Evaluating Marshall Characterization of rubber-modified asphalt used for asphalt concrete - wearing course (AC-WC)

Mahmuda Mahmuda[1], Didi Yuda Wiranata[2*], Sumiati Sumiati[3], Dwie Antini Agustina[4], Athala Rania Insyra[5]

[1-5] Civil Engineering Departement State Polytechnic of Sriwijaya, Jl. Srijaya Negara Bukit Besar Palembang 30139, Indonesia
didi.yuda@polsri.ac.id

Abstract. The increasing number of vehicles in an area is the cause of road damage. The load from these vehicles can cause deformation in the road layer, especially in the asphalt concrete-wearing course (AC-WC) layer. Improving the quality of road layers requires materials that meet specifications and additives that can support pavement stability at an economical cost. Natural additives that can be used are natural elastomers or rubber gum. The resulting sap is called latex (natural rubber) and then processed into various kinds of rubber products, one of which is vulatex, namely natural rubber latex with 0.2% - 0.6% ammonia and 2% - 3% surfactant. From the results of tests conducted with Marshall parameters, the optimum asphalt content (KAO) is obtained on asphalt with 12% rubber latex additives (vulatex) with 5.2% asphalt content. From the test results, the VMA value of 15.1%, VIM of 4.75%, VFA of 69.23%, Stability of 2461.3 kg, and flow of 3.68 mm meet the specifications.

Keywords: Asphalt Concrete – Wearing Course (AC-WC), Vulatex, Marshall.

1 Introduction

1.1 Background

Road damage is increasing every year, even more and more every day; this occurs due to several factors, such as increasing traffic density, axle loads, and low levels of service maintenance. An effort to reduce road damage is to increase the durability of the flexible pavement itself. The bituminous materials currently used need to be increased in their resistance to cracking and rutting (permanent deformation). Modification of this bituminous material has occurred in recent years, intending to improve the performance of flexible pavement (Mashaan et al., 2012).

There are many modification processes have been used today in modified asphalt, such as crumb rubber modifier (CRM), styrene-butadiene rubber (SBR), ethylene vinyl acetate (EVA), styrene butadiene styrene (SBS), rubber-modified asphalt (Mashaan et al., 2012; Sumiati et al., 2019). Among these asphalt modification products, rubber-

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modified asphalt is one of the potentials that can be developed further with a multiplier effect on the economic welfare of rubber farmers, especially in Indonesia.

According to the research by Prastanto et al., 2015, the addition of natural rubber in asphalt can improve several criteria for asphalt binder performance, such as increasing elasticity, adhesiveness, and softening point. Prastanto also mentioned that rubber-modified asphalt is more powerful compared to conventional asphalt binder due to more stable in terms of cracking resistance (Prastanto et al., 2015).

Research by Siswanto, 2016, reported that asphalt containing natural rubber has a higher dynamic stability value and increased resistance to permanent deformation, so it could support the long-term performance of pavement (Siswanto, 2017).

1.2 Research Objective

This research aims to evaluate marshall characterization of rubber-modified asphalt used for asphalt concrete-wearing course (ac-wc). Four different variations of rubber will be added into the asphalt binder (pen 60/70) by weight of asphalt and one control with 0% rubber. The examination of materials will start from the raw material level (aggregate and binder), and the next level to asphalt mixture performance will be analyzed using marshall parameters and criteria.

2 Methodology

Figure 1 displays the framework of the research. The laboratory testing was carried out at the Materials Testing Laboratory of the Civil Engineering Department of the State Polytechnic of Sriwijaya. The research began with raw materials testing, such as the physical properties of coarse aggregate and fine aggregate, the physical properties of asphalt binder, the physical properties of filler (cement), and the level of asphalt mixture (Marshall testing). All of the tests followed the Indonesia National Standard (SNI).

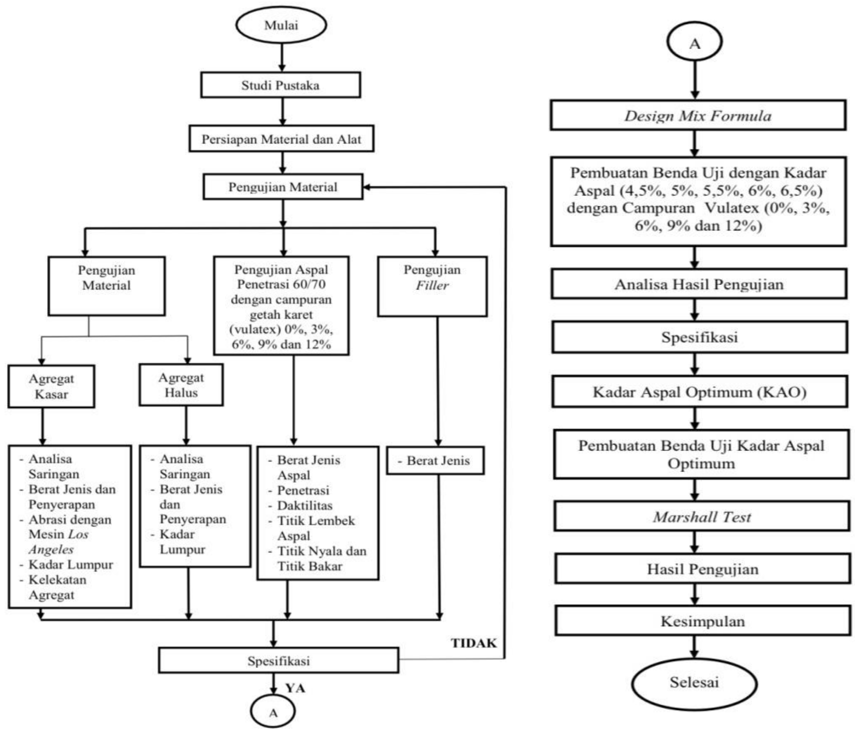

Figure 1. The framework of the research.

2.1 Aggregate Testing

The aggregates used in this research are coarse aggregate and fine aggregate were obtained from PT Bintang Selatan Agung, which comes from Bojonegoro, Indonesia. The mixed aggregate gradation uses continuous aggregate gradation according to the AC - WC mixture specifications as shown on figure 2. The sieve analysis test uses a 19 mm sieve, 12.5mm; 9.5mm; 4.75mm; 2.36mm; 1.18mm; 0.6mm; 0.3mm; 0.15mm; 0.075mm. Then, the aggregate was separated into coarse aggregate (crushed stone 1-1 and 1-2), fine aggregate (sand), and filler (cement). Sieve analysis testing, as well as specific gravity and aggregate absorption, was tested following SNI 1969:2019 standards, abrasion analysis on coarse aggregates using SNI 2417:2008 standards. Meanwhile, for fine aggregates, sieve analysis, specific gravity and absorption, and cleanliness of fine aggregates are carried out using sand equivalent values. The aggregate characteristics used are following the General Specifications for Asphalt Mixtures from Bina Marga 2018.

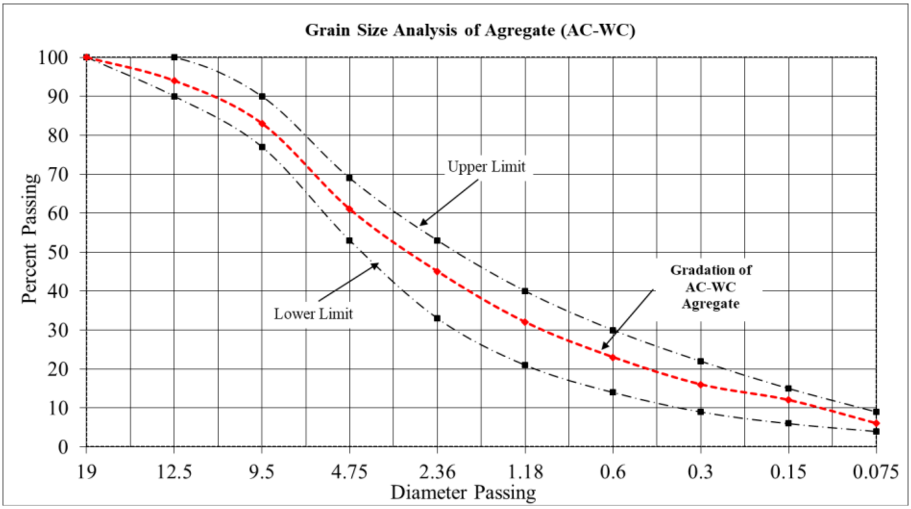

Figure 2. Aggregate gradation curve for AC-WC specifications.

2.2 Aspalt Binder Testing

The asphalt material used is 60/70 penetration asphalt with a fifth variation percent of asphalt content (4,5,5%, 5%, 5,5%, 6%, and 6,5%). Furthermore, rubber latex (vulatex) from PT. Riset Perkebunan Nusantara was added with variations of 0%, 3%, 6%, 9% and till 12%. This scenario was built up to see or explore the optimum asphalt content and a maximum of rubber latex can be added into the 60/70 penetration asphalt commonly used for AC-WC mixtures. The binder level testing carried out in the laboratory includes penetration tests, softening point, ductility, and asphalt-specific gravity in accordance with SNI 2011.

2.3 Asphalt Mixture Testing

The asphalt mixtures were prepared using manual cooking and marshall equipment while maintaining a constant mixing temperature of 165°C and a compaction temperature of 135°C. The compaction followed the marshall standard, where 75 blows were applied.

Marshall testing was carried out to examine the performance of asphalt mixtures. The Marshall testing refers to the ASTM D6927-15 standard or SNI 03-2489-1991. The performance of asphalt mixtures using the Marshall method produced several parameters such as Stability, Flow, Void filled with Asphalt (VFA), Void in the Mix (VIM), Void in Mineral Aggregate (VMA), and will be concluded by Marshall Quotient (MQ).

3 Results and Discussion

3.1 Aggregate Results

Table 1 displays the results of the aggregate testing; the test was divided into two types of aggregate characterization (coarse and fine aggregate). As displayed in Table 1, all the aggregate test results meet the specifications. For specific gravity aggregate (coarse and fine), which has three conditions (bulk, SSD, and apparent), all meet the criteria. The specific gravity is the ratio between the weight of a unit volume of something material to the weight of water to the same volume at a certain temperature. Coarse aggregate with a smaller specific gravity has larger pores, so more asphalt will be needed and vice versa. Furthermore, aggregate absorption is the ability of an aggregate material to absorb water, voids, or pores in aggregate. The aggregate having a large pore content has a large absorption value, so it will require more asphalt. The test results are only 0.58% for coarse aggregate and 0.87% for fine aggregate, which is far from the maximum limit allowed, 3%; this means the aggregate is ideally used for asphalt mixtures. In addition, the adhesiveness of aggregate to asphalt is a percentage of a surface area aggregate covered by asphalt on the aggregate surface. With the test result, aggregate adhesion to asphalt shows a value of 99%, which means all of the surface of aggregate is almost covered by asphalt, and this is good for improving ties between aggregate. Another result that is very important is Los Angeles Abrasion. The testing aims to determine the aggregate's resistance to destruction (degradation) using a Los Angeles machine. Degradation aggregates were obtained from the ratio between the weight of the loss or degradation aggregate No. 12 and the initial or original aggregate weight. The test results show a value of 4.84%, which indicated strong enough to the maximum limit specifications of 6%.

Table 1. Aggregate Characterization.

Testing	Results	Specifications	Status
1. Coarse Aggregate			
Bulk Specific gravity	2,64	2,5 – 2,7	Accepted
SSD Specific gravity	2,66	2,5 – 2,7	Accepted
Apparent Specific gravity	2,69	2,5 – 2,7	Accepted
Absorption (%)	0,58	Maks 3%	Accepted
Los Angeles Abration (%)	4,84	Maks 6%	Accepted
Adhesiveness (%)	99	Min 95%	Accepted
2. Fine Aggregate			
Bulk Density	2,54	2,5 – 2,7	Accepted
Specific gravity SSD	2,56	2,5 – 2,7	Accepted
Specific gravity Apparent	2,59	2,5 – 2,7	Accepted

Absorption (%)	0,87	Maks 3%	Accepted

3.2 Asphalt Binder Results

Table 2 displays the test results of asphalt binder with added rubber latex (vulatex) from 0% up to 12%. At the softening point results, the control scenario with 0% rubber latex showed that the results of the pen 60/70 asphalt material used as a control material did not meet the standard specifications issued by Bina Marga, where the results were at 46.9˚C, and the specifications should be ≥48. However, it is still 1.1˚C close to the minimum requirement, so the results still can be accepted, especially at this point, as no rubber latex was added to the control 0%.

Furthermore, when the percentage of rubber latex (vulatex) was added to 3%, almost all of the asphalt material testing parameters met specification standards; only the asphalt penetration and ductility testing did not meet Bina Marga's requirements. The results of the 3% vulatex test obtained a penetration value of 36.87 mm below the control material used before adding rubber latex, where it should be around 60 – 70 mm. The results indicate an increasing viscosity of the asphalt material, where the results tend to decrease and have a relatively low level of ductility. However, these results are pretty relevant if the modified material with the addition of 3% rubber latex is used at high-temperature conditions because this modified material is quite robust against extreme temperature changes (Sumiati et al., 2019; Ye et al., 2021).

When adding vulatex at a dose of 6%, all standard test parameters from Bina Marga were met. Meanwhile, at an additional dose of 9 -12%, several parameters do not meet the requirements, such as penetration, softening point, and burning point of asphalt tend to decrease at a vulatex dose of 12%. These results indicate that adding a dose of vulatex to asphalt pen 60/70 without changing the basic properties of the asphalt criteria produces an optimum value for adding vulatex of 6%. The results that do not comply do not mean that it cannot be used, but it can be used with adjusted where placing later.

Table 2. Asphalt binder characterization for all scenarios.

Testing	Scenario of Rubber Latex (%)					Specifications
	0%	3%	6%	9%	12%	
Specific gravity (gr)	1,022	1,040	1,035	1,037	1,037	≥1
Penetration (mm)	66,83	36,87	62,78	37,34	39	60-70
Softening point (˚C)	46,9	57,5	48,65	52,5	73,5	≥48
Flash Point (˚C)	263,3	251	258,1	328	234,1	≥232
Burning Point (˚C)	333,4	290	292,1	340	247,6	>288
Ductility (cm)	100	97	118	30,5	9,5	≥100

3.3 Asphalt Mixture Performance Results

Table 3 displays a summary of asphalt mixture performance from the Marshall test. Each parameter was evaluated using three specimens with variations in asphalt content of 4.5%, 5%, 5.5%, 6%, and 6.5% and added rubber latex (vulatex) 0%, 3%, 6% , 9%, and 12%. Then, the Marshall characteristics can be obtained to determine Optimum Asphalt Content.

Table 3 shows the stability value of all mixtures above the specifications. Stability shows the ability of the pavement to resist deformation due to traffic loads. The deformation that occurs can be in the form of waves or grooves. Stability in the Marshall test is the maximum ability of an asphalt mixture test specimen to accept a load until failure occurs. On the other hand, the flow test shows some of the mixtures exceed the requirement 2,0 - 4,0. This result is interesting to discuss, where flow is the amount of change in the plastic shape of a mixed specimen that occurs due to a load to the maximum limit, expressed in length units. A high value of flow indicates that the mixture is plastic and easily changes shape due to traffic loads.

Furthermore, the result of Quotient Marshall, which is a quotient from Stability and Flow, shows that all are above the requirement of ≥ 250. Quotient Marshall is used as an approximation of the level of stiffness of a mixture. High Stability accompanied by low flow will produce hardening, which is stiff so that the resulting mixture will be brittle; on the contrary, low Stability with high flow will produce a mixture of plastic, which results in the pavement experiencing large deformations if it receives traffic loads. Based on the results of Quotient Marshall can be seen in Table 3.

Table 3. Asphalt mixtures performance from Marshall test.

Variasi Vulatex (%)	Asphalt content	Marshall Parameter						
		VMA	VIM	VFA	Gmb	Stability	Flow	MQ
	%	%	%	%	t/m3	kg	mm	kg/mm
Specifi-cations		≥ 15	3.0-5.0	≥ 65		≥ 800	2.0-4.0	≥ 250
0% Vulatex	4.5	18.1	7.4	59.2	2.2	2595.9	3.8	691.6
	5.0	14.8	3.7	74.8	2.3	2795.0	4.3	651.9
	5.5	14.6	3.5	75.9	2.3	2564.1	4.6	556.0
	6.0	13.6	2.4	82.3	2.4	1750.2	6.6	264.1
	6.5	14.9	3.9	73.9	2.3	1639.5	7.1	229.3
3% Vulatex	4.5	18.3	7.7	58.1	2.2	2807.0	4.6	613.9
	5.0	19.2	8.7	54.7	2.2	2667.8	4.6	584.3
	5.5	17.7	7.0	60.3	2.3	2715.3	5.0	548.2
	6.0	17.1	6.4	63.0	2.3	2126.3	7.2	293.3

	6.5	16.7	5.9	64.6	2.3	1859.9	6.6	281.0
6% Vulatex	4.5	19.4	9.0	53.9	2.2	3322.9	3.1	1083.7
	5.0	17.9	7.2	59.6	2.3	3259.3	4.3	751.3
	5.5	17.9	7.2	59.6	2.3	3410.0	4.9	699.1
	6.0	16.8	6.0	64.1	2.3	2498.2	5.8	433.3
	6.5	16.5	5.7	65.6	2.3	1939.3	6.6	292.0
9% Vulatex	4.5	19.0	8.5	55.3	2.2	2332.8	3.8	612.6
	5.0	18.1	7.4	58.8	2.2	2737.8	4.5	602.1
	5.5	17.4	6.7	61.8	2.3	2098.9	5.3	398.9
	6.0	17.0	6.2	63.5	2.3	2102.5	5.4	390.0
	6.5	18.4	7.8	57.8	2.2	1884.3	6.3	299.2
12% Vulatex	4.5	18.3	7.7	58.6	2.2	2244.1	3.5	640.6
	5.0	15.9	5.0	68.8	2.3	2426.0	3.1	787.6
	5.5	15.1	4.1	73.0	2.3	2681.4	3.8	704.6
	6.0	13.6	2.4	82.2	2.4	1882.5	6.4	294.8
	6.5	14.6	3.5	76.0	2.3	1908.2	7.0	273.8

3.4 Determination of Optimum Asphalt Content

From the Marshall test results above, the percentage of rubber latex (vulatex) that meets the standards is found in the addition of rubber latex (vulatex) 12%, and all Marshall characteristic test results meet the specifications determined by Bina Marga standards. The following are the Marshall characteristic values for optimum asphalt content in asphalt with added rubber latex (vulatex) as shown in Figure 3.

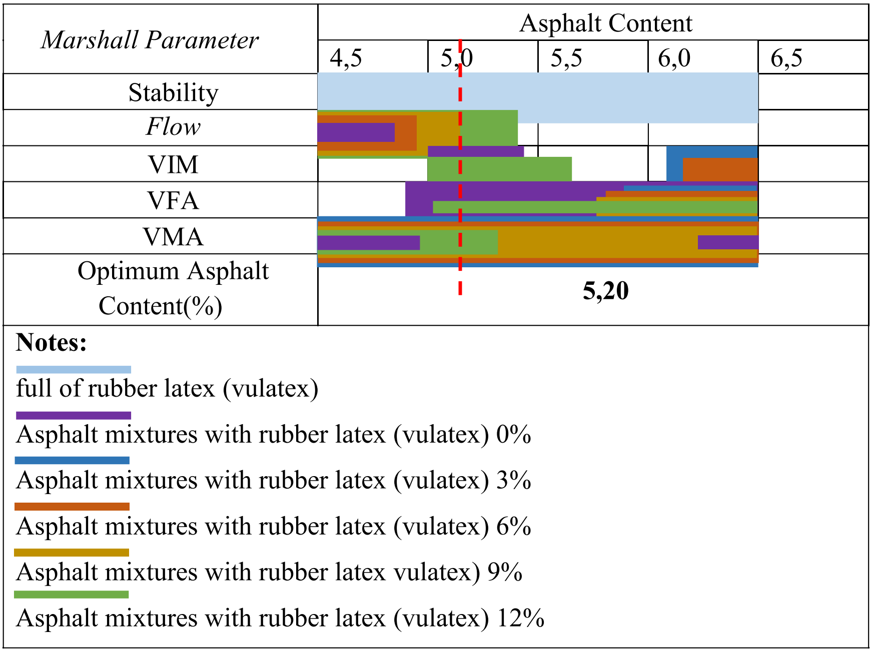

Figure 3. Summary of optimum asphalt content determination.

4 Conclusions

1. This research uses asphalt with added rubber latex (vulatex), which is used in the Marshall test, to find the optimum asphalt content value starting from 0%, 3%, 6%, 9%, and 12%. From this test, the optimum asphalt content value for asphalt with added rubber latex (vulatex) was 12%, with a variation in asphalt content of 5.2%.
2. Based on the research results, test results were obtained with Marshall parameters followed by Bina Marga specifications seen from calculation results such as VMA, VIM, VFA, Stability, and Flow, including:
   - The VMA value of asphalt with added rubber latex (vulatex) on average meets specifications, except for asphalt with added rubber latex (vulatex) 0% and 12% with an asphalt content of 5% – 6%.
   - The VIM value of asphalt with added rubber latex (vulatex) at certain asphalt levels; some meet specifications, and others do not. Asphalt with 0% added rubber latex (vulatex) meets the asphalt content, namely 5% - 5.5%, asphalt with added rubber latex (vulatex) 3% and 6% meets the asphalt content, namely 6.5%, asphalt with 9% added rubber latex (vulatex) nothing meets the specifications and asphalt with added rubber latex (vulatex) 12% the asphalt content meets the requirements, namely 5.5% and the optimum asphalt content (KAO) meets the specifications.

- The VFA value of asphalt with 0% added rubber latex (vulatex) meets specifications at an asphalt content of 5% - 6.5%, asphalt with added rubber latex (vulatex) 3%, 6% and 9% meets specifications at an asphalt content of 6 % - 6.5% and asphalt with added rubber latex (vulatex) 12% at an asphalt content of 5.5% - 6.5%.
- The stability value of asphalt with added rubber latex (vulatex) 0%, 3%, 6%, 9%, and 12% meets the specifications, namely a minimum of 800 kg.
- The flow value of asphalt with added rubber latex (vulatex) on average does not meet specifications except for asphalt with added rubber latex (vulatex) 0%, 6%, and 9% at an asphalt content of 4.5%, asphalt with added rubber rubber (vulatex) 12% at asphalt content 4.5% - 5.5%.

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