaltic Concrete," UNIOSUN Journal of Engineering and Environmental Sciences. Vol. 2, No. 1 March 2020. 2020

[5] B. S. Yoo, et al., "Evaluation of Asphalt Mixture Containing Coal Ash," Byung-Soo Yoo et al. / Transportation Research Procedia 14 (2016) 797 – 803. 2016

[6] G. Vasudevan, "Performance of Coal Bottom Ash in Hot Mix Asphalt," IJRET: International Journal of Research in Engineering and Technology eISSN: 2319-1163 | pISSN: 2321-7308. 2013

[7] J. An, "Sustainable Utilization of MSWI Bottom Ash as Road Construction Materials," Part I: Physical and Mechanical Evaluation. Airfield and Highway Pavements 2015 © ASCE 2015. 2015