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The Durability of Asphalt Concrete Mix (AC-WC) Using Fly Ash from Coal Bottom Ash as Filler Substitution

Ucha Arief Pratama, Sofyan M. Saleh and Yusria Darma

Department of Civil Engineering, Universitas Syiah Kuala, Jl. Syekh Abdurauf As Sinkil No. 7, Banda Aceh, Indonesia

***Correspondence to:**
Department of Civil Engineering,
Universitas Syiah Kuala,
Jl. Syekh Abdurauf As Sinkil No. 7,
Banda Aceh, Indonesia
E-mail: yusriadarma@unsyiah.ac.id

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Abstract

Plastic waste is a big problem and is troubling because it takes a long time to decompose. This is a severe problem that must be resolved immediately. One of the efforts that can be made to manage plastic waste is to reuse it. In addition to plastic waste, using coal as a fuel creates new problems because, after burning, it leaves solid waste in the form of fly ash and coal bottom ash. This study aimed to determine the effect of the asphalt concrete mixture due to using coal bottom ash as a filler substitution in wear layer concrete (AC-WC) with LDPE (Low-density polyethylene) mixture on Marshall characteristics using the wet mixing method. After obtaining the best combination of the best LDPE substitution variations on asphalt, tested the substitution of fly ash from coal bottom ash as a filler with variations in the addition of 0%, 25%, 50%, 75%, and 100% filler. The best variation was obtained from adding fly ash as a filler of 25% with a durability value of 94.65% and already fulfilling the requirements of the 2018 Highways Specifications Revision 2 (2020), namely ≥ 90%. Data analysis was carried out using significant results in the one-way ANOVA (Analysis of variance) test showing the effect of fly ash on the density, VIM (Void in mix), VMA (Void in mineral aggregate), and VFA (Void filled by asphalt) values.

Keywords

Fly ash, Marshall, Coal bottom ash, Wet mixing method

Introduction

Indonesia's coastal population is 187.2 million, producing 3.22 million tons of plastic waste yearly, which must be treated appropriately. Approximately 0.48 - 1.29 million tons of plastic waste pollute the oceans [1]. Plastic comes from the Greek word "plastics," which means fit for molding. Plastics are divided into two main categories, namely thermoplastic and thermoset. Types of thermoplastics include polyethylene, polypropylene, polystyrene, polycarbonate, and others. This type of plastic can be heated to form products and melted again to develop new products [2]. Plastic waste is a significant and worrying problem because decomposing takes a long time. A total of 275 million tons of plastic waste is produced worldwide. Around 4.8 - 12.7 million tons of this amount are wasted and pollute the environment [1]. Therefore, more attention must be paid to plastic waste by reusing plastic waste. One way is to use it as an additive in a mixture of road pavements.

Generally, roads can be made of asphalt, called flexible pavement, or cement concrete, called rigid pavement. Most roads are adjustable with a compacted base, underlay, and surface over the base layer. Plastics are polymers with unique and extraordinary properties. Polymers are materials composed of molecular units called monomers. If the monomers are the same, they are called homopolymers;

if the monomers are different, they are called copolymers. Natural polymers are cellulose, protein, and rubber [3, 4]. Plastics can be divided into two groups: thermoplastics and single-use plastics. Thermoplastic plastics can be pressed repeatedly when heated (recyclable). Thermoplastic plastics include polyethylene, polypropylene, polystyrene, acrylonitrile butadiene styrene, styrene acrylonitrile, nylon, polyethylene terephthalate, polyacetal, polycarbonate, etc. On the other hand, single-use plastics cannot be re-molded under certain conditions because their polymeric structure exists within the plastic as a three-dimensional mesh (non-recyclable). Plastic thermophiles include polyurethane, urea formaldehyde, melamine formaldehyde, polyester, epoxy, and others [4].

Asphalt is a black or dark brown adhesive material whose main component is bitumen, solid to dense at room temperature and thermoplastic for example, asphalt melts when heated to a specific temperature and freezes when the temperature drops. Asphalt is a complex hydrocarbon element, and the molecules that make up asphalt are complicated to separate. Hydrocarbons are the main component of asphalt, also known as bitumen. Generally, the asphalt used today comes from residual oil and the distillation process, or cement asphalt [5, 6].

The asphalt concrete layer (Laston) is a road construction layer consisting of a mixture of hard asphalt and aggregate, which is continuously sorted, mixed, spread, and compacted under hot conditions at a specific temperature [6]. Laston consists of the continuous total with hard asphalt mixed, levelled, and packed at particular temperatures [7, 8]. Continuous gradation is a composition that shows an even distribution of grains from the largest to the smallest size. Asphalt concrete with a constant gradation mixture has a piece of coarse aggregate, fine aggregate, filler, and asphalt (bitumen) as a binder. Another characteristic is that the rock structure has few connecting cavities, so asphalt concrete has high stability and is relatively stiff [9].

Besides plastic waste, using coal as a fuel creates new problems because burning it will leave solid waste in the form of fly ash and coal bottom ash. Therefore, this study tried to utilize both of these wastes as additives in the asphalt concrete mixture, which aims to determine the extent to which the plastic and fly ash are added or substituted m coal bottom ash to the asphalt concrete mixture and obtain the durability of the mix used.

Materials and Method

The research was conducted at the Transportation Laboratory, Faculty of Engineering, Syiah Kuala University, Banda Aceh. The aggregate comes from Stone Crusher PT. Krueng Meuh is located in Indrapuri, Besar District, Aceh. The plastic used is in the form of plastic waste, including clear plastic bags, colored plastic bags, and used snack food packaging. Coal bottom ash, used as a filler substitute, is obtained from PLTU Nagan Raya. In this study, the plastic was added to the hot asphalt using the wet mixing method and stirred at high speed until homogeneous. The sample was pounded with a pounder for 75 collisions, each on the top and bottom surfaces. Samples were immersed in an immersion bath at 60 ˚C for 30 minutes before the Marshall experiment. The materials used were nanomaterials.

Inspection of aggregate gradation was carried out using a filter analysis method. The research results show that aggregates cannot be used directly in the mixture because the totals have yet to be classified into their respective sizes. Therefore, the first step is to adjust the gradation so that the capacity meets the specified specifications. The results of the inspection of the asphalt concrete layer (AC-WC) gradation plan are shown in figure 1.

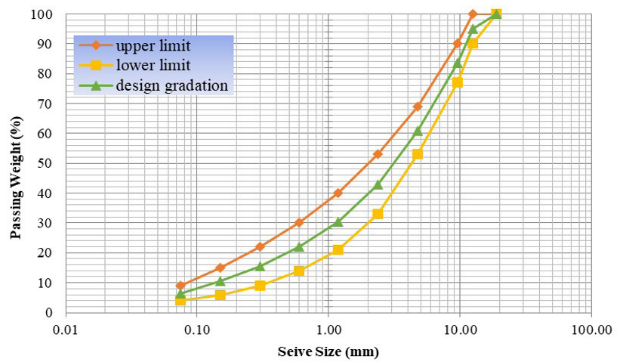

Figure 1: Graph of asphalt concrete layer plan (AC-WC).

Results and Discussion

Examination of the physical properties of the aggregate

Examination of physical properties, including specific gravity and aggregate absorption of water, aggregate density, elongation index and flatness index, impact, and aggregate wear, using a Los Angeles machine. From the research results, the aggregate physical property values were by the specified standards, namely 30.513% and 23.780%, except for the values for the flatness index and elongation index, which exceeded 10%. Previous research that has done something similar explains that in the specifications for the description of coarse aggregate, this value can still be tolerated if there is a discrepancy, provided that other tests meet the requirements of the General Specifications of the Directorate General of Highways (2018) Revision 2, specifically related to the results of the wear tests carried out with the Los Angeles engine that can be seen in table 1 and table 2.

Inspection of the physical properties of asphalt

Testing the physical properties of asphalt includes testing for specific gravity, penetration, ductility, and softening point. The results of testing the physical properties of asphalt indicate that the physical properties meet the standards set by Bina Marga 2018 and can be used for asphalt concrete mixtures. The results of testing the physical properties of asphalt are shown in table 3.

Marshall test results with substitution of fly ash from coal bottom ash in the best mixing composition

For testing with the substitution of fly ash from coal bottom ash. Then one of the best variants of the mixing combination is chosen. Based on the research results, the best asphalt

Table 1: Examination results of coarse aggregate physical properties.

Testing	Standard	Condition	Unit	Results
Heavy type	SNI 1969-2008	min. 2,5	g/cm^3	2,702
Absorption against water	SNI 1969-2008	max. 3%	%	1.04
Heavy content aggregate	AASHTO T-19-74	min. 1 kg/dm^3	kg/dm^3	1,547
Index oval	ASTM D-4791	max. 10%	%	23,780
Index flakiness	ASTM D-4791	max. 10%	%	30,513
collision	SNI 03-4426-1997	max. 30%	%	10.227
Aggregate wear with Machine Los Angeles	SNI 2417:2008	max. 40%	%	19,146
Attachment ggregate against asphalt	SNI 2439:2011	min. 95%	%	98.0

content was obtained at 5.79%, and the best LDPE content at 5.5%. Then the results of the Marshall parameter review on the best-mixed variant will be discussed by substituting fly ash from coal bottom ash which previously used Portland cement as a filler with variations in the addition of 100%, 75%, 50%, 20%, and 0% fly ash from coal bottom ash. on each variation of the test object [10]. Marshall test results on substituting fly ash from coal bottom ash as a filler. The stability value obtained decreases with increasing levels, as has formal bottom ash as a filler in concrete asphalt mixture. Based on the specifications of Bina Marga 2018 Revision 2 for the stability value, which is a minimum of 1000 kg and the addition of each variation of concrete waste, all meet the specified requirements. The highest stability value is at 0% fly ash content, weighing 1199.66 kg. The flow test results for each fly ash substitution from coal bottom ash increased with increasing levels of fly ash substitution. This happens because of the degree of influence of the use of coal bottom ash waste on filler substitution. Obtained at the added content of 75% fly ash and 100% the flow value exceeds the specified specifications. The stability value strongly influences the flow value, the higher the stability value, the lower the flow value. This phenomenon occurs because specimens with increased stability are stiffer, so their collapse tends to be small. The density value of the asphalt concrete mixture with fly ash substitution from coal bottom ash has increased. This increase occurred with the addition of coal bottom ash substitution. The calculation results show that the density values for all fly ash substitutions from coal bottom ash meet the specified specifications, ≥ 2 g/cm^3.

The VIM value of the asphalt concrete mixture with fly ash substitution from coal bottom ash tends to decrease with the addition of fly ash. This is due to the content in coal bottom ash resulting in smaller air pore values in the mixture. The VIM value for each fly ash substitution from coal bottom ash has met the specified requirements. The VMA scores have satisfied specifications (Directorate General of Highways, 2018) by at least 15%. The VMA value decreases with the addition of fly ash substitution from coal bottom ash as a filler. The higher the VMA value, the higher the impermeability of the mixture to water and air, thereby affecting the durability of the mix. Cavity quality affects the performance of a blend because if the VMA is too large, it can cause more space for asphalt blankets.

Table 2: Examination results of fine aggregate physical properties.

Testing	Standard	Condition	Unit	Results
Specific gravity	SNI 1969-2008	min. 2,5	g/cm^3	2,813
Absorption of water	SNI 1969-2008	max. 3%	%	0.071

The value of VFA in asphalt concrete mixture substitutionally ash from coal bottom ash increases with increasing variations of fly ash substitution from coal bottom ash. This happens because, with each addition of fly ash from coal bottom ash, the cavity filled with asphalt also increases, so the mixture has high impermeability to water and air. Based on the test results, the VFA value obtained meets the 2018 Highways Specifications Revision 2 (2020) at a minimum of 65%. The value of Marshall questions (MQ) in asphalt concrete mixture with variations in the percentage of fly ash substitution from coal bottom ash to the Marshall value tends to decrease. This is because, at the level of concrete waste, the stability value is getting smaller while the flow value is getting bigger. The mixture with the best composition can be seen in table 4.

Durability results with 30 minutes and 24 hours of soaking

Based on the test results of the specimens, the samples were prepared and soaked at 60 °C for 30 minutes and 24 hours for the Marshall test. This test was carried out to obtain the asphalt mixture's durability value. The Durability value that meets the specifications based on Highways Revision 2 of 2018 is ≥ 90%, as seen in table 5. The results of the Marshall parameter review show that the variation in the addition of fly ash as a filler substitution in the best composition mix is at levels of 25% and 50%, which still meet the requirements of the Bina Marga 2018 Revision 2 (2020) specification. Because the stability value of adding fly ash as a filler at a content of 25% is more significant than at a range of 50%, one variation was chosen for the du-

Table 3: Examination results of the physical properties of asphalt penetration 60/70.

Testing	Standard	Condition	Unit	Results
Specific Gravity (25 °C)	SNI 2441:2011	≥ 1	-	1,031
Penetration (25 °C; 5 seconds; 0.1 mm; 100 g)	SNI 2456:2011	60 - 70	(0.1 mm)	65,2
Ductility (25 °C; 5 cm/min)	SNI 2432:2011	≥ 100	cm	> 120
Softening point (°C)	SNI 2432:2011	≥ 48	°C	48

Table 4: Marshall test results on fly ash substitution as a filler in the mixture with the best composition.

Mixed Characteristics	Asphalt content 5.79%					Highway 2018 specs
	LDPE content 5.5%					
	Variation of fly ash (%)					
	0%	25%	50%	75%	100%	
Stability (kg)	1199.66	1192.45	1173,19	1129.78	1079.56	min. 1000
Flow (mm)	3,23	3,47	3.70	4.03	4,13	min. 2 - 4
Density (t/m³)	2.43	2.44	2.44	2.44	2.45	-
VIM (%)	4,17	4.04	3.89	3.77	3.64	min. 3 - 5
VMA (%)	17,83	17,71	17.59	17,48	17,37	min. 15
VFA (%)	76,60	77,20	77,88	78,44	79.07	min. 65
MQ (kg/mm)	371.87	346.92	322.74	280.94	265,43	min. 250

Table 5: Durability test results with substitution of fly ash as filler.

Mixed Characteristics	Asphalt content 5.79%		Highway 2018 specs
	LDPE content 5.5%		
	Variation fly ash 25%		
	Soak 30 minutes	24 hour soak	
Stability (kg)	1129,33	1068,88	min. 1000
Flow (mm)	3.60	3.77	min. 2 - 4
Density (t/m³)	2.40	2.39	-
VIM (%)	4.99	4.68	min. 3 - 5
VMA (%)	18.44	18.88	min. 15
VFA (%)	72.98	75,29	min. 65
MQ (kg/mm)	315,11	285.61	min. 250

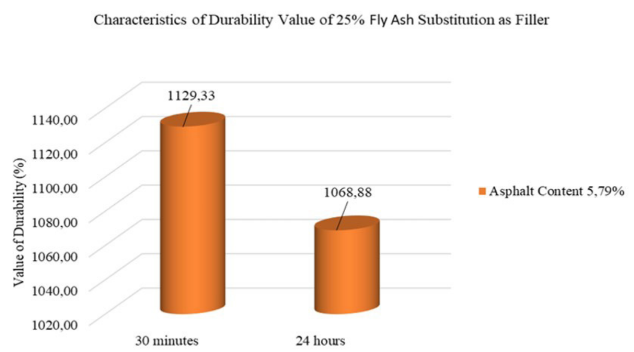

Figure 2: Characteristics of durability value of 25% fly ash substitution as filler.

ty test. Then the durability value for the asphalt concrete mix with 25% fly ash as a filler and pure LDPE substitution fulfils the General Specifications for Highways 2018 revision 2 (2020) requirements, namely ≥ 90%. The percentage value of durability obtained is 94.65%, as seen in figure 2.

Results of ANOVA

Calculating the one-way ANOVA test results with variations of fly ash substitution from coal bottom ash on a mixture composition with 5.79% asphalt content. The results of one-way ANOVA with variations in the substitution of fly ash from coal bottom ash in the design of the mixture with asphalt content of 5.79% by comparing the calculated F values and F tables and the sig. Values and α. Value. As can be seen in table 6, it shows the estimated F value < F table and sig. > α, then Null Hypothesis is accepted, and Alternative Hypothesis is rejected. Significant results in the one-way ANOVA test showed an effect of fly ash on the Density, VIM, VMA, and VFA values.

Conclusion

It is based on the research results on the properties of the AC-WC asphalt concrete mix, replacing LDPE on asphalt and using coal bottom ash as a filler. The results of an examination of the material's physical properties in the form of aggregate, asphalt penetration 60/70 still meet the required specifications and can be used in research, except for the value of the flatness and elongation index, which are affected by the stone crusher tool. The durability value obtained for the

Table 6: ANOVA test results for Marshall parameters.

Marshall parameters	Substitution of fly ash as filler + 5.5% LDPE with 5.79% asphalt content				Conclusion
	Fcount and Sig.	Ftable and α values	Value of df1 and df2	ANOVA test	
Stability	Fcount = 1.0705 Sig. = 1.0704	Ftable = 3.478 α = 0.050	df1 = 4 df2 = 10	Ho Accepted Ha Rejected	Not significant
Flow	Fcount = 3.4304 Sig. = 0.0518	Ftable = 3.478 α = 0.050	df1 = 4 df2 = 10	Ho Accepted Ha Rejected	Not significant
Density	Fcount = 5.4799 Sig. = 0.0115	Ftable = 3.478 α = 0.050	df1 = 4 df2 = 10	Ho Rejected Ha Accepted	Significant
VIM	Fcount = 8.7803 Sig. = 0.0026	Ftable = 3.478 α = 0.050	df1 = 4 df2 = 10	Ho Rejected Ha Accepted	Significant
VMAs	Fcount = 8.3780 Sig. = 0.0031	Ftable = 3.478 α = 0.050	df1 = 4 df2 = 10	Ho Rejected Ha Accepted	Significant
VFAs	Fcount = 8.5202 Sig. = 0.0029	Ftable = 3.478 α = 0.050	df1 = 4 df2 = 10	Ho Rejected Ha Accepted	Significant
MQ	Fcount = 2.4282 Sig. = 0.1163	Ftable = 3.478 α = 0.050	df1 = 4 df2 = 10	Ho Accepted Ha Rejected	Not significant

effective asphalt mixture from the best mix composition and fly ash substitution from coal bottom ash as filler meets the requirements for the 2018 Revision 2 (2020) General Highways Specifications (2020), namely ≥ 90% by 94.65%. It would be best not to use fly ash for asphalt concrete mixtures because the stability value will decrease, and the flow value will increase as the addition of fly ash variations in filler substitution increases. Therefore, further research is needed by considering variations in the accumulation of fly ash.

Acknowledgements

None.

Conflict of Interest

None.

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