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Characteristics of Asphalt Concrete Mix Using Coal Bottom Ash as Fine Aggregate Substitution

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Abstract

The use of coal as fuel in steam power plants creates problems for the environment because the residual combustion produces solid waste such as fly ash and bottom ash. This study aims to determine the value of the Marshall parameters in asphalt-concrete mix due to the use of coal bottom ash (CBA) to substitute fine aggregate. Aggregates used were taken from Indrapuri, Aceh Besar District. Variations in CBA are 5% and 15%. This study uses the Marshall method. The results obtained from this study show that the best CBA content is 5% with 6.05% asphalt content. The durability of asphalt concrete mix without CBA is 98.29% and the asphalt concrete mix using 5% CBA content is 96.11%, respectively. Thus, the durability value is ≥ 90%, this indicates that the durability value fulfills the 2020 Bina Marga specifications.

Keywords

Marshall parameters, Coal bottom ash, Durability, Flexible pavement

Introduction

As highways serve nearly 80 - 90% of the population's mobility and the transport of goods, the development of road transport infrastructure is a priority. This resulted in an increase in the need for road materials, both asphalt and aggregate [1]. The use of coal as fuel raises new problems because the rest of its combustion produces solid waste in the form of fly ash and bottom ash. The need for coal to operate all steam power plants in Indonesia requires 82 million tons of coal so that it will produce 4.1 million tons of solid waste (0.82 million tons of bottom ash and 3.28 million tons of fly ash) [2]. Basically, fly ash does not have the ability to bind, but fine particles presence as well as the water, silica oxide in fly ash will cause a chemical reaction with calcium hydroxide which is lead to the cement hydration process which may produce substances that have the ability to bind [3]. The use of bottom ash as a substitute for fine aggregate is targeted to reduce environmental pollution and can also to produce pavement that is with the same or better quality.

This study aims to determine the effect on asphalt concrete mix due to the use of CBA as an aggregate. The materials used in this study are aggregates taken from Indrapuri, Aceh Besar District. CBA used as a fine aggregate substitution was taken from the electric steam power plant, Nagan Raya, the substitution variations of 5% and 15%. The filler material used is Portland cement and the asphalt used is asphalt penetration 60/70.

Materials and Method

The research was conducted at the Highway Laboratory, Department of Civil Engineering, Faculty of Engineering, Universitas Syiah Kuala. The aggregates used were obtained from Indrapuri, Aceh Besar District, and asphalt penetration 60/70, while the CBA was obtained from electric steam power plant, Nagan Raya. In determining the optimal asphalt content, five asphalt contents variations are used, namely 5%, 5.5%, 6%, 6.5%, and 7%. Each specimen was compacted for 2 x 75 blows. Then tested using the Marshall method to get optimum asphalt content (OAC). The data analysis used is Analysis of Variance to determine the effect of using CBA on fine aggregate substitution of asphalt concrete mix. The materials used were nanomaterials.

Results and Discussion

The physical properties of aggregate tested are complied with the 2020 Bina Marga specifications [4]. The results of the physical properties tests of the aggregate can be seen in table 1.

From the distribution of the data collected, the non-linear regression was considered the most appropriate for the relationship pattern between asphalt content and Marshall characteristics. The graph of the OAC value of asphalt concrete of the Marshall parameter evaluation can be seen in figure 1. Marshall test results produce parameters namely stability, flow, density, VIM (Void in mix), VMA (void in mineral aggregate), VFA (Voids filled by asphalt), and MQ so that by using the overlapping method the value of OAC is obtained.

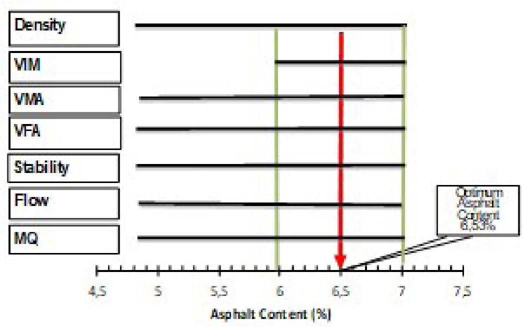

Figure 1: Graph of OAC.

Based on the results, the OAC of the asphalt concrete mix is 6.05%, while the best substitution of CBA as fine aggregate is found 5%. Based on the results of the analysis on the Marshall parameters, the values obtained fulfill the 2018 Bina Marga highways specifications revision 2 (2020) [5]. Figure 2 indicates that the stability obtained decreased with increasing CBA contents of the asphalt concrete mixtures. The use of CBA as a substitution to the new aggregates, resulting in lower strength to sustain the loads. Based on the specifications of Bina Marga 2018 revision 2 (2020) [6] the minimum stability is 800 kg and the addition of all variations of CBA fulfill the specified requirements. The highest stability is found at 5% CBA content of the asphalt concrete mix. Figure 3 shows that the flow increases in line with the increasing CBA substitution. The flow is greatly influenced by the magnitude of the stability value, the higher the stability value, the lower the flow value.

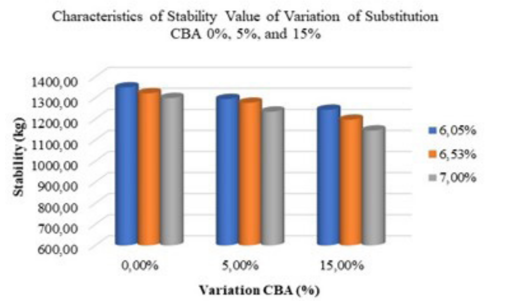

Figure 2: Effect of CBA substitution variation on the stability.

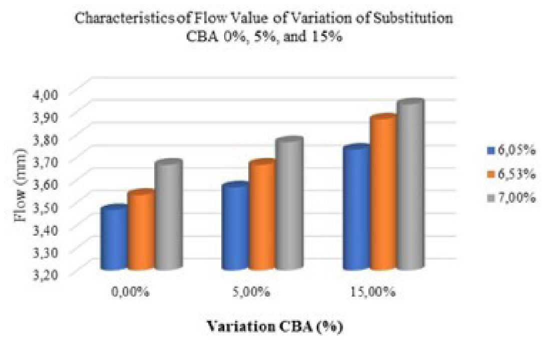

Figure 3: Effect of CBA substitution variation on flow.

Based on figure 4, the VIM of the asphalt concrete mix with CBA substitution as fine aggregate tends to decrease as the increasing of CBA used. This is due to the content in CBA resulting in smaller voids in the mixture. The VIM value for each CBA substitution has fulfilled the specified requirements. Based on figure 5, the VMA of each CBA substitution of the asphalt concrete mix fulfills the Bina Marga 2018 revision 2 (2020) [7] specifications, which the minimum is 15%. The VMA value decreases with the increasing of CBA substitutions. The higher the VMA, the higher the impermeability of the mixture to water and air, thereby affecting the durability of the mix. Voids quantity affects the performance of an asphalt mix, when the VMA is too large, creates more space for asphalt blankets. The value of VFA increases in asphalt con-

Table 1: Results of examination of physical properties of aggregate.

Test	Standard	Requirements	Unit	Location 1 Result
Specific gravity	SNI 1969-2008	Min. 2.5	-	2.789
Absorption of water	SNI 1969-2008	Max. 3	%	1.044
Unit weight	AASHTO T-19-74	Min. 1	kg/dm	1.532
Elongation index	ASTM D-4791	Max. 10	%	7.924
Flakiness index	ASTM D-4791	Max. 10	%	9.907
Impact	SNI 03-4426-1997	Max. 30	%	6.480
Abrasion	SNI 2417:2008	Max. 40	%	16.440

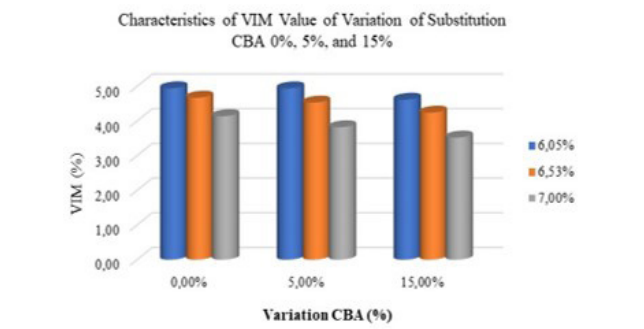

Figure 4: Effect of CBA substitution variation on VIM.

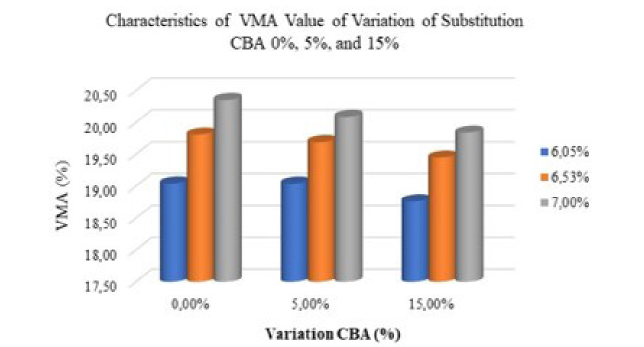

Figure 5: Effect of CBA substitution variation on VMA value.

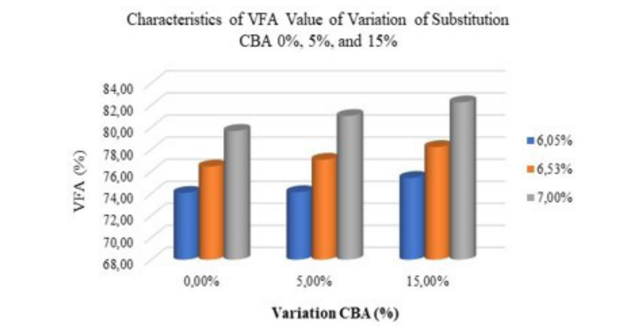

Figure 6: Effect of CBA substitution variation on VFA.

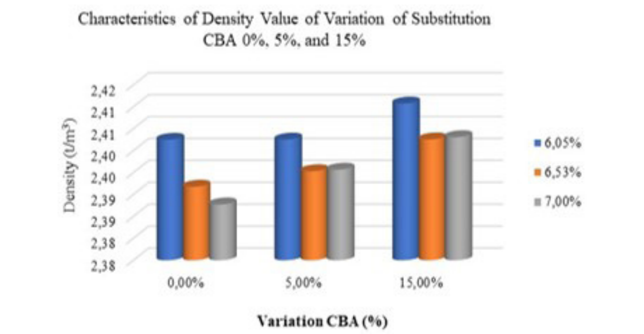

Figure 7: Effect of CBA substitution on density.

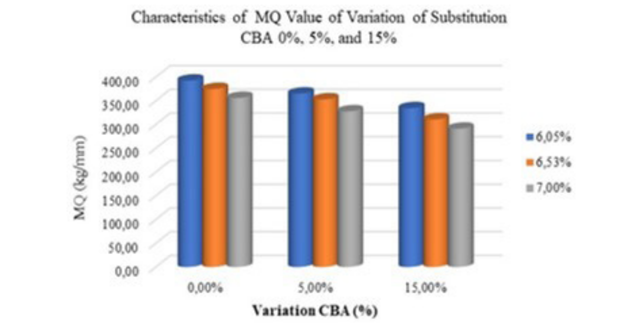

Figure 8: Effect CBA substitution variation on MQ.

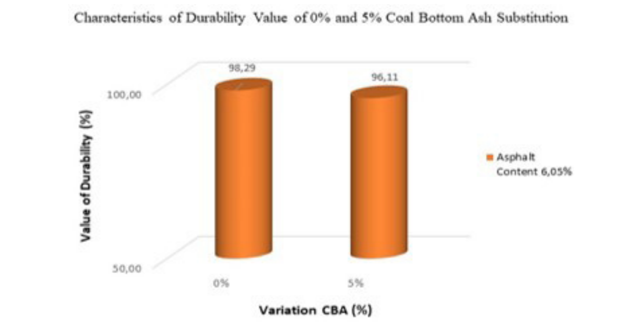

Figure 9: Durability of asphalt mix with 0% and 5% CBA substitution.

crete mixture with the increasing CBA substitution (Figure 6). This occurs because with each addition of CBA, the VFA also increases, thus the mixture has high impermeability to water and air. Based on the results, the VFA obtained fulfills the specifications whereas the minimum is 65%. The density of the asphalt concrete mixture with CBA increased is shown in figure 7.

This increase occurred in line with the increase of CBA substitution. From the results, the density for all CBA substitutions fulfills the specified specifications, namely ≥ 2 g/cm^3. The Marshall questions for asphalt concrete mixtures with CBA tend to decrease (Figure 8). This is because at the CBA content of 15% the stability is getting smaller while the flow is getting higher. Referring to the 2018 revision 2 (2020) highways specifications [8], the minimum Marshall quotient is 250 kg/mm.

Durability of asphalt mix with CBA substitution is shown in figure 9. The durability values of the 0% and 5% CBA substitution and found comply with the requirements of the general specifications for highways 2018 revision 2 (2020) [9], namely ≥ 90%. The value obtained for 0% CBA substitution is 98.29% and for 5% CBA substitution is 96.11%, which means the mixture is durable.

Conclusion

The OAC of asphalt mix with CBA as a substitution on the fine aggregate are varies, namely, 6.05%, 6.53%, and 7%. Based on the evaluation of the Marshall parameters, the most suitable is at 5% CBA variation, with 6.05% asphalt content. The durability of the 0% CBA substitution is 98.29% and 5% CBA substitution is 96.11%, respectively. The durability value of ≥ 90% indicates that the durability fulfills the Bina Marga specifications.

Acknowledgments

None.

Conflict of Interest

None.

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