CERUCUK
Volume 6 No. 1 2022 (37-66)

MARSHALL CHARACTERISTICS ANALYSIS USING VARIATIONWITHOUT BROKEN AND MANY FRACTURES OF GRAVEL ON MIXED HOT ROLLED SHEET - WEARING COURSE (HRS-WC)

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ABSTRACT

The asphalt pavement layer is composed of a mixture of coarse aggregate, medium aggregate, fine aggregate and asphalt. The use of coarse aggregate and medium aggregate derived from natural aggregates or rivers which are taken directly without the process of breaking the stone with a stone crusher (*Stone Crusher*) resulted in poor quality and will affect all Marshall test parameters. Therefore, research usinggravel without broken planes, one broken plane, two broken planes, and many cracked areas on coarse aggregate were carried out to determine the characteristics of gravel, and carried out Marshall testing to obtain optimal asphalt content, as well as analyzing the results of the comparison of Marshall characteristic values, among others, resistance (stability), plastic melting (flow), VIM, VMA, VFB, Marshall quotient (Marshall Quotient/MQ) and density of the HRS-WC mixture.

The results of the study show The value of the optimum asphalt content in HRS-WC without cracks and many cracked areas is 6.5%, the density value between the HRS-WC asphalt mixture without cracked areas and the HRS-WC asphalt mixture with many cracked areas from the optimum asphalt content is the same value. The value of stability, flow, VFB, and Immersion Index of the HRS-WC asphalt mixture without cracks is smaller than the value of the HRS-WC asphalt mixture with many cracked areas. The value of VIM, VMA, and MQ of the HRS-WC asphalt mixture without cracks is greater than the value of the HRS-WCasphalt mixture with many areas.
Keywords: Aggregate Fracture Field, Marshall Test, Optimum Asphalt Content.

I. INTRODUCTION

Asphalt material is one of the main choices for use as a surface layer. The material has plastic properties and is in good condition at normal temperatures, but in hot temperatures the material will soften and decrease in density. The mixing process between asphalt material with coarse and fine aggregate is carried out at very high temperatures. When the temperature decreases, the asphalt mixture will harden and form a surface layer of pavement. Usually coarse aggregate and medium aggregate are obtained from the breakdown of large rocks with a stone crusher. However, in Indonesia, there are still locations far from where the stone crusher is used to crush stones, so they choose to use natural aggregates or rivers that are broken down manually or by the local people as road pavement aggregates. The addition of the percentage of aggregate grains without cracks in the asphalt concrete mixture can affect all Marshall parameters. Based on the Technical Specifications of Highways by the Ministry of Public Works, Directorate General of Highways in 2010 revision 2012 the types of hot mix asphalt used in Indonesia, include Thin Layers of Asphalt Sand (Sand Sheet, SS) consisting of SS-A and SS-B, Lapis Thin Asphalt Concrete (Hot The addition of the percentage of aggregate grains without cracks in the asphalt concrete mixture can affect all Marshall parameters. Based on the Technical Specifications of Highways by the Ministry of Public Works, Directorate General of Highways in 2010 revision 2012 the types of hot mix asphalt used in Indonesia, include Thin Layers of Asphalt Sand (Sand Sheet, SS) consisting of SS-A and SS-B, Lapis Thin Asphalt Concrete (Hot The addition of the percentage of aggregate grains without cracks in the asphalt concrete mixture can affect all Marshall parameters. Based on the Technical Specifications of Highways by the Ministry of Public Works, Directorate General of Highways in 2010 revision 2012 the types of hot mix asphalt used in Indonesia, include Thin Layers of Asphalt Sand (Sand Sheet, SS) consisting of SS-A and SS-B, Lapis Thin Asphalt Concrete (Hot

Rolled Sheet, HRS), consists of HRS Foundation (HRS-Base) and HRS Lapis Aus (HRS Wearing Course, HRS-WC), Lapis Asphalt Concrete (AC) consists of AC Lapis Aus (AC Wearing Course, AC- WC), AC Lapis Intermediate (AC

Binder Course, AC-BC) and AC Lapis Foundation (AC Base), which are selected based on pavement needs.

In this study, the use of gravel without cracks and many cracks in coarse aggregate was carried out. The purpose of this study was to determine the characteristics of gravel, and perform marshall tests to obtain optimal asphalt content, as well as analyze the results of the comparison of Marshall characteristic values, among others, stability, plastic melting (flow), VIM, VMA, VFB, Marshall quotient (Marshall Quotient/MQ) and the density of the HRS-WC mixture.

II. LITERATURE REVIEW

2.1 Pavement Layer

Management There are three types of pavement layers found in Indonesia, namely Flexible Pavement with the characteristics of asphalt as a layer of binding material, the nature of the layer carrying and distributing traffic loads to the subgrade. Rigid Pavement characterized by cement as a layer of binder (with or without reinforcement), the traffic load is borne by the concrete slab, can/without the use of a foundation layer. Composite Pavement with characteristics is a combination of flexible pavement with rigid, flexible pavement on rigid pavement.

2.2 Asphalt (Surface Course)

Asphalt is a natural material with the main chemical component of hydrocarbons being adhesive, brownish black in color, plastic to liquid, insoluble in dilute acid and alkali or water, but soluble mostly in Aether, CS2, Bensol and Chlorofom. Asphalt used for road pavement consists of several types, namely:

1. Natural Asphalt: Mountain Asphalt (Rock Asphalt), Lake Asphalt (LakeAsphalt).
2. Artificial Asphalt : Oil Asphalt

2.2.1 Paved Mix Type

The mix type and layer thickness shall be as specified in the 2018 General Specification Revision 2 (Year 2020).

1. *Stone Matrix Asphalt (SMA)*
2. Asphalt Concrete Thin Layer (Hot Rolled Sheet, HRS)
3. Asphalt Concrete (AC)

2.3 General Specification

2.3.1 Hot Asphalt Mixed Material

1. Coarse Aggregate
2. Fine Aggregate
3. Filler
4. Combined Aggregate Gradation
5. Asphalt Material For Hot Mix Asphalt
6. Anti Peeling Ingredients (Additives)

2.3.2 Requirements and Properties of Asphalt Concrete Thin LayerMixture (HRS)

In general, according to Bina Marga (2010), two things affect the lataston mixture, namely:

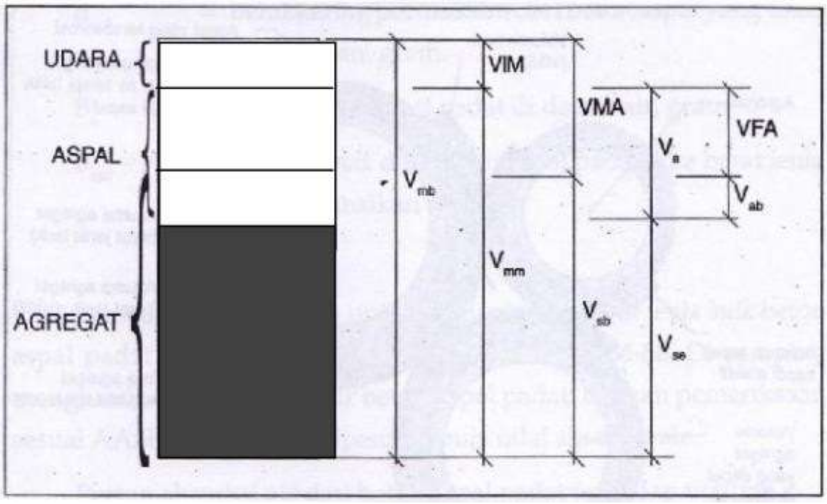
a. Really gaping gradation.
b. Air voids at refusal density must comply with the requirements indicated bythe guidelines.

In planning, in general the properties of asphalt concrete are:

1. Stability
2. Durability
3. Flexibility
4. Skid Resistance
5. Yield (Fatique Resistance)
6. Ease of Work (Workability)
7. Watertight (Impermeability)

2.3.3 Mixed Test Object Volumetric

Various types of volumes contained in a solid asphalt concrete mixture, canbe shown as in Figure 2.1.



Source: Silvia Sukirman, 2003

Figure 2.1 Schematic of Various Types of Asphalt Concrete Volume

Description :

Vma = Volume of voids between mineral aggregates (VMA).Vmb = Bulk volume of asphalt mixture.

Vmm = Volume of solid mixture without voids.vfb = Volume of voids filled with asphalt. va/vim = Volume of voids in the mixture.

Vb = asphalt volume.

Vba = Volume of asphalt absorbed by the aggregate.vsb = Aggregate volume (based on bulk density).

Vse = Aggregate volume (based on effective density).

2.3.4 Marshall Test Method

The Marshall test method is the most commonly used method and is standardized in the American Society for Testing and Materials 1993 (ASTMD 1993). This test is intended to determine the characteristics of the mixture, determine the resistance or stability to plastic melting (flow) of the asphalt mixture. In this method there are 3 important parameters in the test, namely the maximum load that can be carried by the test object before it is destroyed or often referred to as Marshall Stability and permanent deformation of the test object before it is destroyed which is called Marshall Flow and the derivative which is a comparison between the two (Marshall Stability). with Marshall Flow) which is called Marshall Qutient (MQ). MQ is the value of developing stiffness (Speedo Stiffness),

2.3.5 Test Method *Immersion Test*

The testing method of the Immersion Test or the Immersion Test method is basically the same as the Marshall test method, the difference is the immersion time of the test object. This immersion test is shown to determine the durability of an asphalt mixture which is expressed as the value of the residual strength index or "Index Retained Of Stability" (IRS), which is formulated:

$$\mathbf{IRS} = \frac{\boldsymbol{Stabilitas\ Rendaman\ 24\ Jam}}{\boldsymbol{Stabilitas\ Rendaman\ 30\ menit}} \times \mathbf{100\%}$$

2.3.6 Basic calculation

The calculation analysis used is contained in the Marshall method at The Asphalt Institute, MS-2, (1993) and the General Specifications for Roads and Bridges - Research and Development Center for Roads and Bridges (2010).

III. RESEARCH METHODS

3.1 Research Material

The research in this final project will discuss about how the characteristics of the asphalt mixture without broken plane, one broken plane, two broken planes, and many broken fields to determine Stability, Flow (melting), Marshall Quotient, Asphalt Content and others by carrying out Marshall Tests (Marshall Test) and knowing the asphalt resistance to the influence of water by doing testing (Immersion Test) in the Laboratory for asphalt coating *Hot Rolled Sheet-Wearing Course* (HRS-WC).

3.2 Research methods

1. Descriptive method, namely by analyzing and processing the data obtained factually and thoroughly.
2. Comparative method, namely by comparing the results of asphalt and aggregate characteristics without cracked plane, one broken field, two cracked areas, and many cracked areas on the Hot Rolled Sheet-Wearing Course (HRS- WC) asphalt mixture.

3.3 Project location

The location of this final project research was carried out at the Transportation and Road Laboratory of the Civil Engineering Study Program, Faculty of Engineering, Lambung Mangkurat University, Banjarbaru.

3.4 Test Specifications

1. SNI ASTM C136:2012 : Test method for sieve analysis fine aggregate and coarse aggregate.

2. SNI 1969:2016 : How to test specific gravity and absorption coarse aggregate water.
3. SNI 1970:2016 : How to test specific gravity and absorption fine aggregate water.
4. SNI 2417:2008 : How to wear aggregate by machine abrasion *Los Angeles.*
5. SNI 2432:2011 : How to test asphalt ductility.
6. SNI 2433:2011 : How to test the flash point and burning point asphalt with tools *Cleveland Open Cups.*
7. SNI 2434:2011 : How to test the softening point of asphalt with ring and ball tool (*Ringand Ball*).
8. SNI 2438:2015 : How to test the solubility of asphalt.
9. SNI 2411:2011 : How to test the specific gravity of hard asphalt.
10. SNI 2456:2011 : How to test asphalt penetration.
11. SNI 06-2440-1991 : Weight loss test method oil and asphalt with way A.
12. SNI 06-2489-1991 : Asphalt mix testing with tool *Marshall* (Marshall Test).
13. AASHTO T. 165-74 / ASTM D. 1075-54 : Test *Immersion Test.*

IV. RESULTS AND DISCUSSION

4.1 Material Properties Test Results

The results of this study include the examination of materials for Aggregate and Asphalt, Marshall Test to determine density, Stability, Flow (melting), Marshall Quoentient, Optimum Asphalt Content and Immersion Test and using a mixture of plastics and without using plastic.

4.1.1 Material Check

Material inspection includes Asphalt Inspection, Coarse Aggregate, Fine Aggregate, and Filler. This material inspection aims to determine the characteristics of the material to be used so that it can be known whether the material has met the specifications for use in the mix design. The materials used are 60/70 penetration asphalt and Kusan River Coarse Aggregate, Barito Sand Fine Aggregate.

4.1.2 Asphalt Test

In asphalt testing there are several tests carried out with the aim of knowing whether the asphalt material meets the requirements of the 2018 Highways General Specifications:

1. Asphalt Penetration Test

   Testing in the laboratory obtained readings on the penetration device, namely 63, 65, 64, 67, 66 so that the average penetration value of the asphalt tested was 65. From the test results it can be concluded that the asphalt material used meets the requirements for asphalt penetration of 60/70, namely penetration must be between 60 to 70. (General Specifications 2018 Division 6 Asphalt Pavement).

2. Asphalt Ductility Test

   In this test, the length of the test object is 106cm, in which this test the asphalt ductility tested has met the requirements, namely at least 100cm (General Specifications 2018 Revision 2).

3. Asphalt Specific Gravity Test

In this test, it was found that the Specific Gravity of Asphalt was 1.046 grams, which the results of this test met, namely (General Specifications 2018 Division 6 Asphalt Pavement)

4. Asphalt Softening Point Test

From the results of the softening point test, it was found that the temperature value of the asphalt reached its softening point, namely in test object 1 of 60 C and test object 2 of 62 C with a difference of 1 C and an average of 61 C. This value already meets the specifications for the softening point value. for asphalt penetration 60/70, namely 48 C (General Specifications 2018 Division 6 Asphalt Pavement).

5. Asphalt Flash Point and Burn Point Test

From the flash point and burning point test results, the flash point temperature is 305 C and the burning point temperature is 308 C. These results are in accordance with the specifications for asphalt 60/70, namely a flash point of at least 232 C (General Specifications 2018 Division 6 Pavement Asphalt).

4.1.3 Coarse Aggregate Test

In the Coarse Aggregate test there are several tests carried out with the aim of knowing whether the aggregate material meets the requirements of the 2018 Highways General Specification:

4.1.4 Fine Aggregate Test

1. Sieve Analysis Test

This test is for checking and determining the grain distribution (gradation) of fine aggregate, namely Cempaka sand by using a set of sieves as shown in Table 4.3.

2. Specific Gravity Test and Fine Aggregate Water Absorption

From the experiment, the specific gravity of the fine aggregate of Barito sand obtained a specific gravity (Bulk) of 2.09 g, a saturated surface dry density (SSD) of 2.23 g, an apparent density of 2.42 g and water absorption of 0.064 (<3 %). The fine aggregate has complied with the quality provisions of Article 6.3.2(1), namely the maximum water absorption by theaggregate is 3%.

4.1.5 Filler Test

1. Sieve Analysis Test

This test is for checking and determining the Filler grain (gradation)from Stone Ash by using a set of sieves as shown in Table 4.4.

Table 4.4 Analysis of Filler Sieve

NO. SARINGAN	ERTAHAN(GRAM)	AH TERTAHAN(GRAM)	%	
			TERTAHAN	LOLOS
3/4	0	0	0	100
1/2	0	0	0	100
3/8	0	0	0	100
No. 8	0	0	0	100
No. 30	190	190	15.73	84.27
No. 50	156	346	28.64	71.36
No. 200	230	576	47.68	52.32
PAN	632	1208	100	0

2. Density and Absorption of Air Filler Test

From the Filler specific gravity experiment, it was found that the specific gravity (Bulk) was 2.01 g, the saturated surface dry density (SSD) was 2.24 g, the apparent density was 2.61 g and the water absorption was 0.114 (<3%). The fine aggregate has complied with the quality provisions of Article 6.3.2(1), namely the maximum water absorption by the aggregate is 3%.

4.1.6 Aggregated Gradation Data

The percentage of each aggregate can be seen in Table 4.5 and Table 4.6.

Table 4.5 Gradation of Combined Aggregate Without Fractional Plane

GRADASI CAMPURAN TANPA BID. PECAH								
No. Saringan	Agregat Kasar 65.00%		Agregat Halus 29.00%		Filler 6.00%		Jumlah Total	Spec. Gradasi
	Lolos		Lolos		Lolos			
# 3/4	100.0	65.00	100	29	100	6	100	**100**
# 1/2	87.6	56.92	100	29.00	100	6	91.9	**90-100**
# 3/8	61.6	40.01	100	29.00	100	6	75.0	**75-85**
# 8	40.5	26.33	100	29.00	100	6	61.3	**50-72**

# 30	21.9	14.22	61.5	17.84	84.3	5.1	37.1	**35-60**
# 50	19.3	12.54	29.2	8.46	71.4	4.3	25.3	**25-43**
#200	8.3	5.41	4.4	1.27	52.3	3.1	9.8	**6-10**

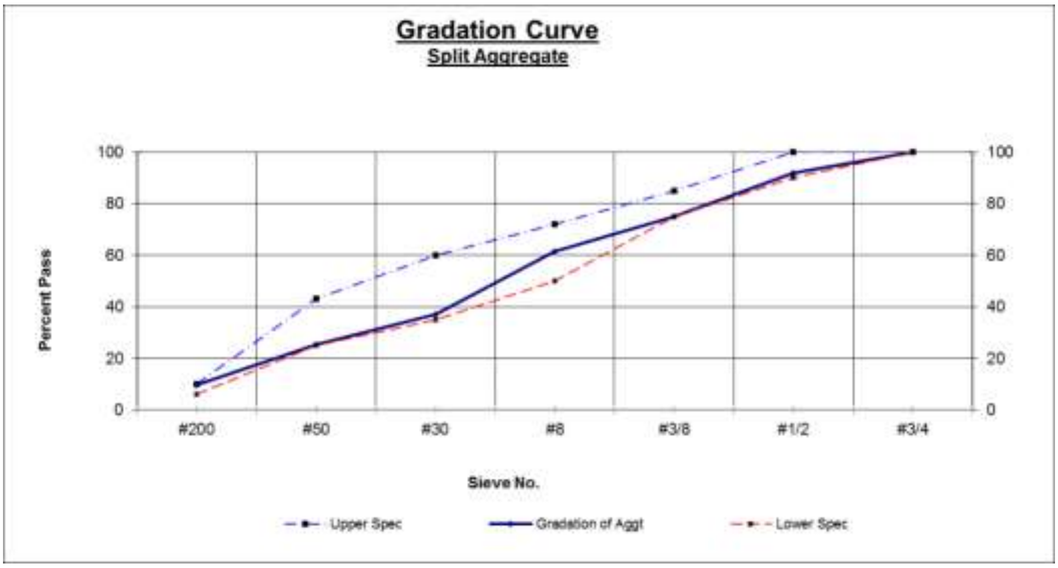


Figure 4. 1 Gradation Graph of the Combined HRS-WC Asphalt without Broken Fields

Table 4. 6 Gradation of Combined Aggregate of Many Fractional Planes

GRADASI CAMPURAN BANYAK BID. PECAH						
No. Saringan	**Agregat Kasar 65.00%**		**Agregat Halus 29.00%**		**Filler 6.00%**	**Jumla**
	Lolos		**Lolos**		**Lolos**	
# 3/4	100.0	65.00	100	29		
# 1/2	90.2	58.66	100	29		
# 3/8	65.5	42.58	100			
# 8	46.2	30.03				
# 30	23.8					
# 50						
#2						

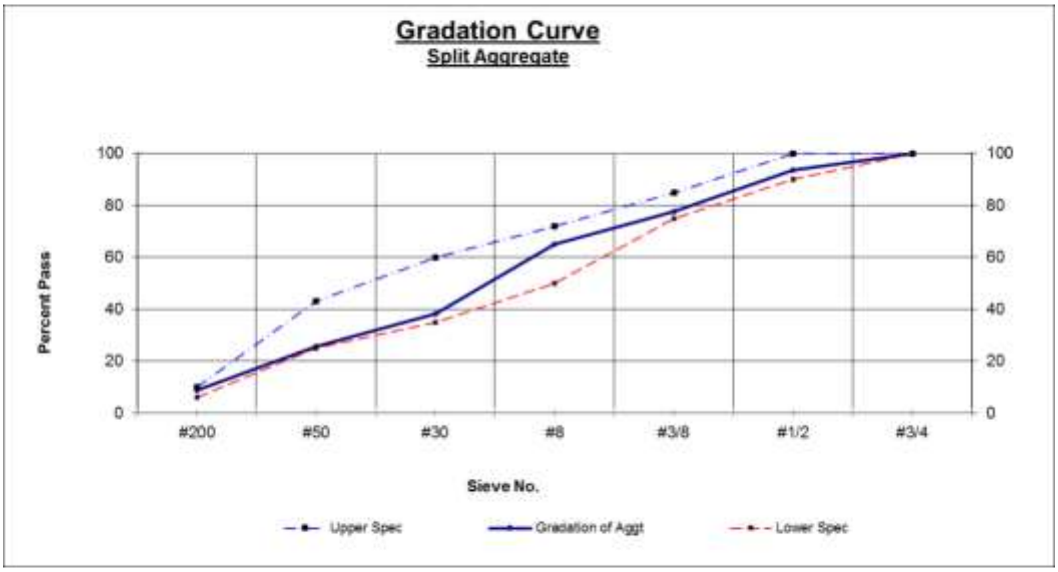


Figure 4. 2 Gradation Graph of HRS-WC Asphalt Combined with Many Fractures

4.1.7 Design Asphalt Content (Pb)

After the combined aggregate gradation is obtained, the design asphalt content (Pb) can be determined by the formula:

Pb = 0.35 (%CA) + 0.045 (%FA) + 0.18 (%Filler) + K → K = 2

- No Broken Fields

Pb = 0.035 (39) + 0.045 (56.586) + 0.18 (4.414) + 2
= 6.70%

- Many Fields Broke

Pb = 0.035 (34.97) + 0.045 (60.616) + 0.18 (4.414) + 2= 6.74%

Design asphalt content obtained by Pb:

No broken plane → 6.70% Number of broken fields → 6.74%

Then the sample to be made using a variation of asphalt content of 3%; 4% ; 5% ; 6% ; 7%, according to the Asphalt Institute method which assumes that the asphalt content variation consists of 5 variations with a range from 0.5 to 1.

4.2 Marshall Test To Get KAO Score

The results of this test will be compared with the General Specifications of Highways 2018 Revision 2 so that it can be determined whether these materials have met the specifications and can be used for mix design and continued with Marshall testing.

From the results of the Marshall test, it will be known the characteristics of the HRS-Wearing Course (HRS-WC) asphalt mixture without cracks and many cracked areas. After the characteristics of the HRS-Wearing Course asphalt mixture without cracks and the number of broken areas of each aggregate are known, the analysis of the difference between the two can be carried out.

4.2.1 Analysis of the Characteristics of Lataston Mixtures (HRS-WC) With Aggregate Mixtures Without Fractures

From the results of the Marshall test without a broken plane, each test object was compacted 75 times. The data obtained from the Marshall test are data on sample height, stability, and flow. The test results data can be seen in Table 4.7.

Table 4. 7 Marshall Test Results Data Without Broken Fields

Kadar Aspal	Aspal HRS-WC Tanpa Bidang Pecah		
	H (mm)	Stab (kg)	Flow (mm)
3	62.48	680	3.6
	62.67	765	3.45
	62.04	720	3.5
4	62.93	865	3.56
	63.60	965	3.2
	62.40	960	3.12
5	63.17	1020	2.86
	63.93	1110	2.94
	62.13	1155	3
6	62.06	1035	3.2
	63.21	992	3.24
	62.07	860	3.5
7	60.25	780	3.4
	62.37	820	3.62
	62.07	725	3.7

From the data from the Marshall test results as shown in Table 4.7, the characteristic values for the HRS-Wearing Course (HRS-WC) asphalt mixture without cracks are obtained. The characteristic values of HRS-WC asphalt without cracks can be seen in Table 4.8.

Table 4.8 Values of HRS-WC AsphaltCharacteristics Without Cracks

Karakteristik Campuran	Kadar Aspal				
	3%	4%	5%	6%	7%
VIM (%)	12.32	9.69	6.09	4.30	3.78
VMA (%)	18.69	18.34	18.34	17.80	19.47
VFB (%)	34.74	48.48	48.48	78.67	84.15
Stabilitas (Kg)	900.16	1137.35	1321.59	1190.41	989.87
Flow (mm)	3.52	3.29	2.93	3.31	3.57
MQ (kg/mm)	256.26	345.98	450.10	360.81	277.78
Kepadatan	2.19	2.23	2.28	2.29	2.28

1. Density (Density)

Density is the density level of the mixture after it has been compacted.

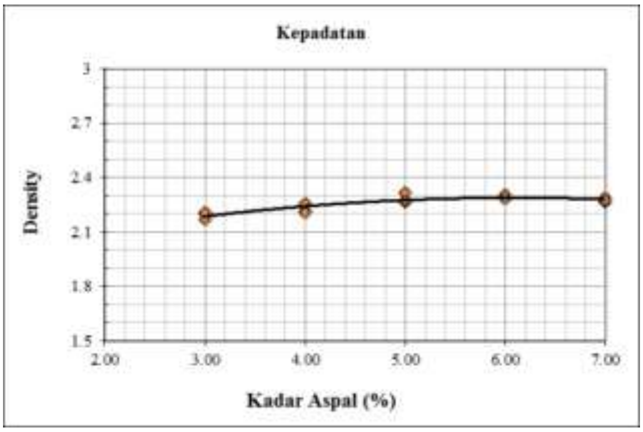


Figure 4.3 Relationship between Asphalt (%) and Density

As shown in Figure 4.3, the higher the asphalt content, the denser the mixture until it reaches the optimum asphalt content limit. This is because every time the asphalt content is added, the voids in the mixture can still be filled with asphalt so that the mixture gets tighter. In the new specification there are no special requirements regarding the density level.

2. Stability

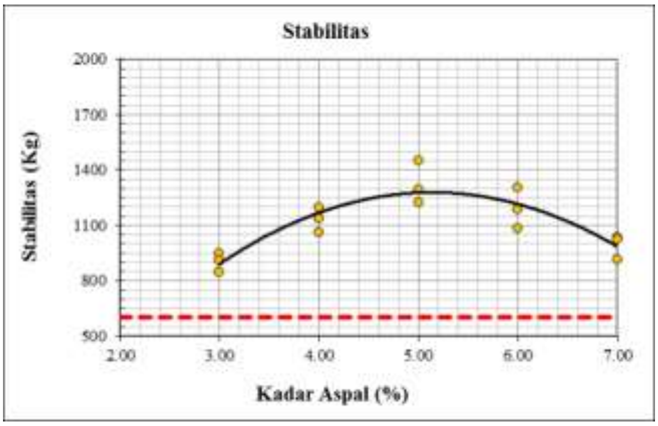


Figure 4.4 Relationship between Asphalt (%) and the stability of HRS-WC

From Figure 4.4 above, it can be seen that the HRS-WC asphalt mixture without cracks, according to the specifications, is above the minimum stability of 600 kg required.

3. Flow (melting)

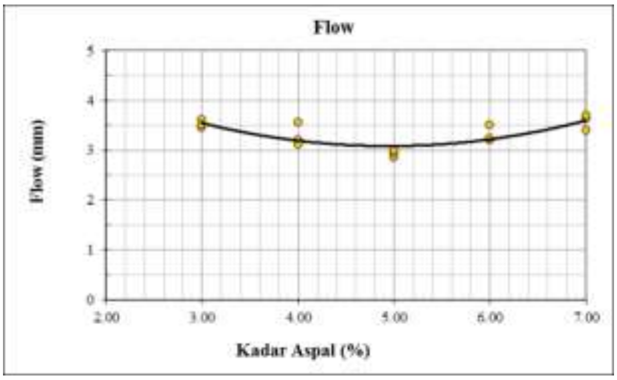


Figure 4. 5 Relationship between Asphalt (%) and Meltability (flow)

From Figure 4.5, it can be seen that in the HRS-WC mixture without a broken plane. In the new specification there are no specific requirements regarding flow rates for HRS-WC mixtures. As a reference, the recommended flow rate is 2-4. From the research results in Figure 4.5 can be seen at the asphalt content of 3% -7% flow value.

4. VFB (Void Filled Bitumen)

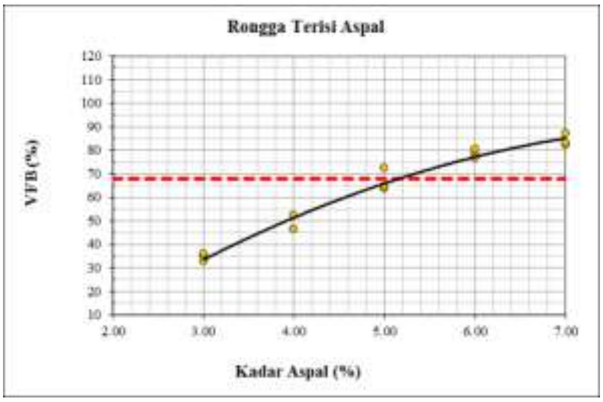


Figure 4.6 Relationship between Asphalt (%) and Cavity Filled Asphalt (VFB)

From Figure 4.6, it can be seen that the HRS-Wearing Course (HRS-WC) asphalt mixture has a VFB value that increases with increasing asphalt content. In this study, it was found that the VFB value met the requirements of the 2018 Highways General Specification Revision 2 > 68%.

5. VIM (Void In Mix)

Figure 4.7 Relationship between Asphalt (%) and Air Cavity in Mixture(VIM)

From Figure 4.7 it can be seen that the HRS-Wearing course (HRS-WC) asphalt mixture is in accordance with the General Specifications of Highways of 2018. In this study, the VIM value in Figure 4.7 that meets the requirements (3% - 5%) is at an asphalt content of 6 % - 7%.

6. VMA (Void In Mineral Aggregate)

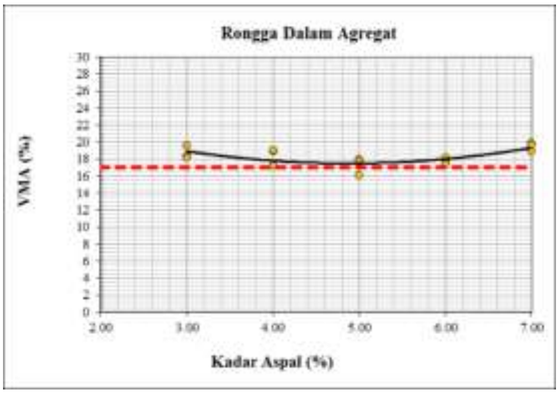


Figure 4.8 Relationship between Asphalt (%) and Air voids BetweenMineral Aggregate (VMA)

From Figure 4.8 it can be seen that as the asphalt content increases, the VMA value of the mixture decreases, because the cavities filled with asphalt are increasing. From the graph the results of this experiment show that all asphalt content meets the specifications. In this study, the VMA value that meets the requirements of the 2018 Highways General Specification Revision 2 is >17% for the wear layer, in Figure 4.8 the asphalt content is 3% - 7% or all percent asphalt content.

7. Marshall Quotient (MQ)

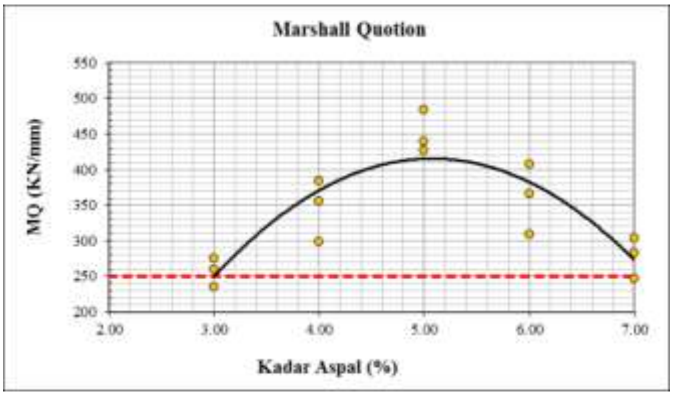


Figure 4.9 Relationship between Asphalt (%) and Marshall quotient (MQ)

From Figure 4.9, it can be seen that the HRS-Wearing Course (HRS-WC) asphalt mixture is in accordance with the 2018 Highways General Specification. The results in Figure 4.9 all asphalt content from 3% - 7% MQ value meet the General Specifications of Highways 2018 Revision 2 of > 250 kg/mm.

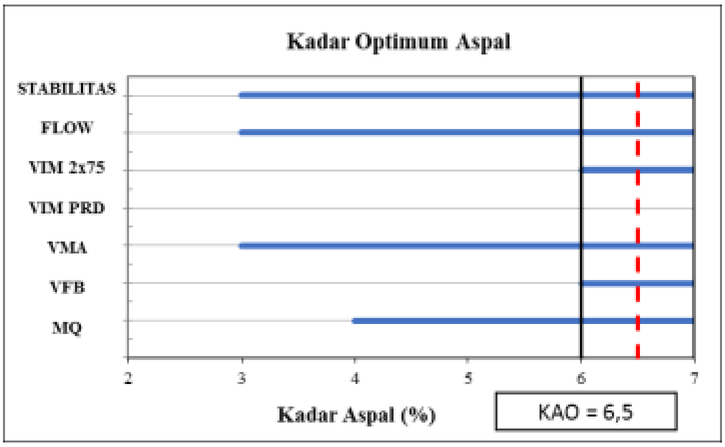


Figure 4. 10 Optimum Asphalt Content HRS-WC

In Figure 4.10 the graph of the optimum mix asphalt content, it is known that the optimum asphalt content is 6.5% and the maximum can be used up to 9% because at these points all Marshall parameters produced meet all General Specifications of Highways 2018 Revision 2.

Table 4.9 Characteristics Results of Optimum Asphalt Content of Asphalt MixingHRS Wearing Course (HRS-WC) Without Cracked Fields

Karakteristik Campuran	Spesifikasi	KAO (6.5%)	Ket.
VIM	3%-5%	4.04	Memenuhi
VMA	Min. 17%	18.63	Memenuhi
VFB	Min. 68%	81.41	Memenuhi
Stabilitas	Min. 600 Kg	1090.14	Memenuhi
Flow	-	3.44	Memenuhi
MQ	Min. 250 Kg/mm	319.30	Memenuhi

Marshall characteristics of HRS-Wearing Course (HRS-WC) asphalt mixture without cracks obtained the optimum content of 6.5% with the value of Stability, Flow, Cavities in Mixture (VIM), Cavities in Aggregate (VMA), Cavity Filled Asphalt (VFB) , Marshall Quotient (MQ) meets the requirements of Bina Marga 2018 Revision 2, as shown in Figure 4.11.

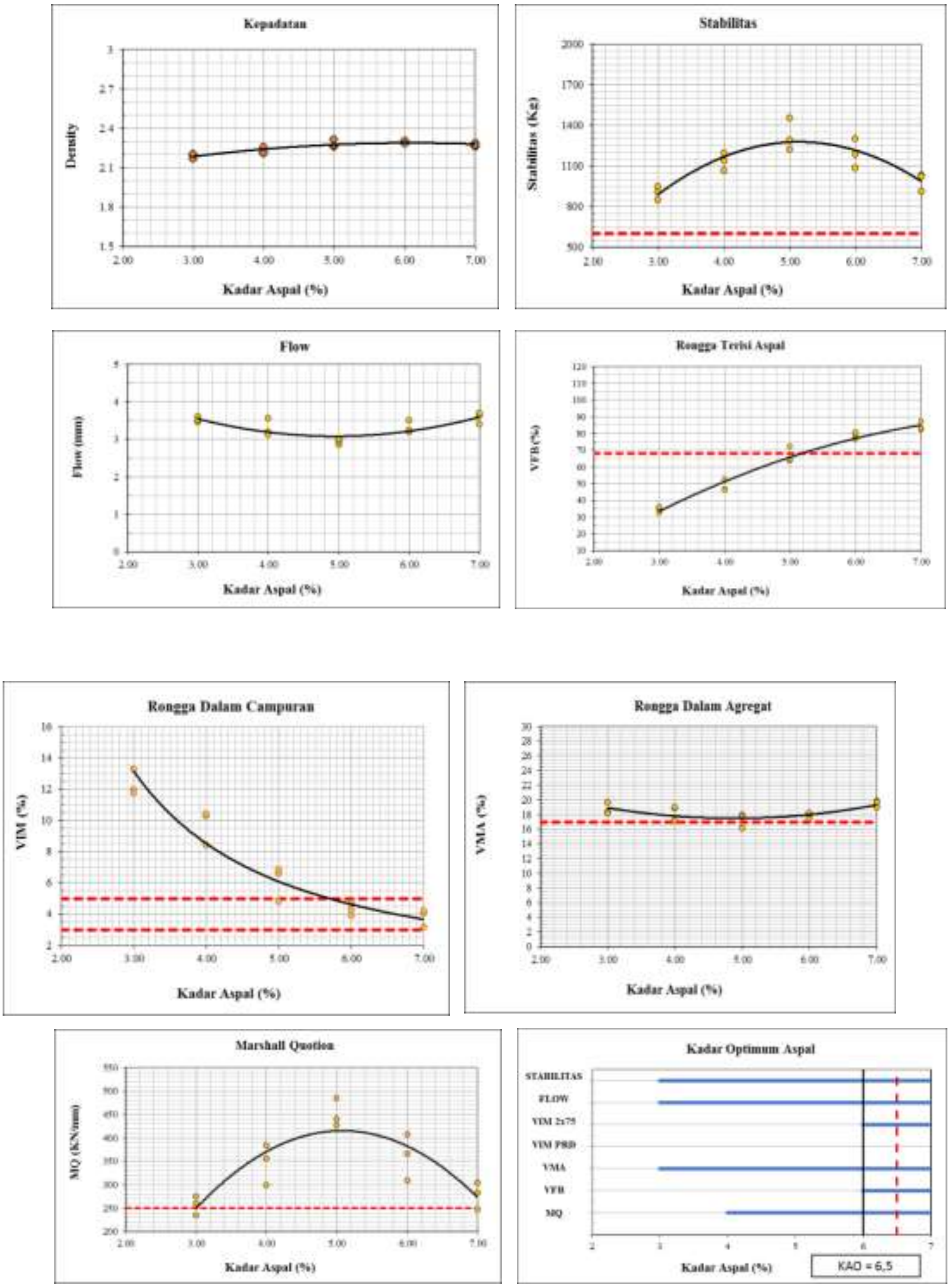


Figure 4. 11 Graph of Marshall Test Results

4.2.2 Analysis of the Characteristics of Lataston Mixtures (HRS-WC) With Aggregate Mixtures of Many Fractures

From the results of the Marshall test without a broken plane, each test object was compacted 75 times. The data obtained from the Marshall test are data on sample height, stability, and flow. The test result data can be seen in Table 4.10.

Table 4.10 Marshall Test Result Data Many Fields Broken

Kadar Aspal	Aspal HRS-WC Banyak Bidan H (mm)	g Pecah Stab (kg)	Flow (mm)
	65.90	795	3.5
3	65.04	755	3.25
	63.93	780	3.44
	64.61	875	3.12
4	64.98	925	2.92
	63.25	1010	2.84
	64.75	1045	2.95
5	64.99	1140	3.1
	65.01	1140	2.85
	62.82	1135	3.25
6	62.97	965	3.6
	62.15	810	3.43
	60.10	985	3.52
7	59.88	760	3.55
	60.85	720	3.6

Table 4. 11 Values of Asphalt Characteristics HRS-WC Many Broken Fields

Karakteristik Campuran	Kadar Aspal				
	3%	4%	5%	6%	7%
VIM (%)	13.19	8.72	6.08	3.49	3.22
VMA (%)	19.49	17.12	17.2	17.99	19.01
VFB (%)	32.92	52.56	66.79	77.63	86.59
Stabilitas (Kg)	852.45	1044.66	1287.1	1184.94	1014.33
Flow (mm)	3.25	2.92	3.1	3.6	3.55
MQ (kg/mm)	262.29	357.76	415.19	329.15	285.72
Kepadatan	2.17	2.25	2.82	2.28	2.28

1. Density

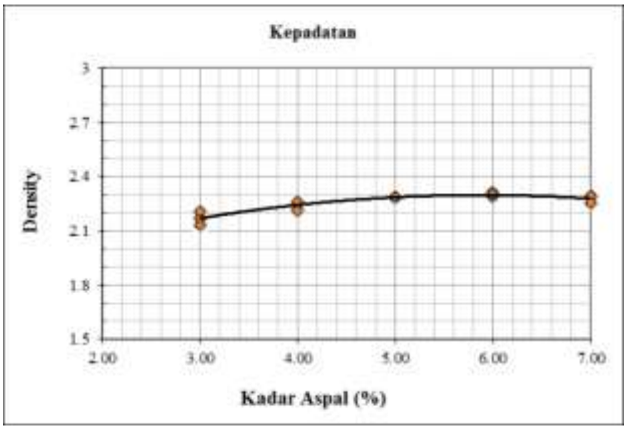


Figure 4.12 Graph of Relationship Between Density and Asphalt Content

2. Stability

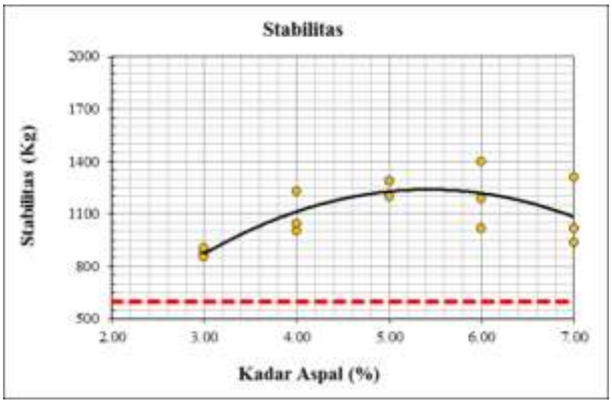


Figure 4.13 Graph of Relationship Between Stability and Asphalt Content

3. Flow

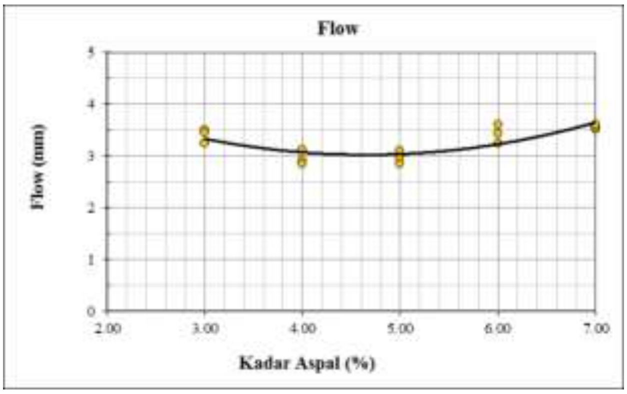


Figure 4.14 Graph of Relationship Between Flow and Asphalt Content

4. Cavity in Mix (VIM)

Figure 4.15 Graph of Relationship Between VIM and Asphalt Content

5. Cavity in Aggregate (VMA)

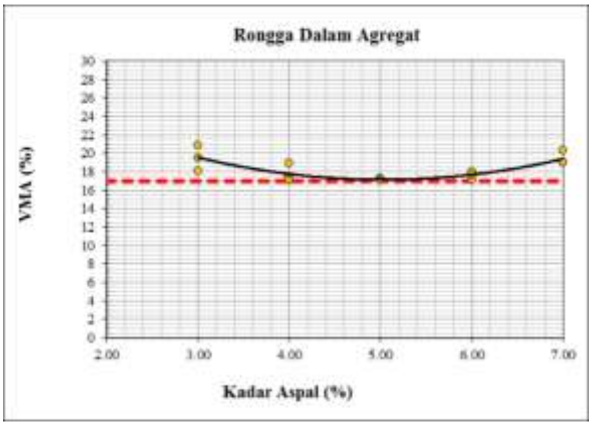


Figure 4. 16 Graph of Relationship BetweenVMA and Asphalt Content

6. Asphalt Filled Cavity (VFB)

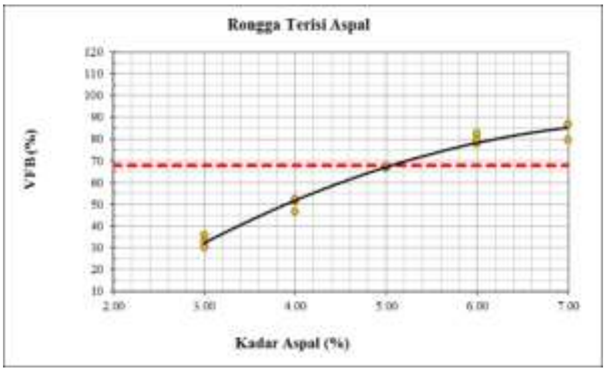


Figure 4. 17 Graph of Relationship BetweenVFB and Asphalt Content

7. Marshall Quotient (MQ)

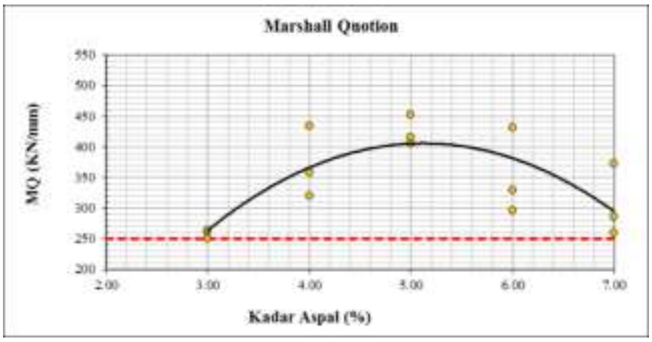


Figure 4.18 Graph of Relationship Between MQ and Asphalt Content

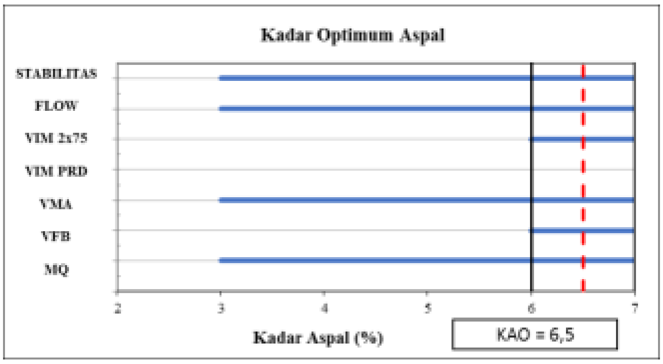


Figure 4. 19 Optimum Levels of HRS-WC Mixture with Many Fractures

In Figure 4.19 the graph of the optimum mix asphalt content, it is known that the optimum asphalt content is 6.5% and the maximum can be used up to 9% because at these points all Marshall parameters produced meet all the General Specifications of Highways for 2018. The results of the graph of the relationship between The optimum asphalt content and the HRS-Wearing Course asphalt mixture according to the General Specifications of Highways 2018 Revision 2 canbe seen in Table 4.12.

Table 4.12 Characteristics Results of Optimum Asphalt Content of Asphalt MixtureHRS Wearing Course (HRS-WC) Many Cracked Fields

Karakteristik Campuran	Spesifikasi	KAO (6.5%)	Ket.
VIM	3%-5%	3.35	Memenuhi
VMA	Min. 17%	18.5	Memenuhi
VFB	Min. 68%	82.11	Memenuhi
Stabilitas	Min. 600 Kg	1099.63	Memenuhi
Flow	-	3.57	Memenuhi
MQ	Min. 250 Kg/mm	307.43	Memenuhi

Marshall characteristics of HRS-Wearing Course (HRS-WC) asphalt mixture without cracks obtained the optimum content of 6.5% with the value of Stability, Flow, Cavities in Mixture (VIM), Cavities in Aggregate (VMA), Cavity Filled Asphalt (VFB) , Marshall Quotient (MQ) meets the requirements of Bina Marga 2018 Revision 2, as shown in Figure 4.20

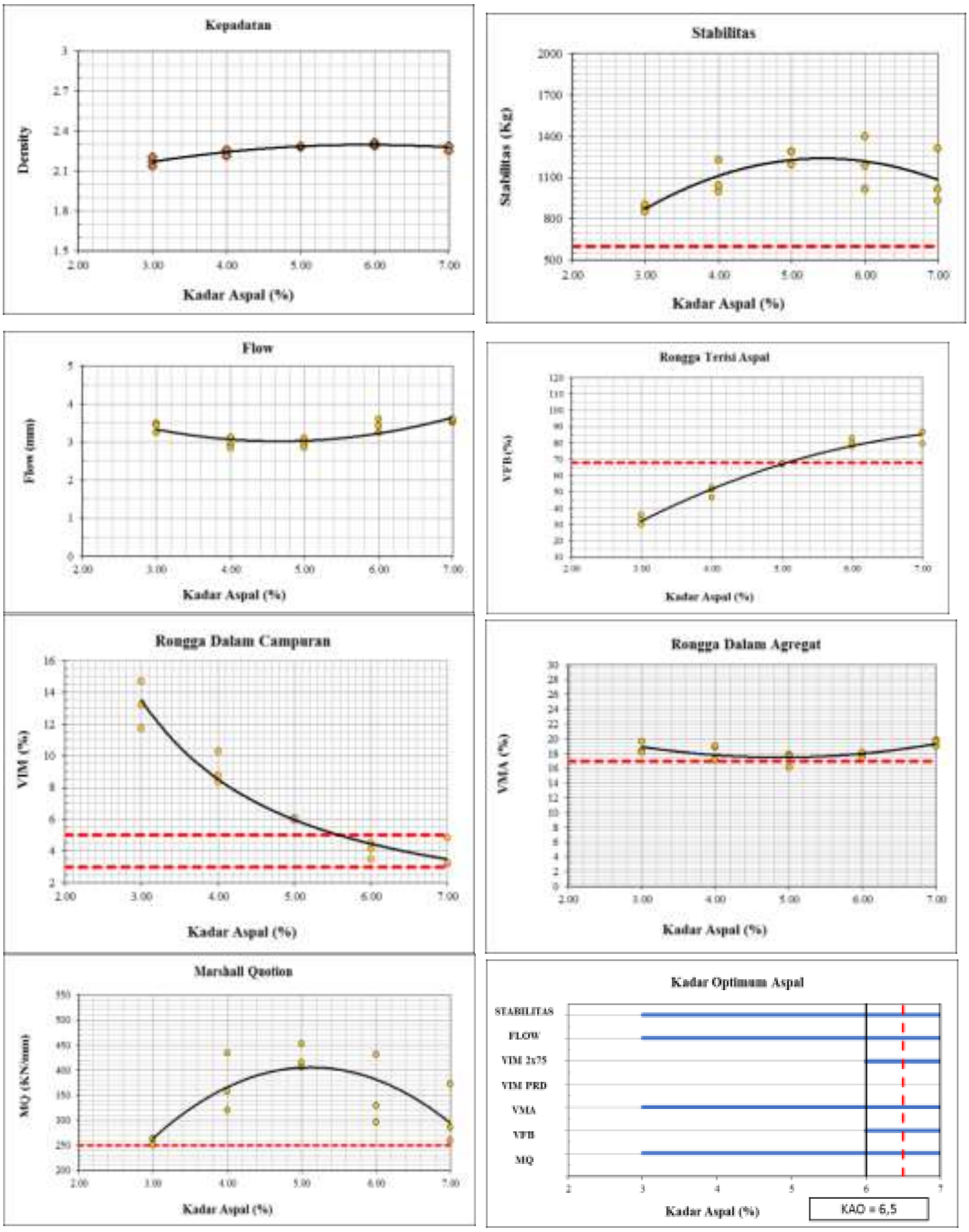


Figure 4.20 Graph of Marshall Test Results with Many Broken Fields

From Marshall's test of HRS-Wearing Course (HRS-WC) asphalt mixture/Many cracked areas, the optimum content was 6.5%. The comparison of the characteristics of the mixture without cracks and many cracks is shown in Table 4.13.

Table 4.13. Comparison Between Asphalt Mixture Without Cracks And Many Fields Broke

No	acteristics	Without Broken Field	Lots Broken Field
1	Density	2.28	2.28
2	Stability	1090.14	1099.63
3	Flow	3.44	3.57
4	VIM	4.04	3.35
5	VMA	18.63	18.5
6	VFB	81.41	82.11
7	MQ	319,30	307.43

4.3 Discussion Results

1. The density results between the HRS-WC asphalt mixture without cracks and the HRS-WC asphalt mixture with many cracked areas from the optimum asphalt content are the same value.
2. The stability results between the HRS-WC asphalt mixture without cracks and many cracked areas both meet the 2018 Highways Specifications Revision 2. The stability value of the HRS-WC asphalt mixture without cracks is smaller than the value of the HRS-WC asphalt mixture with many cracked areas. Even so, the stability values both meet the 2018 Revision 2 Bina Marga Specifications.
3. The flow results between the HRS-WC asphalt mixture without cracked areas and many cracked areas both meet the 2018 Highways Specification Revision

2 . The flow value of the HRS-WC asphalt mixture without cracks is smaller than the HRS-WC asphalt mixture with many cracked areas.

4. The VIM results between the HRS-WC asphalt mixture without cracks and many cracked areas both meet the 2018 Revision 2 Highways Specifications. HRS-WC asphalt mixture without cracks has larger air voids than HRS-WC asphalt mixture with many cracks. Even so, both VIM values meet the 2018 Revision 2 Bina Marga Specifications.
5. The VMA results between the HRS-WC asphalt mixture without cracks and many cracked areas both meet the 2018 Highways Specifications Revision 2. The VMA value of the HRS-WC asphalt mixture without cracked areas is greater than the HRS-WC asphalt mixture with many cracked areas. Even so, both VMA values meet the 2018 Revision 2 Highways Specifications.
6. The VFB results between the HRS-WC asphalt mixture without cracks and many cracked areas both meet the 2018 Highways Specifications Revision 2. The VFB value of the HRS-WC asphalt mixture without cracked areas is smaller than the HRS-WC asphalt mixture with many cracked areas.
7. The MQ results between the HRS-WC asphalt mixture without cracks and many cracked areas both meet the 2018 Highways Specifications Revision 2. The MQ value of the HRS-WC asphalt mixture without cracked areas is greater than that of the HRS-WC asphalt mixture with many cracked areas.
8. The results of the immersion test between the HRS-WC asphalt mixture without cracks and the HRS-WC asphalt mixture with many cracked areas both meet the 2018 Highways Specification Revision 2, which is at least 90, where the soaking index value of the HRS-WC asphalt mixture without cracks is 127, 99 and the mixture of asphalt HRS-WC with many broken areas is 139.29. The soaking index value of the HRS-WC asphalt mixture without cracks is smaller than that of the HRS-WC asphalt mixture with many cracks.

5 CONCLUSIONS AND SUGGESTIONS

5.1 Conclusion

From the results of research on HRS-WC asphalt mixtures without cracks and HRS-WC asphalt mixtures with many broken areas using the General Specifications of Highways 2018 Revision 2, the conclusions are:

1. The optimum value of HRS-WC asphalt content without cracked areas and many cracked areas after the marshall test was carried out was the same, which was obtained at 6.5%.
2. Comparison of the results of the Mashall test between the HRS-WC asphalt mixture without cracks and the HRS-WC asphalt mixture with many cracked areas, namely: Mark *density* between the mixture of asphalt HRS-WC without cracks and asphalt mixture of asphalt HRS-WC with many cracks of the optimum asphalt content is the same value. The value of stability, flow, VFB, and Immersion Index of the HRS-WC asphalt mixture without cracks is smaller than the value of the HRS-WC asphalt mixture with many cracked areas. The value of VIM, VMA, and MQ of the HRS-WC asphalt mixture without cracked areas is greater than the value of the HRS-WC asphalt mixture with many cracked areas.

5.2 Suggestion

Suggestions that can be submitted based on the research that has been done include:

1. Further research needs to be carried out using aggregate materials/materials sourced from other regions/quarry as comparison materials.
2. The results of this study can be used as a guide for further research.

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