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The Effect of Asphalt Modification With PET Plastic Waste and Latex Rubber on AC-WC Asphalt Pavement Mixture with Local Aggregate from East Kalimantan

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Abstract

The need for Asphalt materials that yield a high stability value to prevent road damage and improve driving safety and comfort will continue to increase. However, the availability of asphalt is dwindling because it is a non-renewable material. This study aims to determine the effect of adding PET plastic waste and latex rubber as a partial replacement for asphalt in the AC-WC mixture. This research was carried out by testing asphalt penetration 60/70 with 3 types of addition of partial asphalt replacement materials and making 63 samples, of which 45 samples with 3 types of mixtures and 5 variations of asphalt content for the Marshall test, as well as 18 samples for the Marshall Immersion test. The test method used is based on the General Specifications for Highways 2010 Revision 3. This modified asphalt mixture research summarizes that the mixture with the addition of 3% PET plastic waste obtained a VMA value of 17.90%, a VFA of 75.16%, a VIM of 4.44%, a stability of 2901 kg, and a flow of 3.1 mm, at mixture with the addition of 3% latex rubber obtained VMA 17.93%, VFA 80.76%, VIM 3.45%, stability 2335 kg, and flow 3.2 mm, in a mixture with the addition of latex rubber 6% obtained VMA 18.07 %, VFA 79.53%, VIM 3.70%, stability 2176 kg, and flow 3.1 mm. As well as the results of the Marshall Immersion test on asphalt mixtures with the addition of PET plastic waste and latex rubber as a partial replacement for asphalt, with the addition of 3% PET plastic waste, 3% latex rubber, and 6% latex rubber of the total weight of the asphalt mixture, the residual Marshall stability value has been obtained. each of 81.2%, 94.5% and 90.7%. So, the addition of latex rubber as a partial replacement for asphalt can make the mixture more resistant and stronger, reducing damage from water and weather.

Keywords: *Asphalt Concrete-Wearing Course (AC-WC), Latex Rubber, Marshall Characteristics, Modified Asphalt, Polyethylene Terephthalate (PET.)*

1. Introduction

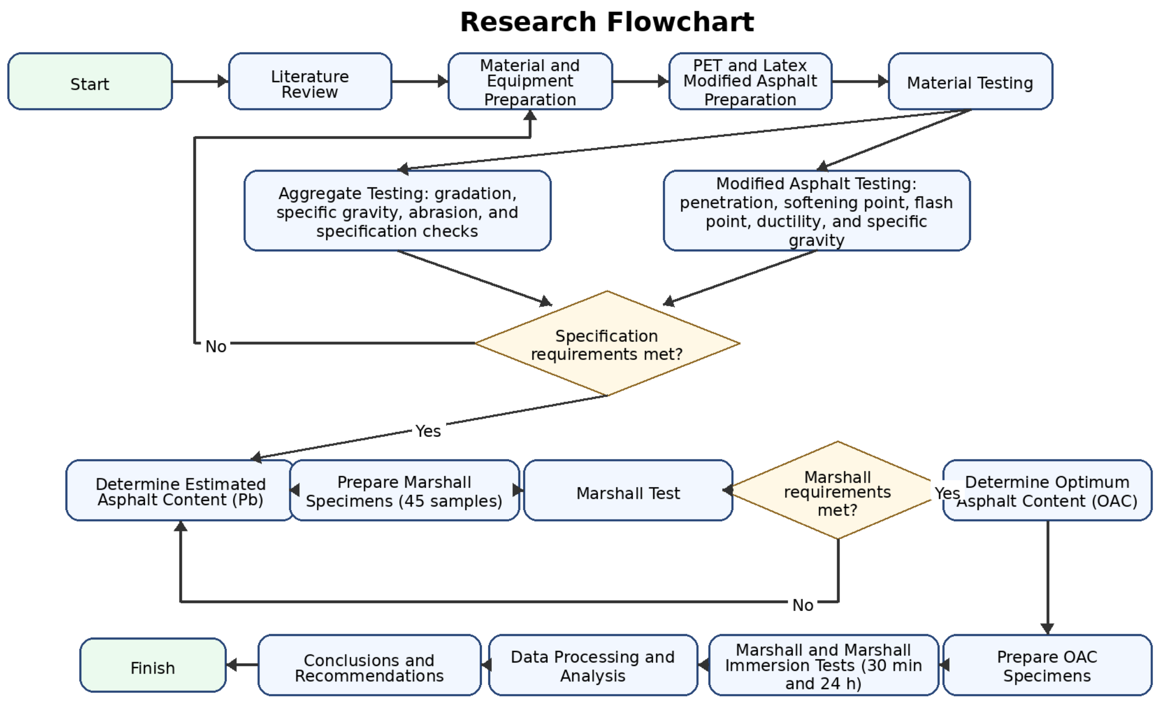
Road pavement is a mixture of aggregate and binding material used to serve traffic loads. According to Sukirman, there are three types of road pavement: pavement that uses asphalt as a binder (flexible pavement), pavement that uses cement as a binder (rigid pavement), and pavement that combines rigid and flexible pavement (composite pavement) [1]. In flexible pavement, the binder and aggregate interaction strongly determine mixture stability, resistance to deformation, and durability under repeated traffic loading; therefore, asphalt modification has become an important approach to improve pavement performance while reducing dependence on conventional asphalt.

Polyethylene terephthalate (PET) waste is one of the polymer wastes that is relevant for asphalt modification because it is widely generated from beverage packaging and can be processed as a modifier or partial aggregate/binder substitute. Previous studies reported that PET-containing asphalt mixtures can improve stiffness and fatigue-related performance [2], influence Marshall stability, flow, density, and Marshall quotient when used as an aggregate replacement [3], and enhance the physical and engineering properties of asphalt mixtures when the PET content is properly optimized [4]. In addition, recycling PET into paving materials has been considered a sustainable strategy because it diverts plastic waste from disposal and can contribute to more durable road infrastructure; chemical recycling of waste PET into asphalt additives has also shown potential for producing sustainable paving materials when combined with rubberized asphalt technology [5].

Natural rubber latex is another promising modifier because it is renewable, elastomeric, and locally relevant for countries with natural rubber production, including Indonesia. Natural-rubber-latex modification has been reported to improve asphalt elasticity and pavement-related behavior, although compatibility and additive formulation such as sulfur or phosphoric acid addition can affect the final binder properties [6]. Rheological studies further indicate that natural-rubber-modified bitumen can improve performance-related characteristics under temperature and loading conditions [7], while natural rubber latex has also been positioned as a renewable and sustainable modifier for asphalt binders [8]. However, the combined evaluation of PET plastic waste and latex rubber as partial asphalt substitutes in AC-WC mixtures using local aggregate from West Kutai Regency, East Kalimantan, is still needed to support both pavement performance and local resource utilization. Therefore, this study aims to test the use of PET plastic waste and latex rubber as substitutes for a certain percentage of asphalt, combined with local aggregates from West Kutai Regency, East Kalimantan. Modifying asphalt with PET and latex rubber is expected to reduce asphalt use and improve the quality of road pavement and the stability of the asphalt mixture.

2. Methods

In conducting this study, the author first mixed asphalt with PET (Polyethylene Terephthalate) plastic and latex rubber as a substitute for a predetermined percentage of asphalt in the mixture. Plastic waste was processed by cutting it into small pieces and mixing it with heated asphalt to the required weight for the research. Similarly, latex rubber was processed as a substitute for a certain percentage of the asphalt content. This research was conducted at the Civil Engineering Laboratory, Faculty of Engineering, Mulawarman University. The research flowchart is as follows:



AC-WC = Asphalt Concrete-Wearing Course; OAC = Optimum Asphalt Content

Fig. 1. Research flowchart

In conducting this research, several steps were taken to obtain the desired results. The first step in the research was to conduct a literature review to identify references from journals, books, and previous theses. The selection and preparation of research materials followed this. Next, the asphalt material was mixed with PET plastic and latex rubber, followed by aggregate testing. In aggregate testing, there are two categories, namely coarse aggregates and fine aggregates. Both categories were tested in accordance with the specification requirements. However, the asphalt was mixed with PET plastic and latex rubber at the planned percentages. After mixing, the asphalt was tested in accordance with the specification requirements.

If the aggregate does not meet the specifications, it will return to the material selection and preparation stage to obtain materials and ingredients that do. However, in asphalt testing, if any tests do not meet the specifications, the manufacture of test specimens and further testing of the asphalt content will continue. After obtaining materials and ingredients that meet the specifications, the average asphalt content is determined. Then, test specimens are made for three variations of estimated asphalt content, totaling 45 test specimens. Next, Marshall testing is performed on the prepared test specimens. If they meet the Marshall requirements, the OAC is determined; if they do not, the process returns to the stage of determining the average asphalt content to obtain the correct asphalt content.

The optimum asphalt content (OAC) is obtained from the Marshall test results graph for the estimated asphalt. After obtaining the optimum asphalt content, test specimens are prepared at that level and then subjected to Marshall and Marshall immersion tests; each optimum asphalt content has 3 test specimens for the Marshall test and 3 for the Marshall immersion test, for a total of 30 test specimens.

After conducting all tests and obtaining the OAC and Marshall residue index values, data processing was carried out, and conclusions and recommendations for this study were obtained.

3. Result and Discussion

In this study, aggregate testing was conducted in accordance with the 2010 Revision 3 General Specifications for Road Construction. The aggregate used in this study was local aggregate sourced from West Kutai Regency, East Kalimantan. The aggregate testing data were obtained from primary data collected at the Civil Engineering Laboratory of Mulawarman University. The characteristics examined were as follows:

3.1 Result and Analysis of Asphalt Testing

In this study, asphalt testing was conducted in accordance with the Revised General Specifications for Road Construction 3. The binder used in this study was hard asphalt from Pertamina with a penetration of 60/70. The asphalt test results were obtained from primary data collected at the Civil Engineering Laboratory of Mulawarman University. The following data were obtained from the characteristic tests conducted:

Table 1. Asphalt Test Recapitulation

No	**Type of Test**	**Specification**		**Test Results**	**Remarks**
		Min	**Max**		
			Modified Asphalt with 3% PET Plastic Addition		
1	Penetration(mm)	40	-	40,5	Meets
2	Soft Point (C˚)	53	-	57,5	Meets
3	Flash Point (C˚)	232	-	310	Meets
4	Ductility (cm)	100	-	40,75	Does not meet
5	Specific Gravity (gr/cc)	1,01	-	1,01	Compliant
			Modified Asphalt with 6% PET Plastic Addition		
1	Penetration(mm)	40	-	18,9	Does not meet
2	Soft Point (C˚)	53	-	75,5	Meets
3	Flash Point (C˚)	232	-	322	Meets
4	Ductility (cm)	100	-	15,5	Does not meet
5	Specific Gravity (gr/cc)	1,01	-	1,07	Compliant
			Modified Asphalt with 3% Latex Rubber Addition		
1	Penetration(mm)	40	-	75	Meets
2	Soft Point (C˚)	53	-	53	Meets
3	Flash Point (C˚)	232	-	300	Meets
4	Ductility (cm)	100	-	123,75	Meets
5	Specific Gravity (gr/cc)	1,01	-	1,03	Compliant
			Modified Asphalt with 6% Latex Rubber Addition		
1	Penetration(mm)	40	-	61,5	Meets
2	Soft Point (C˚)	53	-	54	Meets
3	Flash Point (C˚)	232	-	280	Meets
4	Ductility (cm)	100	-	104,85	Meets
5	Specific Gravity (gr/cc)	1,01	-	1,04	Compliant

3.2 Planning for Aggregate Mixing

The combined aggregate gradation for asphalt in AC-WC, expressed as a percentage of aggregate weight, must meet the upper and lower limits of the Revised General Specifications for Road Construction 3. The percentage for each sieve size is the result of the percentage passing the aggregate sieve analysis test, multiplied by the percentage value for each aggregate obtained by trial and error. After obtaining the multiplication results, they are summed according to the sieve size and the constituent materials of the mixture. The percentage of the mixture's aggregate gradation obtained can then determine whether the mixture's aggregate gradation falls within the specified aggregate's maximum and minimum. From the sieve analysis examination, the aggregate gradation is obtained as shown in Table 2.

Table 1. Aggregate Combination Results

No. Sieve (Inch)	**Size (mm)**	**Percentage of Aggregate Combination**			**Design Composition Mixing Aggregate (%)**	**Limits Specifications**
		Aggregate Coarse CA (%)	**Aggregate Medium MA (%)**	**Aggregate Fine FA (%)**		
		20	**20**	**60**		
3/4”	19,0	20,00	20,00	40,00	100	100
1/2”	12,5	12,02	20,00	60,00	92,02	90-100
3/8”	9,5	7,50	19,72	60,00	87,22	77-90
No. 4	4,75	0,96	5,48	58,57	65,31	53-69

No. Sieve (Inch)	Size (mm)	Percentage of Aggregate Combination			Design Composition Mixing Aggregate (%)	Limits Specifications
		Aggregate Coarse CA (%)	Aggregate Medium MA (%)	Aggregate Fine FA (%)		
		20	20	60		
No. 8	2,36	0,11	1,07	46,61	47,79	33-53
No. 16	1,18	0,04	0,22	26,51	26,77	21-40
No. 30	0,60	0,04	0,20	15,97	16,21	14-30
No. 50	0,30	0,03	0,17	11,26	11,45	9-22
No. 100	0,150	0,02	0,08	7,25	11,45	6-15
No. 200	0,075	0,01	0,07	6,55	6,63	4-9

Based on Table 2, using 20% coarse aggregate, 20% medium aggregate, and 60% fine aggregate. Below is a graph of the aggregate combination of coarse aggregate, medium aggregate, and fine aggregate from West Kutai.

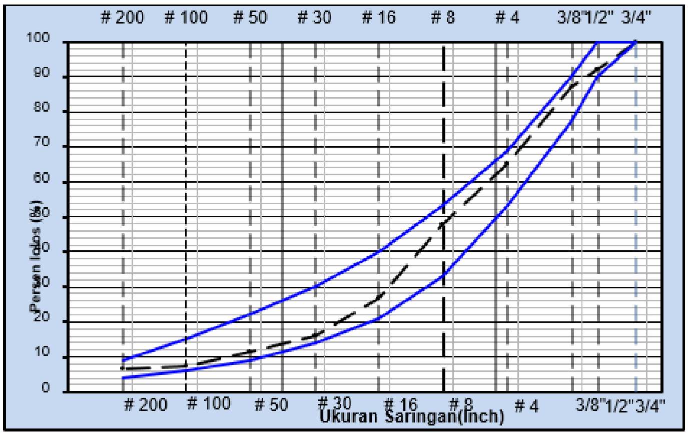


Fig. 1. Aggregate Combination

3.3 Medium Asphalt Content

To determine the middle asphalt content in this study, the following combination of aggregate mixtures from West Kutai was used:

Table 2. Medium Asphalt Content

Mix Type	Gradation (%)			Constant	Medium Asphalt Conten
	CA	MA	FA		
Aggregate mix combination, e.g., West Kutai	34,69	58,68	6,63	1	6%

The average asphalt content (Pb) calculated is 6%. Each test specimen will be made with varying asphalt content, starting at 6% and increasing by 0.5% for each subsequent specimen

3.4 Marshall Test Result and Analysis

Based on the results of the Marshall test analysis, the summary of each Marshall parameter can be seen in Table 4, namely:

Table 3. Summary of Marshall Test Results

Parameter	Specification	Mix Type	Values that Meet Specification	Asphalt Content Meeting Specifications
Stability (kg)	Min. 1000	PET 3%	1772 - 2940	5% - 7%
		Latex 3%	1625 - 2175	5% - 7%
		Latex 6%	2061 - 2939	5% - 7%
Flow (mm)	2-4	PET 3%	2,5 – 3,6	5% - 7%
		Latex 3%	3,1 – 3,5	5% - 7%
		Latex 6%	3,2 – 3,7	5% - 7%
VMA (%)	≥ 15	PET 3%	17,57 – 18,33	5% - 7%
		Latex 3%	17,55 – 18,03	5% - 7%
		Latex 6%	17,77 – 18,25	5% - 7%
VIM (%)	3 - 5	PET 3%	3,42 – 4,06	5% - 5,5%
		Latex 3%	4,03	5%

Parameter	Specification	Mix Type	Values that Meet Specification	Asphalt Content Meeting Specifications
		Latex 6%	4,18	5%
VFA (%)	≥ 65	PET 3%	76,91 – 96,98	5% - 7%
		Latex 3%	77,04 – 98,55	5% - 7%
		Latex 6%	76,51 – 98,93	5% - 7%

In this test, modified asphalt containing 6% PET plastic waste additive was not tested using the Marshall method because two asphalt testing parameters, penetration and ductility, did not meet the General Specifications for Road Construction Revision 3. It can be concluded that the addition of 6% PET makes the asphalt stiff and inelastic. Based on Table 6, the Marshall parameter values for asphalt contents ranging from 5% to 7% do not fully meet the specifications in accordance with the General Specifications for Road Construction, Revision 3.

3.5 Analysis of Optimum Asphalt Content (OAC)

The optimum asphalt content (OAC) is the midpoint of the asphalt content range that best connects asphalt content to the specified Marshall parameters. The optimum asphalt content (OAC) values from the Marshall parameter results are as follows:

Table 4. Optimum Asphalt Content (OAC)

Mix Type	Minimum Asphalt Content Range	Maximum Asphalt Content Range	Optimum Asphalt Content (OAC)
PET Plastic 3%	5%	5,71%	5,36%
Latex Rubber 3%	5%	5,38%	5,19%
Latex Rubber 6%	5%	5,50%	5,25%

Based on Table 5, it can be seen that the results of determining the optimum asphalt content (KAO) were obtained from the optimum asphalt content (KAO) graph, which can be seen in Figures 3 to 5, namely:

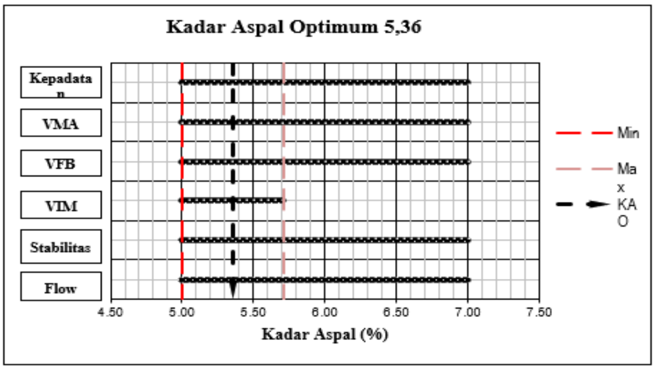


Fig. 2. The Graph of Optimum Asphalt Content PET 3%

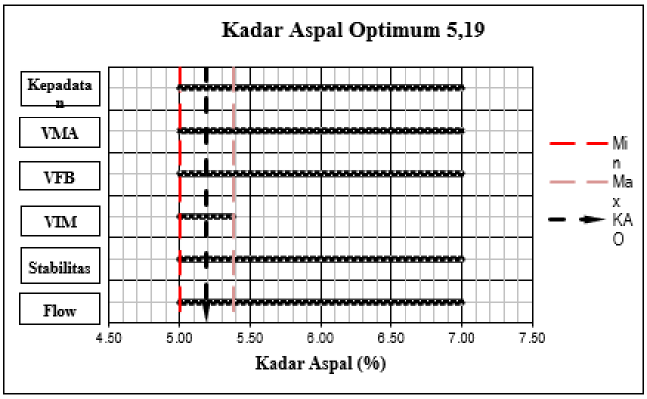


Fig. 3. Optimum Asphalt Content Graph for Latex 3%

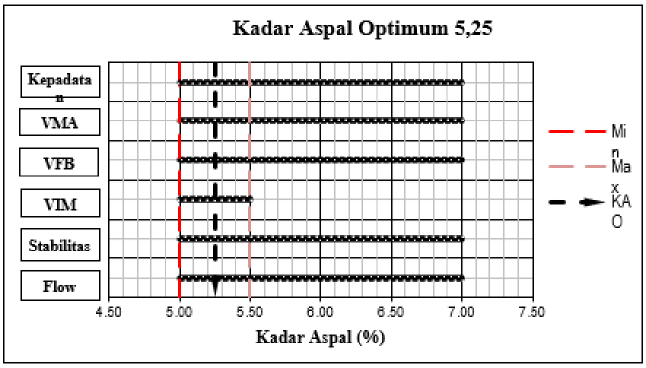


Fig. 4. Optimum Asphalt Content Graph for 6% Latex

After creating a graph of optimum asphalt content (OAC) based on the graphs in Figures 3, 4, and 5, it can be seen that the optimum asphalt content (OAC) with the addition of 3% PET plastic waste is 5.36%, the optimum asphalt content (OAC) with the addition of 3% latex rubber is 5.19%, and the optimum asphalt content (OAC) with the addition of 6% latex rubber at 5.25%. These optimum asphalt content (OAC) values are then used as the asphalt content in the Marshall immersion test.

3.6 Marshall Immersion Test

Marshall immersion testing is conducted after the optimum asphalt content (OAC) is determined. This test is performed to obtain the Marshall residual stability value. Marshall immersion aims to determine changes in mixture characteristics resulting from water, temperature, and weather conditions. The Marshall immersion value is obtained from the results of immersing the test specimen at 60ºC for 30 minutes and 24 hours.

Based on Table 5, it can be seen that the residual Marshall stability value of asphalt mixtures with the addition of 3% PET plastic waste as a partial asphalt substitute obtained a value of 81.2%, asphalt mixtures with the addition of 3% latex rubber as a partial asphalt substitute obtained a value of 94.5%, and the asphalt mixture with the addition of 6% latex rubber as a partial asphalt substitute obtained a value of 90.7%.

Table 5. *Marshall Immersion* Results Recapitulation

Type Parameter	Time Immersion	Percentage of Rubber Content & OAC		
		PET 3%	**Lateks 3%**	**Lateks 6%**
		OAC 5,36%	**OAC 5,19%**	**OAC 5,25%**
VMA (%)	30 minutes	17,90	17,93	18,07
VFA (%)		75,16	80,76	79,53
VIM (%)		4,44	3,45	3,70
Stability (kg)		2901	2335	2176
Flow (mm)		3,1	3,2	3,1
VMA (%)	24 hours	16,96	17,66	17,98
VFA (%)		80,20	82,27	80,03
VIM (%)		3,36	3,13	3,59
Stability (kg)		2355	2206	1975
Flow (mm)		3,9	3,9	4,9
Marshall stability Residual (%)		81,2	94,5	90,7

Based on these results, it is known that mixtures containing 3% and 6% latex rubber meet the specified of 90% requirement. From these results, it can be concluded that the addition of latex rubber as a partial substitute for asphalt can make the mixture more resistant and stronger against water and temperature induced damage.

4. Conclusion

Based on the analysis results of the research conducted on the Worn Asphalt Concrete (AC-WC) mixture with the addition of PET plastic waste and latex rubber as a partial substitute for asphalt, the following conclusions can be drawn are: 1) the effect of adding PET plastic waste and latex rubber as partial asphalt substitutes has met the Marshall parameter values at specific asphalt contents in accordance with the 2010 Revision 3 General Specifications for Road Construction, except for the VIM value, where several asphalt contents did not meet the specifications, namely at 3% PET addition with 6%-7% asphalt content, 3% latex rubber addition at 5.5%-7% asphalt content, and 6% latex rubber addition at 5.5%-7% asphalt content. This indicates that increasing the asphalt content increases the void ratio in the asphalt mixture (VIM), meaning the asphalt mixture cannot provide sufficient space to accommodate compaction from traffic loads; 2) The optimum asphalt content (OAC) in asphalt mixtures with 3% PET plastic waste added is 5.36%, with 3% latex rubber added is 5.19%, and with 6% latex rubber added as a partial asphalt substitute is 5.25%; 3) The Marshall Immersion value in mixtures with the addition of PET plastic waste and latex rubber as partial asphalt substitutes, with 3% PET plastic waste, 3% latex rubber, and 6% latex rubber added to the total weight of the asphalt mixture, obtained residual Marshall stability values of 81.2%, 94.5%, and 90.7%, respectively. The Marshall Immersion value in asphalt mixtures with 3% and 6% latex rubber met the Marshall Immersion specification of 90%. However, in asphalt mixtures with the addition of 3% PET plastic waste, the Marshall Immersion value was below 90%. It did not meet the specification, indicating that the asphalt lost durability and was not resistant to water and weather.

Acknowledgement

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