ISSN No:-2456-2165

Utilization of Natural Rubber in Asphalt Mixtures to Improve the Characteristics of Asphalt

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Abstract:- The increased traffic load encourages premature damage to the pavement. The damage is in the form of potholes, cracks, waves, and deformation of the road pavement. The elastomer content in natural rubber can be used as an asphalt modification material. Indonesia is one of the largest rubber producers in the world. From the results of research that has been done, natural rubber can increase the characteristic value of asphalt concrete mixtures. Stability, flow, VIM, VMA, and VFA values have increased. But the value of the Marshall Quotient has decreased.

Keywords:- Flexible Pavement, Characteristics of Asphalt, Natural Rubber.

I. INTRODUCTION

The increasing traffic volume, vehicle load, and tropical climate conditions in Indonesia are why much road damage is found [1][2]. Based on several studies, the use of unsuitable asphalt is often the cause of premature damage to road pavements [3][4][5][6]. Holes, grooves, waves, and asphalt rising to the surface are some of the types of road damage that often occur in cities in Indonesia [7]. Various efforts have been made to improve the quality of asphalt, including adding an elastomeric modifier [8]. Asphalt modifier materials widely found today are elastomeric modifiers, but the price is still high and difficult to obtain in Indonesia. Several efforts continue to be made to find alternative modifiers that can improve asphalt quality at low prices and are widely available in Indonesia.

The largest natural rubber-producing regions that produce 70% of the world's rubber production are Indonesia, Thailand, and Malaysia [9]. Indonesia is a country that has natural resources that can be used as road pavement. Natural rubber as an additive is expected to improve the quality of the asphalt mixture [10][11]. Natural rubber is used primarily because of its soft texture and flexibility. Natural rubber is obtained from a natural rubber latex called *Hevea Brasiliensis*, which originates from the Amazon region by clumping and drying [12]. Natural rubber contains several ingredients: rubber hydrocarbons, proteins, neutral lipids, polar lipids, carbohydrates, inorganic salts, and others [13].

Rubber sap is a liquid sap (latex) obtained from tapping rubber trees. Good latex must meet the following conditions:

- No dirt or other objects, such as leaves or wood.
- Not mixed with latex slurry, water, or latex serum.
- White color and smells of fresh rubber
- Have a dry rubber content of 20% to 28%.

For the manufacture of rubber asphalt to be used effectively, the added material must meet the requirements. Materials added to asphalt must have the following properties:

- The good properties of the original asphalt must be maintained, including during storage, drying, and service life.
- Easy to process even with conventional equipment
- Physically and chemically remain good during storage, processing, and service period. Natural rubber is felt to increase the usability of asphalt, although the polymer dispersion in the asphalt mixture is usually less homogeneous.

Rubber is a natural polymer of isoprene units composed of carbon atoms (C) and hydrogen atoms (H) whose average molecular weight is spread between 10,000 - 400,000 [14]. This compound is contained in the sap of several types of rubber plants. The main source of the latex used to make rubber is the *Hevea Brasiliensis* (*Euphorbiaceae*) rubber tree.

Latex is obtained from the sap of the rubber plant by injuring the bark of the tree so that the tree will release latex. At low temperatures, rubber is crystalline. But if the temperature increases, the rubber will expand. Lowering the temperature will return the state of the rubber back to its original shape. This is the reason why rubber is elastic. Rubber is the main material for making tires, medical devices, and tools that require flexibility and shock resistance [15].

In each isoprene bond, there is a double bond of a methylene group, and this group is a reactive group that can cause an oxidation reaction that can damage the rubber. Rubber hydrocarbons and non-rubber substances are important ingredients in determining the technical properties of natural rubber. Hydrocarbons are easily oxidized by air, ultraviolet light, and heat so that the breaking of the molecular bond chains gets shorter. As a result of the shortening of the molecular bonds, the viscosity and resistance of rubber to plasticity reactions decrease [16]. Table 1 shows the composition of natural rubber.

ISSN No:-2456-2165

Table 1 Natural Rubber Composition

No	Component	Components in Fresh Latex	Components in Dry Latex
1	Hydrocarbon Rubber	36	92-94
2	Protein	1.4	2.5-3.5
3	Carbohydrate	1.6	-
4	Lipids	1.6	2.5-3.2
5	Other organic compounds	0.4	-
6	Mineral	0.5	0.1-0.5
7	Water inorganic compounds	58.5	0.3-1.0

Source: [17]

From table 1, natural rubber can be divided into 2, namely fresh latex and dry latex. The main components in fresh latex are water inorganic compounds and hydrocarbon rubber. The main components in dry latex are hydrocarbon rubber, protein, and lipids.

The natural rubber used in this study is a type of sap produced directly from the rubber tree, as shown in Figure 1.

Fig 1. Natural Rubber

II. METHODOLOGY

This research uses natural rubber from Bogor Regency, West Java. The materials used include aggregate, sand from Lumajang, East Java, and Pertamina asphalt with a penetration of 60/70. The standard used refers to Bina Marga standards.

A. Research Design

This study uses the wet method, namely by mixing natural rubber in a mixture of aggregate and heated asphalt. This study used variations in asphalt content of 5%, 6%, and 7% to determine the value of KAO and variations in natural rubber content of 0%, 1%, 3%, and 5% of the total weight of the test object to determine the composition of the optimum natural rubber value in KAO.

B. Research Variable

Marshall testing on the AC-BC (Asphalt Concrete-Base Concrete) mixture uses two variables, including the following:

- Independent variables, namely by mixing natural rubber as a mixture in AC–BC.
- The dependent variable, namely the results of the Marshall test, includes:
- Stability Value
- Flow Value
- Voids in Material (VIM) Value
- Voids in Mineral Aggregate (VMA) Value
- Marshall Quotient (MQ)

III. DISCUSSION

The results of the Marshall test of optimum asphalt content were obtained from the manufacture of test specimens with variations in asphalt content, namely 5%; 6%; and 7%. Each variation of asphalt content made 10 test objects. Table 2 shows the test results to determine the optimum asphalt content used in this experiment.

Table 2. Marshall Test Results Optimum Asphalt Content

Parameter Marshall	Unit	Bina Marga Standard	Asphalt Content Variations		
			5%	6%	7%
Stability	kg	Min.800	1705	1736	2053
Flow	mm	2 - 4	3.27	4.00	5
Marshall Quotient (MQ)	kg/mm		521	433	415
VIM	%	3 - 5	4.8	3	1
VMA	%	Min.15	16	16.6	17.4
VFA	%	Min.65	72	82	93

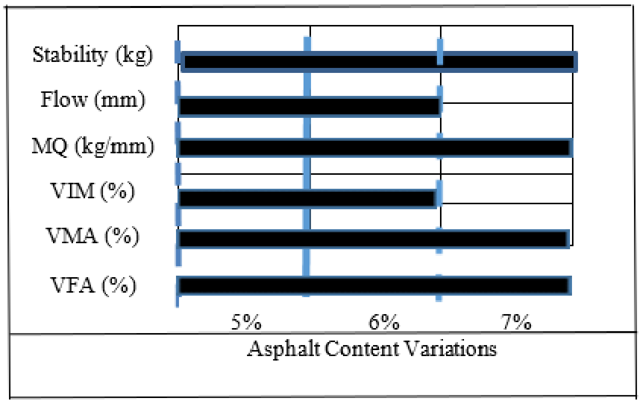

Fig 2. Graph to Find Optimum Asphalt Composition

From table 2 and figure 2, it can be determined that the optimum asphalt content that can be used in this study is 5.5%. At the asphalt content of 5.5%, the values of stability, flow, MQ, VIM, VMA, and VFA meet the requirements of the Bina Marga Standard.

After determining the optimum asphalt composition, it is followed by finding the optimum natural rubber content. In this test, the variation of natural rubber content used was 0%, 1% ; 3%; and 5%. For each level of variation of the mixture made, 10 test objects were. Table 3 is the result of testing Marshall characteristics on asphalt mixtures by adding variations in natural rubber content.

Table 3. Results of Marshall Characteristics Value of Asphalt Mix by Adding Variations in Natural Rubber Content

Parameter Marshall	Unit	Bina Marga Standard	Variations in Natural Rubber Content			
			0%	1%	3%	5%
Stability	kg	Min.800	1736	1897	1912	1897
Flow	mm	2 - 4	2	3	4	4.5
Marshall Quotient (MQ)	kg/mm		432	342	452	544
VIM	%	3 - 5	3	4	5	7
VMA	%	Min.15	16	17	19	20
VFA	%	Min.65	60	65	70	60

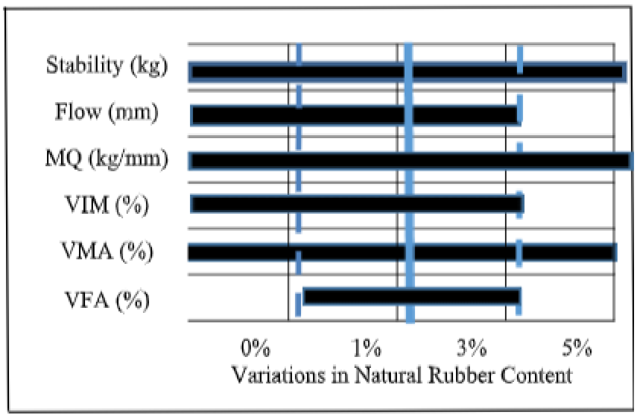

Fig 3. Graph to Find Optimum Natural Rubber Content Composition

Table 3 and figure 3 show that the optimum natural rubber composition value is 2%. In Figure 3, the value of natural rubber composition is in the range of 0.5% to 3.5%, so if an average is taken, the optimum natural rubber composition is 2%.

A. Correlation between Natural Rubber Content Variation and Stability

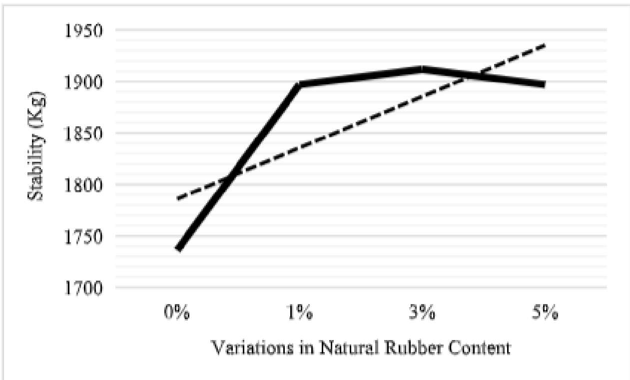

Fig 4. Graph of the Relationship of Variations in Natural Rubber Content with Stability

From Figure 4, the stability value shows that the variation in the content of the natural rubber mixture has increased and the peak of the increase is in the natural rubber content of 3%. Based on the equation in Figure 1, there is an increase in the optimum stability value of 10.14% at 3% natural rubber content. This stability value indicates that the ability of the pavement with the addition of 3% natural rubber content is able to increase the resistance to deformation due to traffic loads that occurs by 10.14%.

ISSN No:-2456-2165

B. Correlation between Natural Rubber Content Variation and Flow

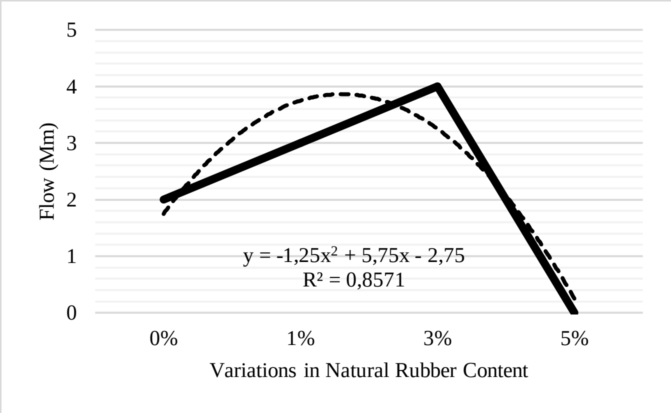

Fig 5. Graph of the Relationship of Variations in Natural Rubber Content with Flow

From the flow test results in Figure 5, it was found that the variation of natural rubber content that met the Bina Marga standard was 0%, 1%, and 3% natural rubber content. A mixture with a flow value less than 2 mm causes the mixture to become stiff so that the pavement is easily cracked, while a mixture with a flow value higher than 4 mm will cause the pavement to have a higher deformation.

A mixture that has a high flow value with a low stability value has plastic properties and is easy to deform when subjected to traffic loading. Mixtures with low flow and high stability have brittle properties.

C. Correlation between Natural Rubber Content Variation and Marshall Quotient

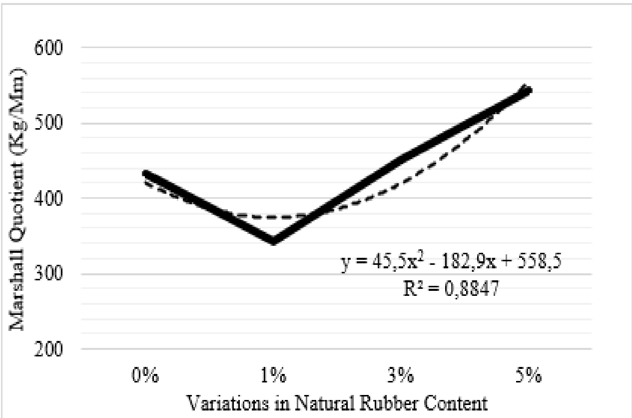

Fig 6. Graph of the Relationship of Variations in Natural Rubber Content with *Marshall Quotient*

In Figure 6, the optimum MQ value occurs at a variation of 1% natural rubber content. The increase and decrease in the value of the Marshall Quotient are caused by the addition of variations in asphalt content. For mixtures that have a Marshall Quotient value that is too high, the asphalt mixture becomes stiff and has low flexibility, so the asphalt mixture is more prone to cracking. While asphalt mixtures have a Marshall Quotient value that is too low, the mixture is flexible and will become plastic.

D. Correlation between Natural Rubber Content Variation and VIM

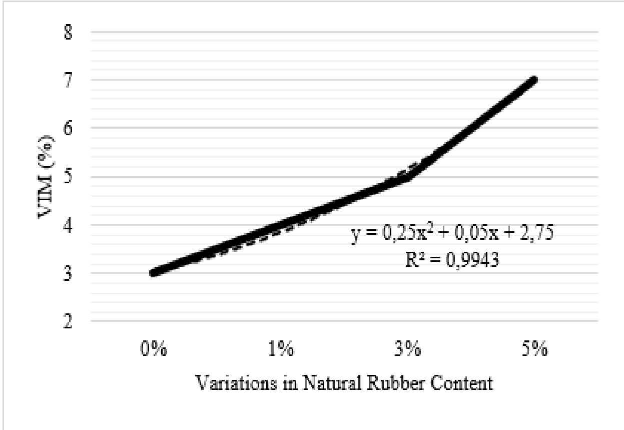

Fig 7. Graph of the Relationship of Variations in Natural Rubber Content with *VIM*

In Figure 7, the relationship between mixed asphalt content and variations in natural rubber content shows that the VIM value increases at 0% to 5% asphalt mixture content. Adding natural rubber content will reduce the VIM value because the voids between the aggregate grains, which are still large enough, will be filled by a mixture of asphalt and natural rubber.

E. Correlation between Natural Rubber Content Variation and VMA

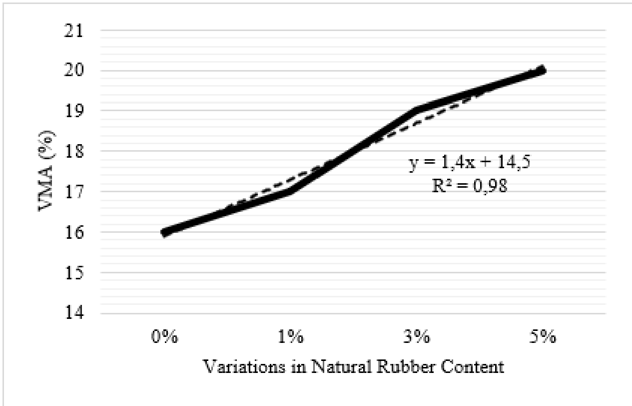

Fig 8. Graph of the Relationship of Variations in Natural Rubber Content with *VMA*

In Figure 8, it can be seen that the mixed asphalt content of 0% to 5% has increased. This occurs because asphalt and natural rubber are able to cover the aggregates properly with sufficient asphalt thickness, causing the distance between the aggregates to be farther apart.

F. Correlation between Natural Rubber Content Variation and VFA

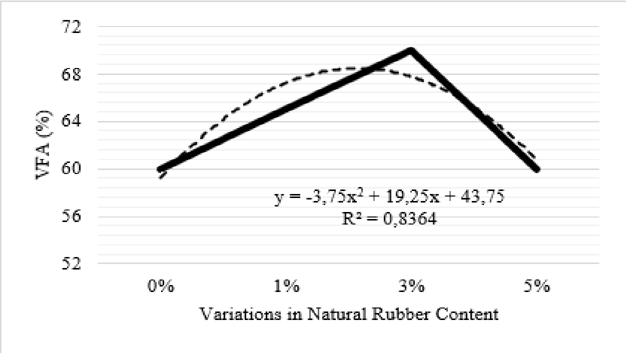

Fig 9. Graph of the Relationship of Variations in Natural Rubber Content with *VFA*

In Figure 9, the relationship graph between the asphalt content of natural rubber mixtures and the VFA value shows that adding excess natural rubber will reduce the VFA value. This happens because the percentage of voids in the mixture filled with asphalt and natural rubber mixture has decreased. This decrease was caused by an increase in the value of VFA, with an increase in the proportion of natural rubber, causing the viscosity of the bonding material to increase.

In Figures 4 to 9, there are regression results with an R^2 value close to 1. If the X value in the regression equation is given a value for variations in natural rubber content, the Marshall characteristic results will be obtained, as shown in Table 3 below.

Table 3. Marshall Characteristic Regression Value with Variation of Natural Rubber Content

Parameter Marshall	**Unit**	**Bina Marga Standard**	**Variations in Natural Rubber Content**				
			0%	**1%**	**2%**	**3%**	**5%**
Stability	kg	Min.800	1516	1741,8	1879,6	1929,4	1765
Flow	mm	2 - 4	-2,75	1,75	3,75	3,25	-5,25
Marshall Quotient (MQ)	kg/mm		558,5	421,1	374,7	419,3	781,5
VIM	%	3 - 5	2,75	3,05	3,85	5,15	9,25
VMA	%	Min.15	14,5	15,9	17,3	18,7	21,5
VFA	%	Min.65	43,75	59,25	67,25	67,75	46,25

Source: Test Result

From Figure 3 and Table 3, the optimum natural rubber content value is 2% with a stability value of 1879.6 kg, a Flow value of 3.75 mm, a Marshall Quotient value of 374.7 kg/mm, a VIM value of 3.85%, a VMA value of 17.3% and VFA value of 67.25%. From the results of the Marshall test with the optimum natural rubber content of 2%, the stability values, Flow, Marshall Quotient, VIM, VMA, and VFA values have met the Bina Marga standards.

From table 3, it can be concluded that the addition of variations in natural rubber content can increase the Marshall characteristics of asphalt mixtures. The increase in the value of the Marshall characteristics is:
a. Stability value increased by 23.98%.
b. The flow value increased by 36.36%.
c. MQ value decreased by 32.91%.
d. VIM value increased by 40%.
e. VMA value increased by 19.31%.
f. VFA value increased by 53.71%.

IV. CONCLUSION

Based on the results of the research on asphalt mixtures using natural rubber, the following conclusions were obtained:

- From the results of calculations that have been carried out, the percentage value of the optimum natural rubber content as an asphalt mixture is 2%. This is because the Marshall parameter value at a variation of 2% already meets the requirements in the Bina Marga Standard.
- The effect of adding natural rubber as an asphalt mixture with an optimum content of 2% indicates an increase in the value of Stability, Flow, VIM, VMA, and VFA. While the value of MQ there is decreased.
- At the optimum natural rubber content of 2%, the cavities in the asphalt-concrete mixture are filled with a mixture of asphalt with natural rubber so that the binding capacity of the asphalt is better, and the pavement is more able to withstand deformation due to traffic loads.

ACKNOWLEDGMENT

Thank you to the Department of Civil Engineering at the University of Pembangunan Nasional "Veteran" Jawa Timur for assisting laboratory facilities so that the process runs successfully. Not to forget, thanks also to my family for their support so far that this journal can be finished.

ISSN No:-2456-2165

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