Effect of Waste Tire Rubber Addition on Marshall Characteristics

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Abstract

The use of waste tire rubber as an additive in Asphalt Concrete-Wearing Course (AC-WC) mixtures is an innovative effort to improve mix performance while reducing solid waste. This research uses the dry process method by adding tire rubber powder to the asphalt mixture at 2%, 5%, 8%, and 11% by weight of asphalt. The evaluation was conducted through Marshall characteristics test, including density, Voids in the Mix (VIM), Voids Filled with Asphalt (VFA), stability, flow, and Marshall Quotient (MQ). The test results showed that the addition of rubber powder increased the Marshall stability value significantly, from 1,916.20 kg (0%) to a maximum of 2,382.16 kg (11%). However, the increase in rubber content also caused a decrease in VIM value from 4.41% to 3.69%, as well as an increase in VFA from 72.52% to 76.55%. Based on the balance between high stability, ideal VIM values, and VFA within specification limits, the optimum content was obtained at 8% by weight of asphalt. At this level, a stability of 2,284.19 kg, VIM of 4.00%, and VFA of 74.60% were obtained, which showed the best overall mix performance. These findings prove that waste tire rubber can be utilized as an additive in AC-WC mixtures to improve the mechanical performance of asphalt mixtures and support the principle of sustainable development in the field of road construction. Keywords: AC-WC, tire rubber powder, dry process, Marshall stability, VIM, VFA, asphalt weight

Keywords: waste rubber tire, Asphalt Concrete-Wearing Course (AC-WC), Marshall characteristics, VIM, VFA, Marshall stability.

I. INTRODUCTION

Asphalt is one of the main materials used in the construction of pavement layers, especially in the type of AC-WC wear layer mixture. However, the quality of the pavement is often not optimal due to the low quality of the material used. On the other hand, the increase in the amount of vehicle tire waste every year is an environmental problem that needs to be addressed immediately.

One approach that can be taken is to utilize waste rubber tires as an additive in asphalt mixtures. The elastomeric content in rubber tires has characteristics that are flexible and resistant to deformation, thus potentially improving the stability and durability of AC-WC mixtures.

This study was conducted to determine the effect of variations in the addition of waste rubber tires of 2%, 5%, 8%, and 11% on Marshall parameters in AC-WC mixtures.

II. RESEARCH METHOD

This research is an experiment conducted in the laboratory of Politekknik Negri Bandung. In this study, material testing was carried out based on the General Specifications of the Directorate General of Highways 2018 Revision 2. Marshall testing was carried out to determine the effect of adding waste rubber tires with a percentage of 0%, 2%, 5%, 8%, and 11% on the resulting value.

2.1 The materials used in this study

1. Coarse Aggregate, Fine Aggregate, and Filler are from Lagadar, Kab, Bandung West Java.
2. Asphalt Using 60/70 Penetration Asphalt from PT Anten Asri Perkasa
3. The additive used is rubber from waste vehicle tires.

2.2 The equipment used in this study are:

1. Pan, used as a place for hot bin material and aggregate.
2. A set of sieves used to separate the aggregates.
3. Triple Beam Balance scales, used to weigh the weight of the material to be used for the asphalt mixture
4. Molding tool (Mold) is a mold for making briquettes
5. Automatic Asphalt Compactor used for compaction of test specimens
6. Supporting tools include a frying pan, heating stove, thermometer, stirring spoon, cloth, and marker to mark the test specimens.
7. Ejector to remove the test specimens after the compaction process.

2.3 Equipment used for testing include

1. Water bath, to soak the test specimens before using the water bath.
2. Water Bath (asphalt soaking tub) equipped with temperature control.
3. Marshall Compression Machine test equipment equipped with a flowmeter.

III. RESULTS AND DISCUSSION

3.1 Material Testing Results

a) Aggregate Testing Results

Table 3.1 Asphalt Testing Results

Inspection Type	Method	Test Result	Specifications		Description
			Minimum	Maximum	
Water Absorption					
Stone Ash	SNI 1969:2016	2,128	-	3	Meets
Split	SNI 1969:2016	2,033	-	3	Compliant
Screening	SNI 1969:2016	1,407	-	3	Meets
Specific gravity					
Stone Ash Filler	SNI 1969:2016.	2,620	2,25	2,7	Meets
Sand Equivalent	SNI 3-4428-1997	90,68%	50%	-	Meets
Mud Content					
Stone Ash	SNI 3-4141-1996	0,942%	-	1%	Meets
Split	SNI 3-4141-1996	0,707%	-	1%	Meets
Screening	SNI 3-4141-1996	0,784%	-	1%	Meets
Abrasion	SNI 2417:2008	22,08%	-	40%	Compliant

(Source: Data Analysis 2024)

The test results show that the aggregates used in this study have met the 2018 Bina Marga General Specifications for AC-WC mixtures.

b) Asphalt Testing Results

Table 3.2 Asphalt Testing Results

Type of Examination	Inspection Method	Test Result	Specifications		Description
			Minimum	Maximum	
Specific gravity	SNI 2441:2011	1,055	1	-	Compliant
Penetration	SNI 2456:2011	66.43 mm	60 mm	70 mm	Meets
Softening Point	SNI 2434:2011	56,5 c	48 c	-	Compliant
Ductility	SNI 2432:2011	>150 mm	100 mm	-	Compliant
Viscosity	SNI 7729:2011	440.7 cst	300 cst	-	Compliant
		TFOT			
Weight Loss	SNI 7729:2011	0,05%	-	1%	Compliant
Penetration	SNI 7729:2011	57.2 mm	54 mm	-	Compliant
Ductility	SNI 7729:2011	87.5 mm	50 mm	-	Compliant

(Source: Data Analysis 2025)

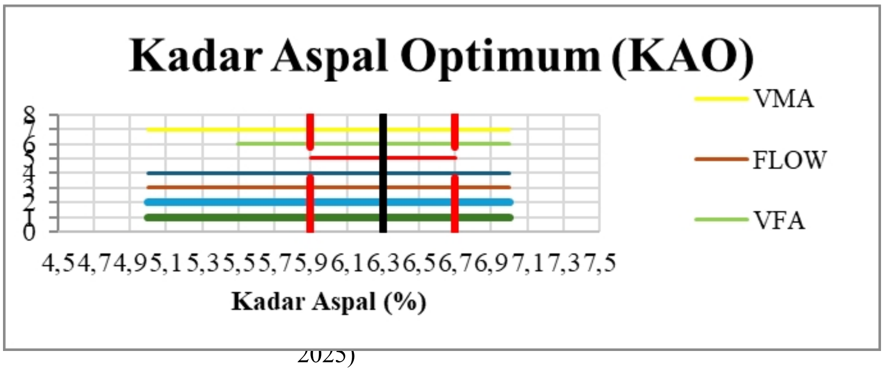
3.2 *Marshall* Testing Results Against Optimum Asphalt (KAO)

Marshall test results were obtained from making specimens with variations in asphalt content of 5%, 5.5%, 6%, 6.5%, and 7% to obtain the value of Marshall characteristics used for the Optimum Asphalt Content value. Each variation in the percentage of asphalt content made as many as 3 (three) test specimens. The Marshall characteristic values from the Marshal test are shown in the following table.

Table 3.2 *Marshall* Characteristic Values

Asphalt Content (%)	***Density* (gr/cc)**	**VMA (%)**	**VIM (%)**	**VFA (%)**	**Stability (kg)**	***Flow* (mm)**	***MQ* (kg/mm)**
5	2.29	15.38	6.88	55.28	1730.67	3.48	497.32
5.5	2.30	15.37	5.61	63.51	1771.00	3.57	496.08
6	2.32	15.21	4.16	72.70	2021.07	3.55	569.85
6.5	2.30	16.32	4.13	74.67	1844.33	3.43	537.18
7	2.25	18.47	5.35	71.09	1708.67	3.38	505.02
Specifications	>2	>15	3-5	>65	>800	2-4	>250

(Source: 2025 Data Analysis)



2025)

From the bar graph in Figure 2, it is obtained that the Optimum Asphalt Content that can be taken from Marshall testing is with an asphalt percentage level of 6.3%. So in the mixing of making test objects using Waste Rubber using a mixture of asphalt content of 6.3%.

3.3 Determining the Variation of Rubber Waste Mix

Varying the level of rubber mixture to see its effect on the characteristics of the Laston mixture. In this study the rubber mixture was combined into 4 variations namely 2%, 5%, 8%, 11% rubber waste mixture and 0% (normal) without rubber waste mixture.

Table 3.3 Variations of 6.3% Asphalt Mixture

Test Item	Percentage of Waste Rubber	Weight of Waste Rubber	Number of Specimens	Total (Pieces)
Normal	0%	0	3 Briquettes	3
Test Item 1	2%	1,51	3 Briquettes	3
Test Item 2	5%	3,78	3 Briquettes	3
Test Item 3	8%	6,05	3 Briquettes	3
Test Item 4	11%	8,32	3 Briquettes	3
Total				15

3.4 *Marshall* test results with Waste Rubber Tires

Marshall test results were obtained by making test specimens that have been added to waste rubber tires with variations in these levels of 0%, 2%, 5%, 8%, and 11%. The average Marshall parameter values of Marshall tests that have been added to waste rubber tires are shown in table 4 as follows:

Table 3.4 *Marshall* Characteristic Value

Description	Unit	Variation of Waste Tire Rubber Filler					Specifications
		0%	2%	5%	8%	11%	Highways
Density	gr/cc	2.303	2.305	2.309	2.313	2.321	Min. 2
Stability	kg	1916.20	2078.27	2153,8	2284,19	2382,16	Min. 800
VMA	%	16.05	15,97	15,83	15,69	15,41	Min. 15
VFA	%	72.52	72,92	73,66	74,60	76,55	Min. 65
VIM	%	4.41	4,33	4,17	4,00	3,96	3 - 5
Flow	mm	3.44	3.53	3.65	3.85	3,91	2 - 4
Marshall Quotient	kg/mm	557.03	589,30	572,82	593,30	608,73	Min. 300

The following is a graph of the results of density testing, stability, melt/flow testing, VIM testing, VMA testing, VFA testing, and MQ testing objects

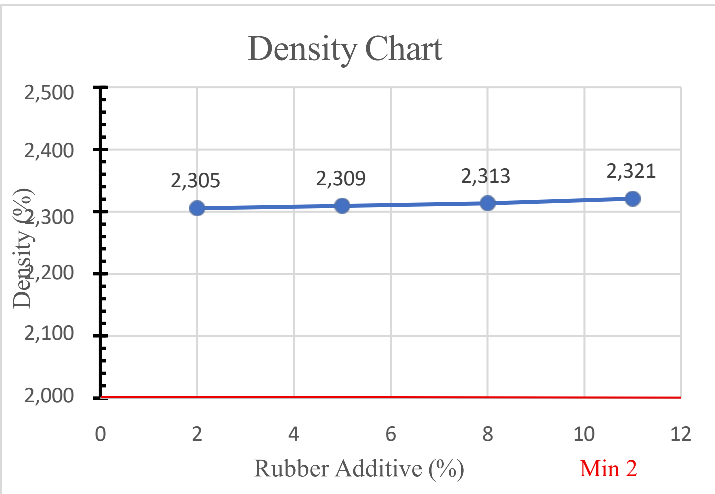


Figure 2 Graph of Density Value
(Source: Data Analysis 2025)

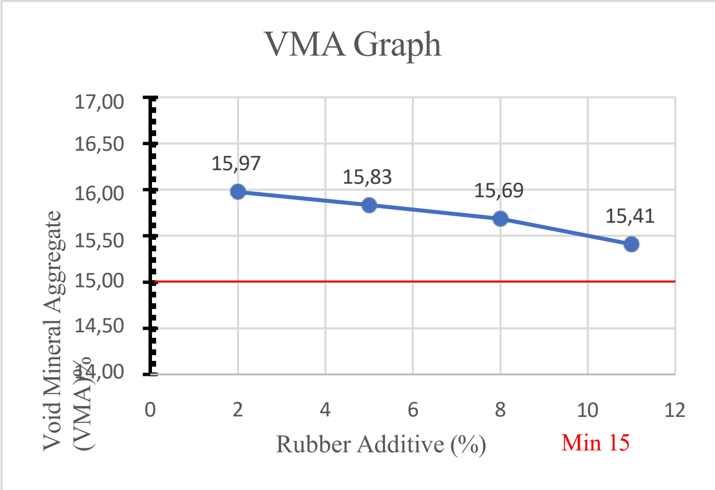


Figure 3 Graph of VMA Value
(Source: Data Analysis 2025)

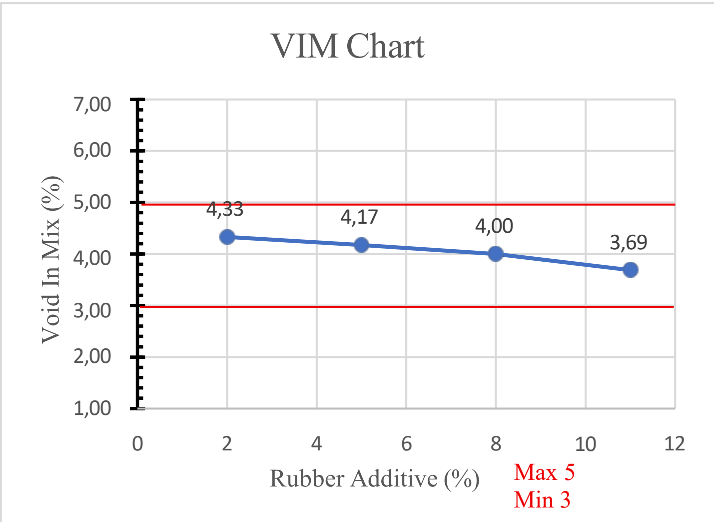


Figure 4 Graph of VIM Value
Source: Data Analysis 2025

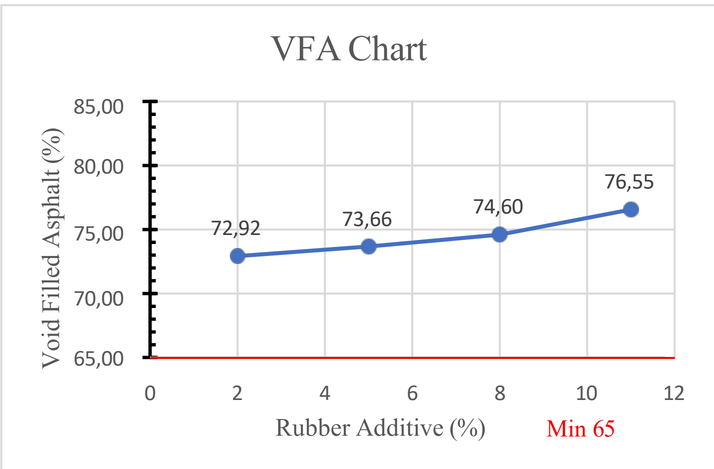


Figure 5 Graph of VFA Value
(Source: 2025 Data Analysis

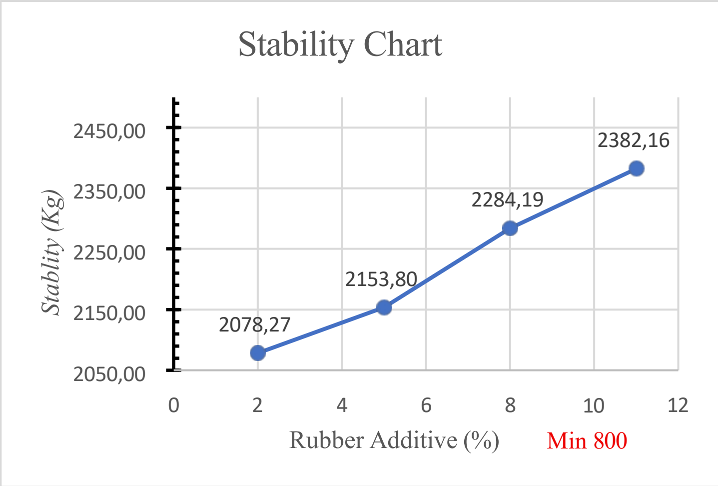


Figure 6 Stability Value Graph (Source: Data Analysis 2025

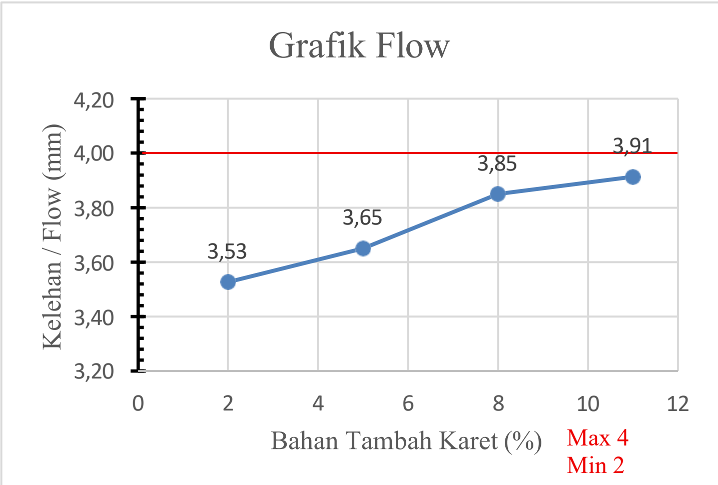


Figure 7 Stability Value Graph (Source: Data Analysis 2025

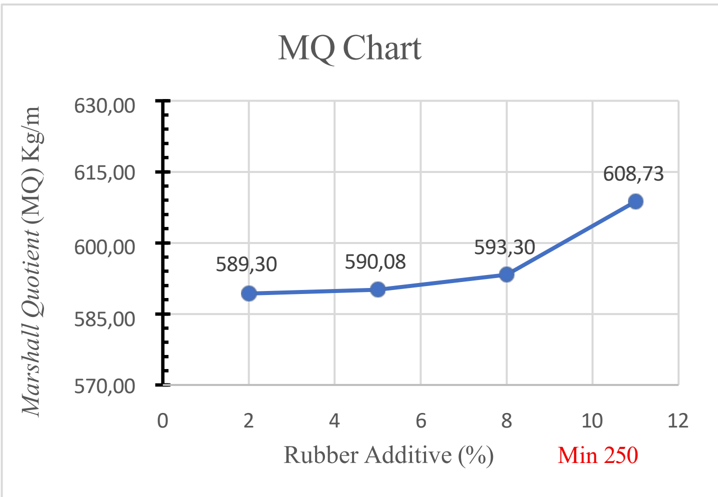


Figure 8 Graph of MQ Value (Source: Data Analysis 2025)

IV. CONCLUSION

Based on the results of Marshall testing of AC-WC asphalt mixtures with variations in rubber powder content of 2%, 5%, 8%, and 11% by weight of asphalt, it was found that 8% rubber powder content showed the most optimal mixture performance. This is indicated by a stability value of 2280.52 kg and a Marshall Quotient of 627.52 kg/mm which is high, and a flow of 3.85 mm which is still within the limits required by the 2018 Bina Marga General Specifications.

The 8% percentage also gives VIM (3.82%), VMA (15.53%), and VFA (75.47%) values that are still within the standard range, so the balance between air voids and structural strength is maintained.

Compared to the 11% content, although it produces higher stability and MQ values, the voids (VIM and VMA) tend to be close to the minimum limit which can affect the durability of the mixture in the long run. Thus, it can be concluded that the use of rubber powder at 8% by weight of asphalt is the most recommended level because it is able to improve the mechanical performance of AC-WC mixtures without sacrificing void parameters that are important for the durability and flexibility of the mixture.

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