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Effect of Latex Rubber as Asphalt Additive to the Characteristics of AC-WC Mixture

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ABSTRACT

Quality improvement can be achieved by making innovations in the development of rubber asphalt material. This research was conducted to determine the effect of adding natural rubber as an additive to the wear-resistant Laston mixture (AC-WC). This study made 33 total samples, which were divided into 18 conventional asphalt mixtures and 15 rubber asphalt mixtures, with normal asphalt variations ranging from 5.5% - 8% and for rubber with variations of 5% - 7% of optimum asphalt weight, respectively each with an interval (0.5 %). It was mixed using a wet process. Based on the 2018 General Highways Specifications, Optimum Asphalt Content (OAC) was obtained at 7.5% and Optimum Rubber Content (ORC) at 6%. The test results for the stability and melting values of normal asphalt were 1786.22 kg and 3.56 mm, while the tests for the stability and melting values for rubber asphalt were 1181.22 kg and 3.6 mm. It can be interpreted that adding this rubber content increases the stability of the value 2x greater than the point where the stability value falls on the normal asphalt content variation of 8%.

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1. INTRODUCTION

Roads are crucial infrastructure for humanity, providing a means for people to move from one place to another and transport goods or services by walking or using vehicles. Roads also connect communities in one region to those in another. The increasing population in Indonesia has led to high mobility among people, necessitating the movement of individuals for their daily needs, such as clothing, food, and shelter [1], [2]. Currently, the demand for road usage is continuously rising, requiring improvement in both the quantity and quality of roads to meet societal needs [3], [4]. According to the Central Statistics Agency (BPS), the growth of vehicles has been consistent each year. In 2021, there were 141,996,832 million vehicles; in 2022, the number increased to 148,212,865 million vehicles. There is a significant annual increase, averaging around 5%, equivalent to approximately 7 million vehicles from the previous year. The road network also expands annually, as the Central Statistics Agency reported in 2022, showing an increase in road length from 545,155 km to 549,161 km between 2020 and 2023.

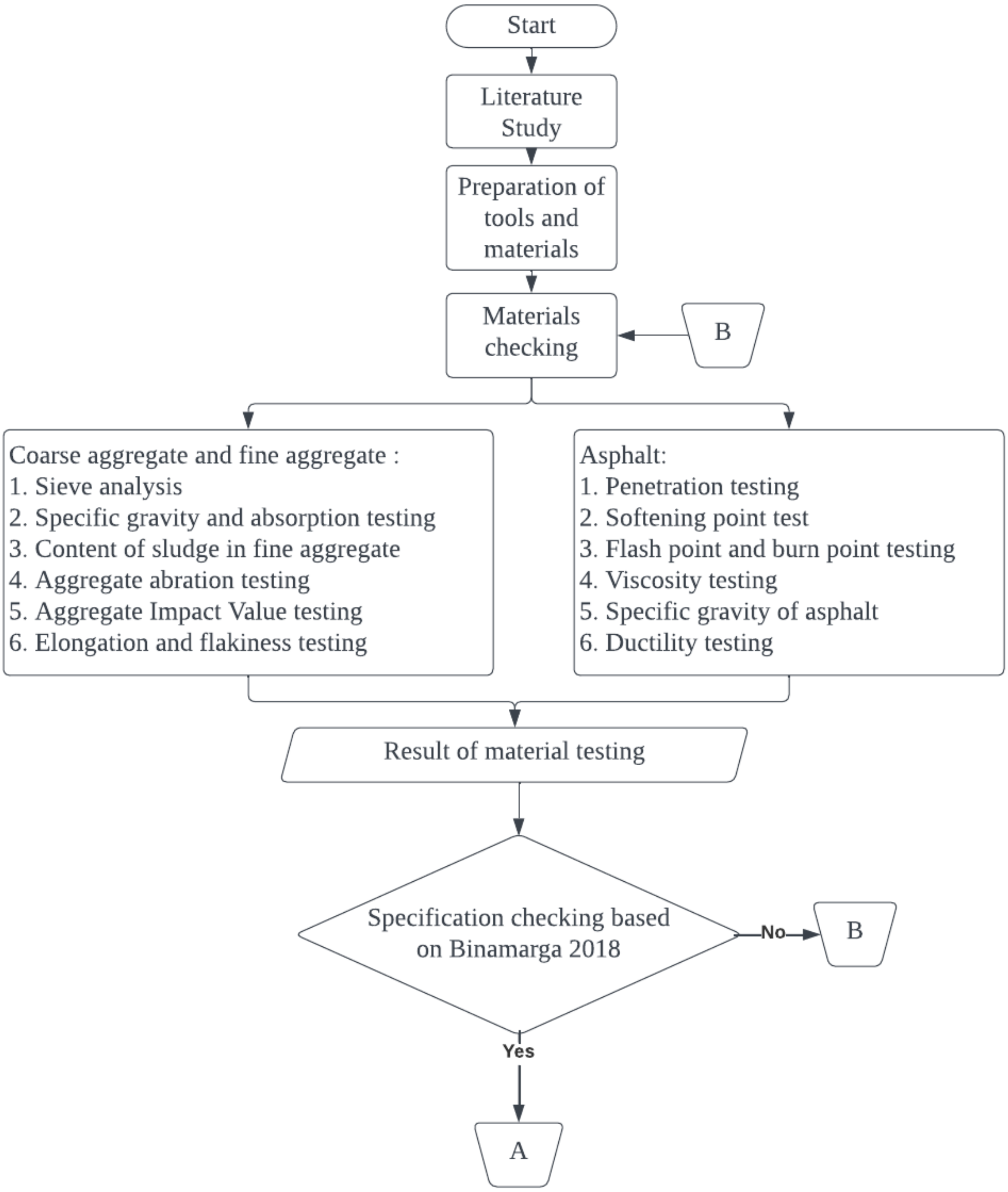
Roads are composed of a mixture of aggregates and binding materials. Aggregates are the primary component in road pavement materials, constituting 90-95% of the pavement structure [5], [6]. Therefore, aggregates play a crucial role in the quality of road pavement. Asphalt Concrete (Laston) is a commonly used mixture used in Indonesia as a flexible pavement. Laston consists of asphalt and aggregates with continuous gradation. Various types of Laston include AC-WC (Asphalt Concrete - Wearing Course), AC-BC (Asphalt Concrete - Binder Course), and AC-Base (Asphalt Concrete - Base) [7], [8].

On the other hand, Indonesia has a significant potential for rubber resources due to its geographical location, making it a country abundant in natural resources. This resource can be used as a road pavement material [9]. Thus, there is a need for innovative solutions that utilize natural rubber as a base material for creating innovative products, especially in road pavement. Using natural rubber as an additive in road pavement materials is expected to enhance the quality of asphalt mixtures.

Researchers in various countries, including Indonesia, have explored the utilization of natural rubber as an additional material for road pavement. Studies conducted by Andi Afriaziz (2019), Risdian (2021), Tondi Mario Sitorus (2020), Muhammad Farid (2021), and Rahmawati (2019) have proven to enhance several parameters in Laston mixtures [9]. Based on existing research, the optimum rubber content falls within the range of 6-8%, depending on the type of rubber, optimal asphalt content, and the type of mixture used [9]–[11]. In this research, a proportion of natural rubber will be used in the range of 5 – 7% (with an interval of 0.5%) of the Optimum Asphalt Content (OAC) weight. The use of an interval of 0.5% is based on increasing the precision of previous research on Laston AC - WC mixtures.

2. RESEARCH METHOD

In the implementation of the research on asphalt material innovation with natural rubber additive in the Asphalt Concrete Wearing Course (AC-WC) mixture, a flowchart based on the working process to be carried out is required.



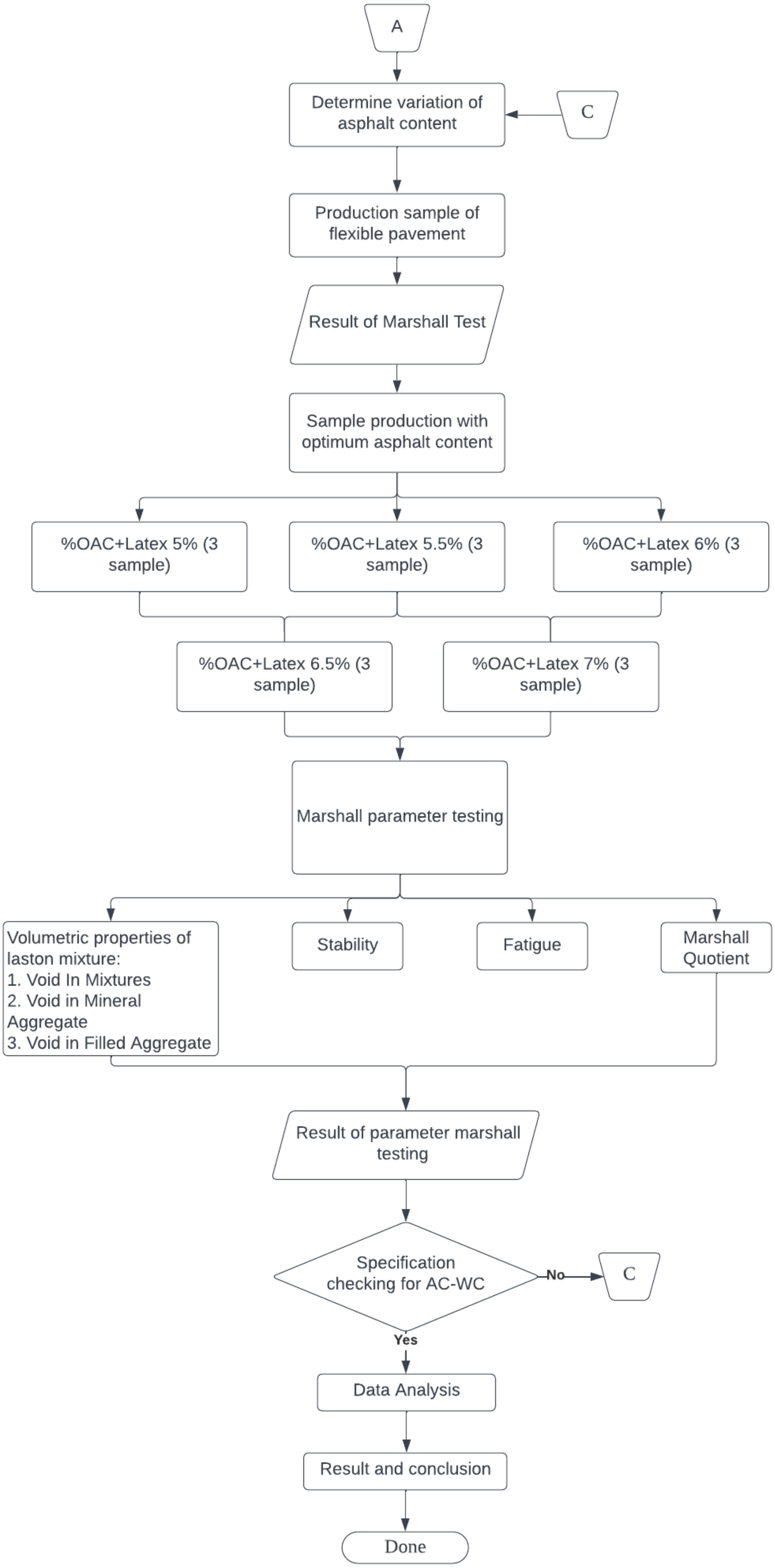


Figure 2. Research Flow Chart

2.1. Research Design

The research was conducted at the Laboratory of Road Structure and Pavement, Pertamina University. This study commenced after a thorough literature review on adding natural rubber to the Asphalt Concrete Wearing Course (AC-WC) mixture using an experimental method. The research is classified as reliable due to its stringent and experimental implementation. Testing on the Laston mixture was based on Marshall Testing, yielding a graph depicting the relationship between asphalt/rubber content and Marshall parameters [12], [13]. Before the commencement of this study, variations in asphalt content were determined to establish the optimum asphalt content (OAC), which served as a reference for determining the optimum rubber content (ORC). The variations in asphalt content used in this study can be found in Table 1.

Table 1. Normal Asphalt Content Variations

No	Asphalt Content	Number of Specimens
1	5,5%	3 Pieces
2	6%	3 Pieces
3	6,5%	3 Pieces
4	7%	3 Pieces
5	7,5%	3 Pieces
6	8%	3 Pieces
	Number of Specimens	**18** Pieces

After obtaining the Optimum Asphalt Content (OAC) and analyzing it in the Marshall testing, variations in the additional natural rubber content to the Laston mixture were determined. The variations of natural rubber used in this study can be seen in Table 2.

Table 2. Rubber Asphalt Content Variations

No	Rubber Content	Number of Specimens
1	5%	3 Pieces
2	5,5%	3 Pieces
3	6%	3 Pieces
4	6,5%	3 Pieces
5	7%	3 Pieces
	Number of Specimens	**15** Pieces

The total number of specimens to be produced in this study is 18 + 15 = 33. The use of 3 (three) specimens for each asphalt content variation is based on a literature review of previous studies [14]. These 3 (three) samples are used to compare if anomalous data is obtained.

2.2. Testing Tools and Materials

Table 2. Testing Tools and Materials

No.	Testing Equipment	
	Aggregate	**Asphalt**
1.	Wire Basket	Penetrometer
2.	Scale	Cup
3.	Oven	A Set of Burners
4.	Cup	Thermometer
5.	Set Saringan	A Set of Flash Point Testing Equipment
6.	Cloth	A Set of Softening Point Testing Equipment
7.	Pycnometer	Marshall Press
8.	Tapered Cone	Asphalt Compactor
9.	Rammer	Asphalt Sample Ejector
10.	Immersion Tray	*Waterbath*
11.		Cylinder Test Mold Set
No.	**Testing Materials**	
1.	Coarse Aggregate	
2.	Fine Aggregate	
3.	Water	
4.	Asphalt Pen 60/70	
5.	Natural Rubber	

3. RESULTS AND DISCUSSION

Normal Mixture

Mixing testing was conducted after the basic testing of coarse and fine aggregates. This mixing aims to determine the composition of materials used to create test samples. The method involves trial and error by estimating the proportionate amount with indications such as "OK" or meeting the standards used.

Table 4. Estimated Aggregate Proportions

%A	=	15%	Crushed Stone 3/4"
%B	=	24%	Crushed Stone 1/2"
%C	=	22%	Sand
%D	=	39%	Stone Dust

Based on the results obtained, the estimated proportions of aggregates used meet the General Specifications for Highway Construction 2018 standards. The respective values are BP ¾ (Crushed Stone), BP ½ (Crushed Stone), Sand, and Stone Dust, at 15%, 24%, 22%, and 39%.

Table 5. Normal Asphalt Mixture Proportions

No.	Sample Weight	Asphalt Content	Asphalt Weight	Weight of BP 3/4"	Weight of BP 1/2"	Weight of Sand	Weight of Stone Dust
				24%	**15%**	**22%**	**39%**
1.	1200	5.50%	66	272.16	170.1	249.48	442.26
2.	1200	6.00%	72	270.72	169.2	248.16	439.92

No.	Sample Weight	Asphalt Content	Asphalt Weight	Weight of BP 3/4"	Weight of BP 1/2"	Weight of Sand	Weight of Stone Dust
				24%	15%	22%	39%
3.	1200	6.50%	78	269.28	168.3	246.84	437.58
4.	1200	7.00%	84	267.84	167.4	245.52	435.24
5.	1200	7.50%	90	266.4	166.5	244.2	432.9
6.	1200	8.00%	96	264.96	165.6	242.88	430.56

Marshall Testing aims to determine a test sample's stability, flow, Marshall Quotient, VIM, VFA, and VMA values. After obtaining all the mixture proportion values in the previous tests, test specimens will be produced to determine the optimum asphalt content. The specimens are measured for dry weight, SSD (Saturated Surface Dry) weight, and submerged weight to obtain the specific gravity of the compacted mixture. The test results include the OAC (Optimum Asphalt Content) for 5 (five) asphalt content variations and will be used as the asphalt-rubber mixture proportion values. The following is an example of Marshall data processing for a mixture with 6.5% asphalt content in normal asphalt.

Table 6. Summary of Marshall Testing Results

Testing	Bina Marga 2018 Standard	Asphalt Content					
		5,5%	6%	6,5%	7%	7.5%	8%
Stability	> 800 Kg	654.13	662.34	1031.74	1165.73	1786.22	502
Flow	(2-4) mm	2.35	2.75	3.43	3.76	3.56	4.3
VIM	(3-5) %	13.70	13.55	13.48	13.05	9.17	7.59
VMA	> 15%	23.29	23.94	24.83	26.60	23.24	22.89
VFA	> 65%	99.41	99.44	99.46	99.46	99.60	99.66
MQ	> 250 kg/mm	275.34	269.87	316.56	285.88	530.39	116.74

Based on the processed data for 6 (six) asphalt content variations, with three samples for each variation. The OAC is found to be at 7.5%, as it yielded the highest stability value. However, the stability value decreases when additional asphalt content is introduced (8%).

Rubber Asphalt Mixture

The variations of Rubber Asphalt used are 5%, 5.5%, 6%, 6.5%, and 7%. The weight of rubber used is based on the previously obtained optimum asphalt content. The following is the calculation of the weight of rubber asphalt used in the mixture at a 6.5% asphalt content.

Table 7. Rubber Asphalt Mixture Proportions

Karet Aditif										
No.	Rubber Additive	Sample Weight Optimum	Rubber Content	Asphalt Weight	Rubber Weight	Weight of Rubber Asphalt	Weight of BP3/4"	Weight of BP 1/2"	Weight of Sand	Weight of Stone Dust
							24%	**15%**	**22%**	**39%**
1	1200	7.5%	5.0%	90	4.5	94.5	265.32	165.825	243.21	431.145
2	1200	7.5%	5.5%	90	4.95	94.95	265.212	165.7575	243.111	430.9695

Karet Aditif										
No.	Rubber Additive	Sample Weight Optimum	Rubber Content	Asphalt Weight	Rubber Weight	Weight of Rubber Asphalt	Weight of BP3/4"	Weight of BP 1/2"	Weight of Sand	Weight of Stone Dust
							24%	**15%**	**22%**	**39%**
3	1200	7.5%	6.0%	90	5.4	95.4	265.104	165.69	243.012	430.794
4	1200	7.5%	6.5%	90	5.85	95.85	264.996	165.6225	242.913	430.6185
5	1200	7.5%	7.0%	90	6.3	96.3	264.888	165.555	242.814	430.443

After obtaining the asphalt mixture proportions, samples are produced for all planned asphalt content variations. Subsequently, Marshall testing is conducted to obtain stability, flow, VIM, VMA, VFA, and MQ values.

Table 8. Summary of Marshall Testing Results

Testing	**Bina Marga 2018 Standard**	**Rubber Asphalt Content**				
		5	5,5	6	6.5	7
Stability	>1000 kg	843.12	850.49	1181.22	1004.095808	926.7834
Flow	(2-4) mm	3.7	3.95	3.6	3.9	3.766667
VIM	(3-5) %	8.65%	7.39%	4.97%	8.25%	7.69%
VMA	>15%	17.76	17.45	16.59	20.48636038	21.00663
VFA	>65%	99.51	99.59	99.70	99.59876657	99.63739
MQ	>250 kg/mm	230.73	216.19	326.66	269.0604423	247.3182

Based on the processed data for 5 (five) asphalt content variations, with three samples for each variation. The ORC is found to be at 6%, as it yielded the highest stability value. However, when additional rubber asphalt content is introduced (6.5% and 7%), the stability value decreases.

Volumetric Properties of Laston

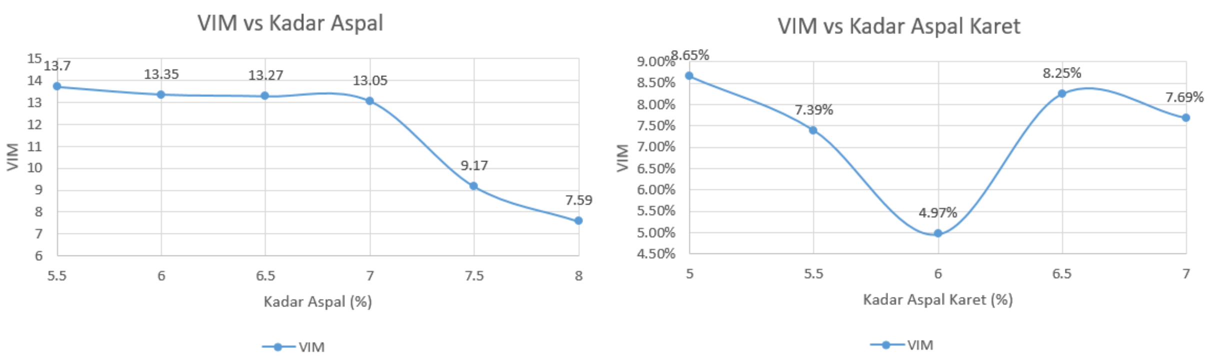


Figure 2. Graph of VIM (Voids in Mineral Aggregate) for Normal Asphalt and Rubber Asphalt

Based on the obtained results, the VIM graph shows a decrease in values with the addition of asphalt content. A high VIM value can potentially lead to increased asphalt aging due to the presence of numerous pores within the mixture, leading to oxidation as there are air voids and a larger surface area of asphalt exposed to air. The decrease in VIM value is because the increasing asphalt content results in the filling of voids within the asphalt mixture. However, the continuous addition of asphalt content can lead to a decrease in stability values and pose the risk of bleeding or rutting.

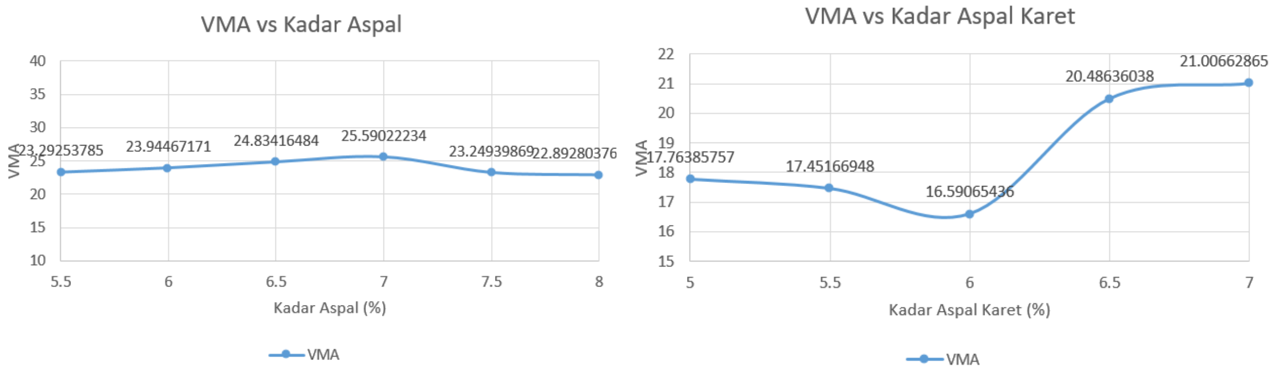


Figure 3. Graph of VMA (Voids in Mineral Aggregate) for Normal Asphalt and Rubber Asphalt

Based on the obtained results, the VMA graph shows fluctuating values with each addition of asphalt and rubber asphalt content, and the values obtained meet the 2018 Bina Marga standards. A low VMA value can potentially result in a decrease in the durability of the mixture, so the VMA value must exceed the 2018 Bina Marga standard of 15%. In the pavement mixture, there should be voids in the aggregate that can be coated with asphalt (asphalt film). The increase in VMA value occurs due to inadequate aggregate gradation during material preparation and suboptimal compaction processes, leading to an increase in VMA value.

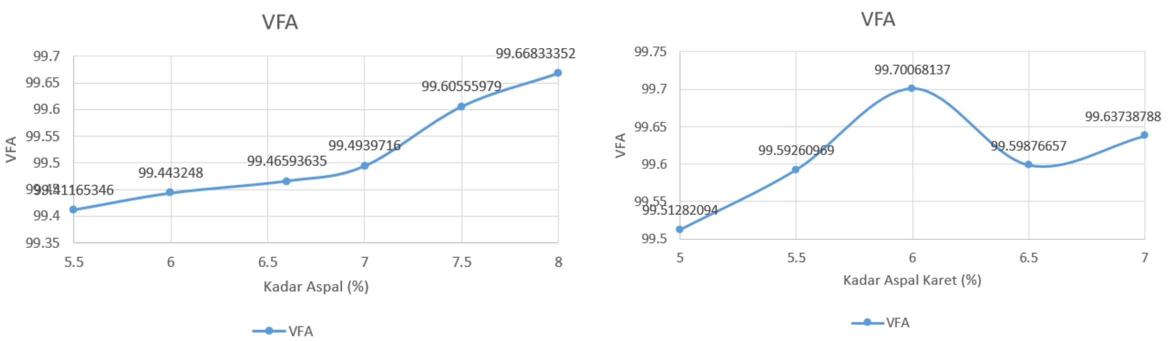
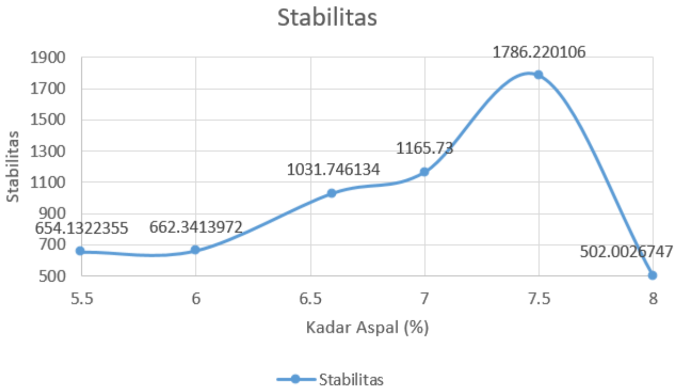


Figure 4. Graph of VFA (Voids Filled with Asphalt) for Normal Asphalt and Rubber Asphalt

The VFA value will increase with the addition of asphalt content. This increase occurs because the asphalt content will fill the voids in the mixture, reducing the percentage of empty voids and making the mixture denser. According to the 2018 Bina Marga standards, the minimum VFA value is 65%. In this test, the VFA values have met the 2018 Bina Marga standards. A high VFA value indicates a thick asphalt film, making the mixture less prone to oxidation.



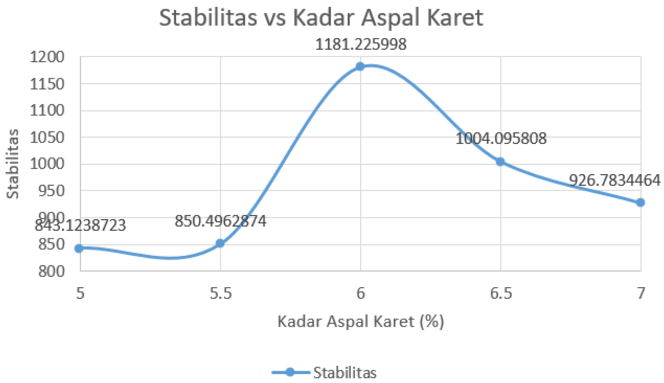
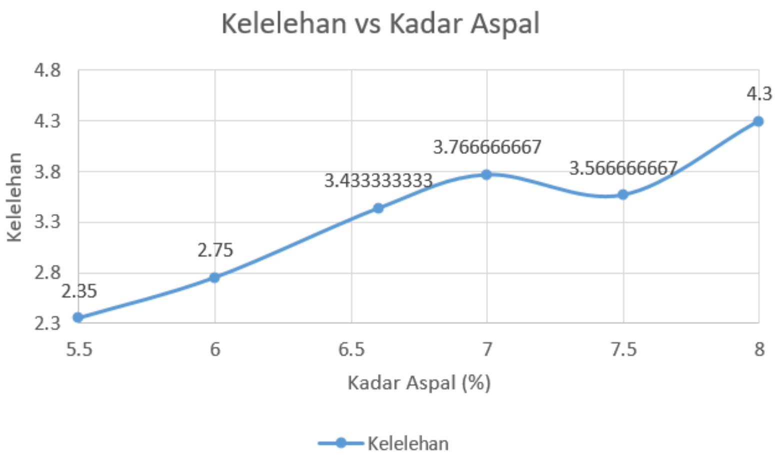


Figure 5. Graph of Stability for Normal Asphalt and Rubber Asphalt

Based on the conducted tests, the stability values on the graph show an increase with the addition of asphalt content up to its maximum limit. For normal asphalt mixtures, the maximum point is reached at 7.5%, while for rubber asphalt, it is at 6%. According to the 2018 Bina Marga standards, the minimum stability value for conventional asphalt is 800kg, and for modified (rubber) asphalt, it is 1000kg. Most of the asphalt content variations do not meet the minimum limits set by the 2018 Bina Marga standards, except for 6% and 6.5% asphalt content, where the values meet the standards. The addition of asphalt content acts as a binder between aggregates in the mixture. However, the continuous addition of asphalt changes its function to a lubricant, causing the mixture's binding capacity to decrease.



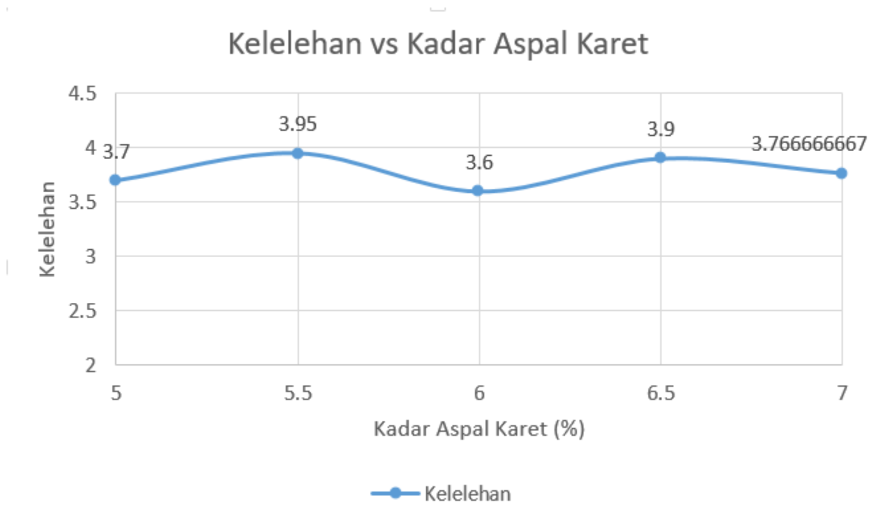


Figure 6. Graph of Flow for Normal Asphalt and Rubber Asphalt

Based on the conducted tests, the graph shows an increase and decrease in flow values with the addition of rubber asphalt content. The flow values should decrease with each addition of rubber asphalt content until reaching a maximum limit, then increase again. The fluctuation in values occurs due to less-than-optimal mixing and testing processes when monitoring the sample temperature.

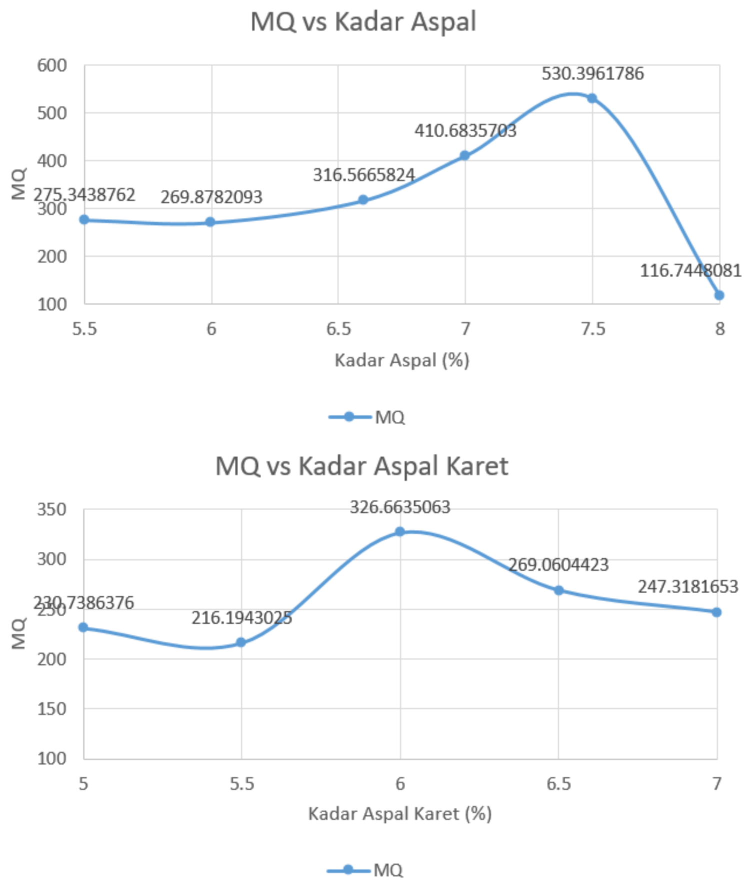


Figure 7. Graph of MQ (Marshall Quotient) for Normal Asphalt and Rubber Asphalt

Based on the conducted tests, the increase in asphalt content will cause the MQ to rise until it reaches its maximum limit and then decrease. This is because, with the addition of asphalt content, the mixture becomes stiffer, making it stronger to withstand traffic loads. The MQ value depends on stability and flow values. Variations from 6% to 6.5% meet the standards. The required Marshall Quotient by Bina Marga for the AC-WC layer is > 250 kg/mm.

4. CONCLUSION

In this study, the Optimum Asphalt Content (OAC) was found to have a 7.5% variation in asphalt content due to having the highest stability value compared to other asphalt content variations. However, there was a decrease in the stability value at the next asphalt content level, which is 8%. This value complies with the 2018 Bina Marga standards for the AUS (AC-WC) pavement layer. For the rubber asphalt mixture, the Optimum Rubber Content (ORC) was found to have a 6.5% variation in rubber content, following a similar approach to finding the OAC. The characteristic values of Marshall testing include void in mixture (VIM), void in mineral aggregate (VMA), void filled with asphalt (VFA), stability, flow, and Marshall quotient. Whether in normal or rubber-added mixtures, the hypothesis was that the VIM value would decrease with each addition of asphalt content to minimize the formation of voids in the mixture. The VMA value would decrease with each addition of asphalt content because the aggregate used decreases, reducing the voids between the aggregates. The VFA value would increase with each addition of asphalt content because the asphalt film thickens when asphalt content is added. Stability would increase with each addition of asphalt content up to its maximum limit because asphalt acts as a binder. The flow would decrease with each addition of asphalt content, and the Marshall Quotient (MQ) would increase with each addition of asphalt content. Among the mentioned Marshall characteristics, all VIM values for both normal and modified mixtures do not meet the 2018 Bina Marga standards. The stability value for the normal mixture is 1786.22 kg, while for the modified rubber mixture, it is 1004.095 kg. The flow value for the normal mixture is 3.56 mm, whereas for the modified rubber mixture, it is 3.76 mm.

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