Index of Retained Strength and Weight Loss on Flexible Pavement Ac-Wc and Hrs-Wc Using Polymer Products Ethylene-Vinyl-Acetate (EVA) and Styrene-Butadiene-Styrene (SBS)

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ABSTRACT

Road pavements in Indonesia often uses a mixture of Asphalt Concrete (AC) and Hot Rolled Sheet (HRS), which frequently occur premature damage to the pavement caused by extreme climate change, and also rapid development of land transportation causing increased loads on the pavement, causing queues of vehicles that make traffic jams. Over loading that is too long due to queuing of vehicles causes the performance of the asphalt to decrease. To improve and repair the performance of the asphalt, additives were added, namely Styrene Butadiene Styrene (SBS) polymer and Ethylene Vinyl Acetate (EVA) polymer into a mixture of Asphalt Concrete-Wearing Course (AC-WC) and Hot Rolled Sheet-Wearing Course (HRS-WC) using Marshall Method Test, Marshall Immersion Test and Cantabro Test. This research method is in the form of laboratory experiments with material testing and direct observation. Based on the General Specifications of Bina Marga Division 6 Revision 1 of 2018 for Marshall Tests Parameters, the best stability value for the Asphalt Concrete-Wearing Course (AC-WC) was obtained with the addition of SBS polymer rather than other mix. The Index of Retained Strength (IRS) results from the Marshall Immersion test have met the requirements greater than 90%. The percent of Weight loss from the Cantabro Test has met the requirements of less than 20%. Based on the two tests that have been carried out, sample of SBS modified asphalt mixture is better than the standard asphalt mixture and EVA modified asphalt mixture. The test specimen for the mixture of SBS modified asphalt AC-WC produces the highest Index of Retained Strength value, which is 93.33% compared to the test specimen for the mixture of standard asphalt AC-WC at 92.37% and the mixture for EVA modified asphalt AC-WC at 92.74%. The test specimen of SBS modified asphalt HRS-WC mixture also produced the highest Index of Retained Strength of 91.48% compared to the standard asphalt HRS-WC mixture test specimen of 90.25% and EVA modified asphalt HRS-WC of 90.58%. On Weight Loss, the specimens of standard asphalt AC-WC mixture are 4.04%, SBS modified AC-WC asphalt mixtures are 3.14%, and EVA modified AC-WC asphalt mixtures are 3.57%. The SBS modified AC-WC asphalt mixture was better Weight Loss than the standard AC-WC mixture and the EVA modified AC-WC mixture. On Weight Loss, the specimen of standard asphalt HRS-WC mixture was 3.91%, SBS modified asphalt HRS-WC mixture was 2.86%, and EVA modified asphalt HRS-WC mixture was 3.34%. The SBS modified asphalt HRS-WC mixture performed better Weight Loss than the standard asphalt HRS-WC mixture and the EVA modified asphalt HR-WC mixture.

Keywords: *index of retained strenght, Ac-Wc and Hrs-Wc*

1. INTRODUCTION

In general, road pavements in Indonesia often suffer premature damage, cracking of Asphalt Concrete and rutting of thin layers of asphalt concrete (Hot Rolled Sheet). The main cause of road damage is the reduced and worsening resistance of the pavement layer in accepting heavy traffic which is often associated with durability, resistance to rutting grooves, damage to pavement structures and high wear of surface texture (Dahlan, 1997) [1]. From these problems, research was carried out with the addition of Styrene-Butadiene-Styrene (SBS) and Ethylene-Vinyl-Acetate (EVA) polymers into the asphalt in the Asphalt Concrete-Wearing Course (AC-WC) mixture and the Hot Rolled Sheet-Wearing Course (HRS-WC) mixture which is expected to improve the performance of the asphalt. This study aims to determine the parameters of the Marshall Test, Marshall Immersion Test and Cantabro Test with reference to the General Specifications of Bina Marga Division 6, Revision 1 of 2018 [2].

Mixture of Asphalt Concrete layers (AC) is divided into three types of mixtures, namely AC Wearing Course (AC-WC), AC Binder Course (AC-BC), and AC Base. Where each maximum particle size of the aggregate for each mixture is 19 mm, 25.4 mm, and 37.5 mm. The Laston or AC mixture which softens the polymer asphalt material is referred to as Modified AC-WC, Modified AC-BC, and Modified AC-Base. While the Thin Asphalt Concrete layer, hereinafter referred to as HRS, consists of two types of mixtures, HRS Foundation (HRS-Base) and HRS Wearing Course (HRS-WC) and the maximum aggregate size of each mixture is 19 mm HRS-Base has an extent of coarse total portion more noteworthy than HRS-WC.

2. LITERATURE REVIEW

2.1. Asphalt Concrete-Wearing Course

Asphalt Concrete-Wearing Course (AC-WC) is the layer that is at the top that is directly related to the vehicle tires, has a smoother layer size than the Asphalt Concrete Binder Course (AC-BC). When receiving traffic loads above it and spread, the layer underneath is in the form of loads (vertical force, horizontal force) and vibration loads from the wheels. According to Silvia (2012) [6]

Figure 1. Asphalt Concrete (AC) Structure

2.2. Hot Rolled Sheet-Wearing Course

Hot Rolled Sheet-Wearing Course is a thin layer of asphalt concrete for road surfaces as a wear layer and as a cover, which is flexible so that it can accept the movement of the layer underneath without experiencing cracks. As a function of pavement construction, the asphalt used must be of the type that is heat resistant because it is located at the top position so that it is not easy to bleed (easily softens) and bulging (changes shape), does not easily experience cracks causing potholes, and it is not easy to lose the stickiness which causes the granulation to occur [3]

Figure 2. Hot Rolled Sheet (HRS) Structure

2.3. Styrene-Butadiene-Styrene (SBS)

Styrene-Butadiene-Styrene (SBS) modified asphalt is an elastomeric polymer type modified asphalt, which has high elastic response characteristics so that it is resistant to deformation caused by tension and will return to its original shape if the load is significant. This type of polymer is starting to get more attention in asphalt modification because it combines elastic and thermoplastic properties in its material properties, so it is called Thermoplastic Rubbers (TR). This property is possible from the types of forming monomers, namely Styrene and Butadine (Pradani, 2011) [5].

The reason for using SBS polymer for asphalt modification is because modified asphalt with SBS polymer has significantly increased properties, among others:

1. Resistant to high temperatures, because polymer asphalt has a softening point higher than 50°C, so it can hold the asphalt from melting.
2. Can be used for traffic conditions that are quite dense so as to reduce high temperature deformation,

because polymer asphalt has a higher softening point and modulus stiffness than ordinary asphalt.

3. Resistance to shear forces because polymer asphalt will increase resistance to shear forces.
4. Can increase the service life because the higher the thickness of the asphalt, the thicker the layer.

Figure 3. Styrene-Butadiene-Styrene (SBS)

2.4. Ethylene-Vinyl-Acetate (EVA)

Ethylene-Vinyl-Acetate (EVA) is a type of Thermoplastic Crystalline polymer or Plastomer composed of copolymers of ethylene and vinyl acetate. Weight percent vinyl acetic acid derivation generally shifts from 10-40% with the remainder being ethylene. EVA is a polymer that is able to overcome the problems of high temperature, high traffic volume and overload on vehicles. This polymer has a good ability to unite with asphalt, so it is expected to improve the weaknesses of Pen 60/70 asphalt (Whiteoak, 1991) [7]

Figure 4. Ethylene-Vinyl-Acetate (EVA)

2.5. Marshall and Marshall Immersion Test

Marshall Test aims to measure the durability (stability) of the aggregate and asphalt mixture against flow. Flow is the change in deformation or strain of a mixture from no load to maximum load. Marshall Equipment is equipped with a proving ring with a capacity of 2500 kg (5000 lbs). In the proving ring there is a measuring watch and flowmeter where each function is used to measure the value of stability, and to measure plastic melt or flow. The standard Marshall specimen is a cylinder with a diameter of 10 cm and a height of 7.5 cm.

Marshall Immersion test aims to determine changes in the characteristics of the mixture due to changes in water, temperature, and weather. In principle, the

Marshall Immersion test is the same as the Marshall test, which distinguishes only the immersion time. According to AASHTO 165-74 or ASTM D.1075-54 (1969) there are two Marshall Immersion test methods, namely the immersion test for 4x24 hours with a temperature of $\pm 50^{\circ}\text{C}$ and the immersion test for 1x24 hours with a temperature of $\pm 60^{\circ}\text{C}$.

Figure 5. Marshall Testing Equipment and Sample Test Object

2.6. Cantabro Test

The Cantabro test is one of the tests in the laboratory to determine the magnitude of the limit for breaking or wear strength due to the effect of the impact (collision/loading) on the load of traffic wheels on the pavement layer. Traffic loading on the pavement surface repeatedly will cause the pavement layer to wear out, this will cause the pavement layer to decrease the durability of the asphalt, so an abrasion test is performed with a Los Angeles machine without using steel balls.

Figure 6. Cantabro Testing with Los Angeles Machine

3. RESULTS AND DISCUSSION

3.1. Test Results of Asphalt Modifications

Characteristics

SBS modified asphalt testing and EVA modified asphalt testing were carried out by using several percent variations of the addition of SBS polymer and EVA polymer. The additions of EVA polymer and SBS polymer are 0.5%, 1% and 2% to the asphalt mixture.

The following table shows the results of testing the characteristics of the modified asphalt mixture.

Table 1. Test Results of Asphalt Pen. 60/70 Characteristics with addition SBS 0.5%, 1% and 2%.

No	Test	Test Method	Asphalt Pen 60/70 Requirements	0% SBS	Modified Asphalt Requirements	SBS Content		
						0.5%	1%	2%
1.	Penetration 25°C, 100 gr, 5 second, 0,1 mm	SNI 2456:2011	60-70	62	Reported	59	57	50
2.	Ductility at 25°C (cm)	SNI 2432:2011	≥ 100	140	-	140	140	103
3.	Flash Point (°C)	SNI 2433:2011	≥ 232	323	≥ 230	340	332	326
4.	Burn Point (°C)	SNI 2433:2011	-	330	-	346	336	331
5.	Softening Point (°C)	SNI 2434:2011	≥ 48	51	Reported	51,5	51,6	52,6
6.	Density	SNI 2441:2011	≥ 1.0	1.032	-	1.033	1.034	1.035

Table 2. Test Results of Asphalt Pen. 60/70 Characteristics with addition EVA 0.5%, 1% and 2%.

No	Test	Test Method	Asphalt Pen 60/70 Requirements	0% EVA	Modified Asphalt Requirements	EVA Content		
						0.5%	1%	2%
1.	Penetration 25°C, 100 gr, 5 second, 0,1 mm	SNI 2456:2011	60-70	62	Reported	60	58	51
2.	Ductility at 25°C (cm)	SNI 2432:2011	≥ 100	140	-	140	140	110
3.	Flash Point (°C)	SNI 2433:2011	≥ 232	323	≥ 230	345	334	325
4.	Burn Point (°C)	SNI 2433:2011	-	330	-	352	343	333
5.	Softening Point (°C)	SNI 2434:2011	≥ 48	51	Reported	51,4	51,6	51,9
6.	Density	SNI 2441:2011	≥ 1.0	1.032	-	1.032	1.034	1.036

Based on the results of testing the modified asphalt mixture, it can be concluded that the asphalt mixture with the addition of 0.5% SBS polymer and EVA polymer has the best performance according to the General Specifications of Bina Marga Division 6, Revision 1 of 2018.

3.2. Marshall Test Results

Marshall Test was carried out to obtain optimum asphalt content, optimum asphalt content was obtained from Marshall characteristics, namely Stability, Flow, Void in Mineral Aggregate (VMA),

Void in Mix (VIM), Void Filled with Asphalt (VFA), and Marshall Quotient (MQ) which is eligible for the AC mix, HRS and AC mix,

modified HRS in accordance with the General Specifications of Bina Marga Division 6 Revision 1 of 2018.

Table 3. Marshall Standard Asphalt Concrete-Wearing Course (AC-WC)

No	Characteristics	Requirements	Asphalt Content				
			5%	5.5%	6%	6.5%	7%
1	VMA	Min. 15	15.879	15.844	15.907	16.386	16.794
2			15.734	15.881	16.026	16.374	16.748
3			15.822	15.872	16.063	16.470	16.659
Average			15.81	15.87	16.00	16.41	16.73
1	VFA	Min. 65	70.382	78.031	85.175	89.542	94.132
2			71.153	77.814	84.426	89.622	94.446
3			70.681	77.870	84.193	89.000	95.048
Average			70.74	77.90	84.60	89.39	94.54
1	VIM	3-5	6.396	5.175	4.051	3.396	2.660
2			6.235	5.216	4.186	3.382	2.606
3			6.333	5.206	4.228	3.493	2.502
Average			6.32	5.20	4.15	3.42	2.59
1	Stability	Min. 800	941.531	944.076	1002.788	975.563	955.144
2			908.700	973.294	972.818	973.294	941.531
3			904.279	975.563	966.185	952.919	926.388
Average			918.17	964.31	980.60	967.26	941.02
1	Flow	Min. 2	3.10	3.25	3.30	3.43	3.58
2		Max 4	3.18	3.19	3.32	3.39	3.6
3			3.09	3.17	3.28	3.47	3.61
Average			3.12	3.20	3.30	3.43	3.60
1	MQ	Min. 250	303.720	290.485	303.875	284.421	266.800
2			285.755	305.108	293.017	287.107	261.536
3			292.647	307.748	294.569	274.617	256.617
Average			294.04	301.11	297.15	282.05	261.65

Based on Table 3, the increasing of asphalt content, the overall estimation value of VMA, VFA, and Flow will also increase, while the VIM

value decreases, and for the asphalt content value of 6% produces the greatest stability and MQ values.

Table 4. Marshall Standard Hot Rolled Sheet-Wearing Course (HRS-WC)

No	Characteristics	Requirements	Asphalt Content				
			7%	7.5%	8%	8.5%	9%
1	VMA	Min. 18	19.987	20.632	21.122	21.709	21.730
2			20.095	20.629	21.081	21.643	21.749
3			20.410	20.644	21.059	21.548	21.795
Average			20.16	20.63	21.09	21.63	21.76
1	VFA	Min 68	76.204	78.885	82.125	84.730	90.096
2			75.693	78.898	82.329	85.058	89.994
3			74.231	78.824	82.436	85.536	89.749
Average			75.38	78.87	82.30	85.11	89.95
1	VIM	4-6	6.231	5.819	5.229	4.758	3.594
2			6.357	5.816	5.180	4.678	3.618
3			6.726	5.834	5.154	4.563	3.675
Average			6.44	5.82	5.19	4.67	3.63
1	Stability	Min. 600	738.453	876.445	934.875	859.856	688.172
2			727.398	885.102	947.859	860.055	688.172
3			753.930	888.797	954.352	864.477	703.320
Average			739.93	883.45	945.70	861.46	693.22
1	Flow	-	3.20	3.3	3.60	3.5	3.4
2			3.00	3.4	3.50	3.6	3.5
3			3.10	3.3	3.50	3.6	3.5
Average			3.10	3.33	3.53	3.57	3.47
1	MQ	Min 250	230.767	265.589	259.688	245.673	202.403
2			242.466	260.324	270.817	238.904	196.621
3			243.203	269.332	272.672	240.132	200.949
Average			238.81	265.08	267.73	241.57	199.99

Based on Table 4, the increasing of asphalt content, the overall estimation value of VMA, VFA, and Flow will also increase, while the VIM

value decreases, and for the asphalt content value of 8% produces the greatest stability and MQ values.

Table 5. Marshall Asphalt Modification 0.5% SBS Asphalt Concrete-Wearing Course (AC-WC)

No	Characteristics	Requirements	Asphalt Content				
			5%	5.5%	6%	6.5%	7%
1	VMA	Min. 15	15.098	15.547	15.959	16.372	16.763
2			15.073	15.505	15.996	16.271	16.871
3			15.120	15.569	16.108	16.278	16.821
Average			15.10	15.54	16.02	16.31	16.82
1	VFA	Min. 65	74.639	79.729	84.763	89.549	94.254
2			74.785	79.986	84.529	90.216	93.529
3			74.510	79.592	83.834	90.167	93.858
Average			74.64	79.77	84.38	89.98	93.88
1	VIM	3-5	5.538	4.851	4.123	3.394	2.638
2			5.510	4.804	4.165	3.277	2.765
3			5.562	4.877	4.292	3.286	2.707
Average			5.54	4.84	4.19	3.32	2.70
1	Stability	Min. 1000	1073.119	1138.639	1195.631	1177.481	1161.600
2			1063.467	1152.525	1178.436	1186.556	1163.869
3			1054.623	1168.406	1191.702	1171.804	1147.483
Average			1063.74	1153.19	1188.59	1178.61	1157.65
1	Flow	Min. 2	2.74	2.93	3.05	3.24	3.63
2		Max 4	2.68	2.88	3.02	3.25	3.5
3			2.63	2.91	3.03	3.3	3.54
Average			2.68	2.91	3.03	3.26	3.56
1	MQ	Min. 250	391.649	388.614	392.010	363.420	320.000
2			396.816	400.182	390.211	365.094	332.534
3			400.997	401.514	393.301	355.092	324.148
Average			396.49	396.77	391.84	361.20	325.56

Based on Table 5, the increasing of asphalt content, the overall estimation or value of VMA, VFA, and Flow will also increase, while the VIM value decreases, and for the asphalt content value of 6% produces the greatest stability and MQ values.

The difference in requirements between standard asphalt Marshall and modified asphalt Marshall for AC is only in the stability value, which is a minimum of 1000 Kg.

Table 6. Marshall Asphalt Modification 0.5% SBS Hot Rolled Sheet-Wearing Course (HRS-WC)

No	Characteristics	Requirements	Asphalt Content				
			7%	7.5%	8%	8.5%	9%
1	VMA	Min. 18	19.724	20.586	21.148	21.900	22.265
2			19.660	20.550	21.127	21.748	22.262
3			19.627	20.489	21.208	21.832	22.213
Average			19.67	20.54	21.16	21.83	22.25
1	VFA	Min 68	77.474	79.105	81.998	83.787	87.328
2			77.788	79.279	82.103	84.534	87.342
3			77.954	79.576	81.704	84.121	87.590
Average			77.74	79.32	81.93	84.15	87.42
1	VIM	4-6	5.923	5.765	5.260	4.990	4.254
2			5.848	5.722	5.235	4.806	4.251
3			5.808	5.650	5.332	4.907	4.190
Average			5.86	5.71	5.28	4.90	4.23
1	Stability	Min. 600	806.992	928.383	1012.781	912.038	772.570
2			784.883	921.891	1006.289	897.641	757.422
3			756.141	952.914	1001.961	886.586	733.617
Average			782.67	934.40	1007.01	898.75	754.54
1	Flow	-	3.10	3.2	3.40	3.4	3.4
2			3.00	3.2	3.30	3.3	3.4
3			3.00	3.3	3.30	3.3	3.3
Average			3.03	3.23	3.33	3.33	3.37
1	MQ	Min 250	260.320	290.120	297.877	268.246	227.227
2			261.628	288.091	304.936	272.012	222.771
3			252.047	288.762	303.625	268.662	222.308
Average			258.00	288.99	302.15	269.64	224.10

Based on Table 6, the increasing of asphalt content, the overall value of VMA, VFA, and Flow will also increase, while the VIM value decreases,

and for the asphalt content value of 8% produces the greatest value of stability and MQ.

Table 7. Marshall Asphalt Modification 0.5% EVA Asphalt Concrete-Wearing Course (AC-WC)

No	Characteristics	Requirements	Asphalt Content				
			5%	5.5%	6%	6.5%	7%
1	VMA	Min. 15	14.960	15.532	15.999	16.285	16.467
2			15.000	15.591	16.016	16.347	16.485
3			15.123	15.519	15.974	16.300	16.420
Average			15.03	15.55	16.00	16.31	16.46
1	VFA	Min. 65	75.521	79.897	84.595	90.206	96.378
2			75.284	79.536	84.486	89.799	96.256
3			74.566	79.973	84.753	90.108	96.707
Average			75.12	79.80	84.61	90.04	96.45
1	VIM	3-5	5.373	4.822	4.155	3.280	2.278
2			5.418	4.889	4.175	3.351	2.298
3			5.555	4.808	4.127	3.297	2.223
Average			5.45	4.84	4.15	3.31	2.27
1	Stability	Min. 1000	1043.625	1120.952	1166.138	1127.569	1020.938
2			1030.303	1145.719	1147.483	1134.375	1027.744
3			1039.147	1159.331	1149.694	1125.374	1023.670
Average			1037.69	1142.00	1154.44	1129.11	1024.12
1	Flow	Min. 2	2.75	3.13	3.21	3.35	3.61
2		Max 4	2.73	3.07	3.23	3.31	3.63
3			2.79	3.05	3.19	3.38	3.62
Average			2.76	3.08	3.21	3.35	3.62
1	MQ	Min. 250	379.500	358.132	363.283	336.588	282.808
2			377.400	373.198	355.258	342.711	283.125
3			372.454	380.109	360.406	332.951	282.782
Average			376.45	370.48	359.65	337.42	282.90

Based on Table 7, the increasing of asphalt content, the overall value of VMA, VFA, and Flow will also increase, while the VIM value decreases, and for the asphalt content value of 6% produces

the greatest stability and MQ values. The difference in requirements between standard asphalt Marshall and modified asphalt Marshall for AC is only in the stability value, which is a minimum of 1000 Kg.

Table 8. Marshall Asphalt Modification 0.5% EVA Hot Rolled Sheet-Wearing Course (HRS-WC)

No	Characteristics	Requirements	Asphalt Content				
			7%	7.5%	8%	8.5%	9%
1	VMA	Min. 18	19.773	20.604	21.230	21.903	22.298
2			19.790	20.473	21.226	21.883	22.266
3			19.728	20.508	21.228	21.907	22.107
Average			19.76	20.53	21.23	21.90	22.22
1	VFA	Min 68	77.239	79.017	81.599	83.769	87.161
2			77.152	79.654	81.619	83.868	87.326
3			77.456	79.483	81.605	83.749	88.131
Average			77.28	79.38	81.61	83.80	87.54
1	VIM	4-6	5.979	5.787	5.358	4.994	4.295
2			6.000	5.631	5.353	4.970	4.254
3			5.927	5.672	5.357	4.999	4.059
Average			5.97	5.70	5.36	4.99	4.20
1	Stability	Min. 600	729.609	921.891	995.469	902.963	705.484
2			756.141	932.711	1012.781	877.742	692.500
3			740.664	930.805	993.305	873.320	688.172
Average			742.14	928.47	1000.52	884.68	695.39
1	Flow	-	3.20	3.2	3.50	3.5	3.4
2			3.10	3.3	3.50	3.5	3.4
3			3.00	3.4	3.40	3.6	3.5
Average			3.10	3.30	3.47	3.53	3.43
1	MQ	Min 250	228.003	288.091	284.420	257.989	207.495
2			243.916	282.640	289.366	250.783	203.676
3			246.888	273.766	292.148	242.589	196.621
Average			239.60	281.50	288.64	250.45	202.60

Based on Table 8, the increasing of asphalt content, the overall value of VMA, VFA, and Flow will also increase, while the VIM value decreases,

and for the asphalt content value of 8% produces the greatest stability and MQ values.

3.3. Optimum Asphalt Content

From the results of standard asphalt Marshall testing and modified asphalt Marshall testing in **Table 9**. Optimum Asphalt Content

Table 3 through 8 can be determined the value of optimum asphalt content, the optimum asphalt content value can be seen in Table 9.

	Standard Marshall	Marshall Asphalt Modification 0,5% SBS	Marshall Asphalt Modification 0,5% EVA
Asphalt Concrete- Wearing Course (AC-WC)	6.16%	6.08%	6.02%
Hot Rolled Sheet- Wearing Course (HRS-WC)	7.9%	7.88%	7.835%

After obtaining the optimum asphalt content, the optimum asphalt content is used as a reference for obtaining the Marshall Parameter value for the

three mixtures of Asphalt Concrete-Wearing Course (AC-WC) and Hot Rolled Sheet-Wearing Course (HRS-WC).

Table 10. Marshall Test Results against Optimum Asphalt Content (KAO)

NO	Parameter	Asphalt Concrete-Wearing Course (AC-WC) Mixture			Hot Rolled Sheet-Wearing Course (HRS-WC) Mixture		
		Standard Asphalt	Asphalt Modification 0,5% EVA	Asphalt Modification 0,5% SBS	Standard Asphalt	Asphalt Modification 0,5% EVA	Asphalt Modification 0,5% SBS
1	KAO	6.16	6.02	6.08	7.9	7.835	7.88
2	VMA	16.128	16.009	16.033	21.054	21.045	21.052
3	VFA	86.130	84.833	85.513	81.324	80.656	81.120
4	VIM	3.923	4.118	4.013	5.385	5.524	5.429
5	Stability	979.484	1162.648	1189.285	934.310	981.339	985.073
6	Flow	3.338	3.226	3.087	3.507	3.432	3.302
7	MQ	293.451	359.947	385.289	267.016	286.101	298.242

3.4. Marshall Immersion Test Results

Marshall Immersion test was conducted to obtain index of retained strength based on the optimum asphalt content. The requirement for the

index of retained strength according to the General Bina Marga Division 6 Revision 1 Year 2018 specifications is more than 90%.

Table 11. Index of Retained Strength on Asphalt Concrete-Wearing Course (AC-WC)

No.	Mixture Type	KAO (%)	Stability (kg)		Index of retained strength (%)	Requirements	Information
			Standard	Immersion			
1	Standard Asphalt Mixture	6.16	988.20	912.79	92.37	≥ 90%	Fulfill
2	SBS modified asphalt mix	6.08	1195.25	1115.47	93.33		Fulfill

3	EVA modified asphalt mix	6.02	1160.43	1076.13	92.74	Fulfill
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Based on Table 11, the test specimen for the mixture of SBS modified asphalt AC-WC produces the highest index of retained strength value, which is 93.33% compared to the test specimen for the mixture of standard asphalt AC at 92.37% and the mixture for EVA modified asphalt AC-WC at 92.74%.

Figure 7. Comparison IRS on AC-WC mixture

Table 12. Index of Retained Strength on Hot Rolled Sheet-Wearing Course (HRS-WC)

No.	Mixture Type	KAO (%)	Stability (kg)		Index of Retained Strength (%)	Requirements	Information
			Standard	Immersion			
1	Standard Asphalt Mixture	7.9	914.6	825.46	90.25		Fulfill
2	SBS modified asphalt mix	7.88	997.40	912.38	91.48	≥ 90%	Fulfill
3	EVA modified asphalt mix	7.83	989.77	896.55	90.58		Fulfill

Based on Table 12, the test specimen of SBS modified asphalt HRS-WC mixture produced the highest index of retained strength of 91.48% compared to the standard asphalt HRS-WC mixture test specimen of 90.25% and EVA modified asphalt HRS-WC of 90.58%.

3.5. Cantabro Test Results

Cantabro testing is carried out to obtain a percent of weight loss (wear value) based on the optimum asphalt content. Requirements for the wear index value of the 2010 General Bina Marga specification are less than 20%.

Figure 8 . Comparison IRS on HRS-WC mixture

Table 13. Percent of Weight Loss of Asphalt Concrete-Wearing Course (AC-WC)

No.	Type of Specimen	Optimum Asphalt Content	Initial Weight (gram)	Final Weight (gram)	Percentage of Weight Loss (%)	Average (%)	Requirements Specification	Information
1	Standard Asphalt Mixture	6.16%	1135.7	1089.5	4.07	4.04	<20%	Fulfill
			1136.2	1091.3	3.95			Fulfill
			1137.4	1090.8	4.10			Fulfill
2	SBS modified asphalt mix	6.08%	1136.1	1099.8	3.20	3.14	<20%	Fulfill
			1133.6	1097.9	3.15			Fulfill
			1135.8	1100.7	3.09			Fulfill
3	EVA modified asphalt mix	6.02%	1136.4	1096.2	3.54	3.57	<20%	Fulfill
			1139.7	1098.5	3.61			Fulfill
			1138.3	1097.8	3.56			Fulfill

Based on Table 13, the specimens of standard asphalt AC-WC mixture are 4.04%, SBS modified AC-WC asphalt mixtures are 3.14%, and EVA modified AC-WC asphalt mixtures are 3.57%. The SBS modified AC-WC asphalt mixture was better than the standard AC-WC mixture and the EVA modified AC-WC mixture.

Figure 9. Weight Loss on AC-WC

Table 14. Percent of Weight Loss of Hot Rolled Sheet-Wearing Course (HRS-WC)

No.	Type of Specimen	Optimum Asphalt Content	Initial Weight (gram)	Final Weight (gram)	Percentage of Weight Loss (%)	Average (%)	Requirements Specification	Information
1	Standard Asphalt Mixture	7.9%	1134.7	1090.3	3.91	3.91	<20%	Fulfill
			1135.8	1091.6	3.89			Fulfill
			1135.3	1090.8	3.92			Fulfill
2	SBS modified asphalt mix	7.88%	1136.9	1103.2	2.96	2.86	<20%	Fulfill
			1134.7	1102.5	2.84			Fulfill
			1135.4	1103.8	2.78			Fulfill
3	EVA modified asphalt mix	7.83%	1134.5	1097.3	3.28	3.34	<20%	Fulfill
			1135.7	1096.6	3.44			Fulfill
			1133.6	1096.1	3.31			Fulfill

Based on Table 14, the specimen of standard asphalt HRS-WC mixture was 3.91%, SBS modified asphalt HRSWC mixture was 2.86%, and EVA modified asphalt HRS-WC mixture was 3.34%. The SBS modified asphalt HRS-WC mixture performed better than the standard asphalt HRS-WC mixture and the EVA modified asphalt HRS-WC mixture.

Figure 10. Weight Loss on HRS-WC

4. CONCLUSION

4.1. Based on the Asphalt Pen. 60/70, SBS Modified Asphalt, and EVA Modified Asphalt Characteristics Testing

- The penetration and ductility test results of SBS modified asphalt are smaller than EVA modified asphalt and asphalt Pen. 60/70. This is because when mixing, SBS modified asphalt hardens faster in cold conditions, so it has stiffer properties, and during ductility testing makes SBS modified asphalt break faster.
- The results of the flash point and burn point test, EVA modified asphalt were higher than SBS modified asphalt and asphalt Pen. 60/70, so that the EVA modified asphalt was not susceptible to burn at high temperatures.
- The test results for the softening point of SBS modified asphalt and EVA modified asphalt were higher than asphalt Pen. 60/70, so that modified asphalt (SBS and EVA) had the advantage of being more resistant to high temperatures and would not easily melt where for the requirements of the asphalt resistant to high temperature and does not melt is $\geq 48^{\circ}\text{C}$.

4.2. Based on Standard Marshall Testing

- The KAO values obtained by a mixture of AC Asphalt Standard, AC asphalt modification 0.5% EVA and AC asphalt modification 0.5% SBS were 6.16%, 6.02% and 6.08%, respectively. Meanwhile, the KAO values

obtained by a mixture of Standard Asphalt HRS, HRS asphalt modification 0.5% EVA and HRS asphalt modification 0.5% SBS were 7.9%, 7.835% and 7.88%, respectively. AC mixture, HRS asphalt modification 0.5% EVA and AC, HRS asphalt modification 0.5% SBS have lower KAO values than the AC mixture, HRS Standard Asphalt. So it can be concluded, the addition of EVA and SBS polymers in the asphalt mixture makes the use of asphalt content less than using no polymer.

- The mixture of AC-WC and HRS-WC asphalt modification 0.5% SBS is superior in stability and MQ values but has the smallest flow value than the other two mixtures, which causes the mixture to be better at withstanding permanent deformation when receiving past loads without changing shape. The mixture of AC-WC and HRS-WC asphalt modification 0.5% EVA has a stability and MQ value that is not much different from the mixture of AC-WC and HRS-WC asphalt modification 0.5% SBS but has a higher flow value. The VFA value obtained by the AC-WC mixture and HRS-WC asphalt modification 0.5% EVA is the smallest from the two other mixtures. The AC and HRS Standard Asphalt mixture had the smallest stability and MQ values, but had the largest VFA and flow values of the other two mixtures.

4.3. Based on Marshall Immersion Testing

The Index of Retained Strength (IRS) on the test specimens of the AC-WC asphalt mixture was 92.37%, the AC-WC mixture of SBS modified asphalt was 93.33%, and the AC-WC mixture EVA modified asphalt was 92.74%. The Index of Retained Strength on the test specimen of standard asphalt HRS-WC mixture is 90.25%, the HRS-WC asphalt modified SBS mixture is 91.48%, and the HRS-WC asphalt modified EVA mixture is 90.58%. The sample specimen of SBS modified asphalt mixture produced the best index of retained strength compared to the sample of standard asphalt mixture and EVA modified asphalt mixture. The greater the index of retained strength value, indicating that the sample has better resistance to damage due to the influence of water, temperature and weather.

4.4. Based on Cantabro Testing

The average percent of weight loss (wear value) of the standard AC-WC and HRS-WC asphalt mixture was 4.04% and 3.91%, the SBS modified asphalt mixture of AC-WC and HRS-WC layers was 3.14% and 2.86%, then the EVA modified asphalt mixture of AC-WC and HRS-WC layers with an average wear rate of 3.57% and 3.34%. From the results of the data analysis, it can be seen that the test specimens of the SBS modified asphalt mixture are more resistant to wear than the standard asphalt mixture and EVA modified asphalt mix specimens, because the smaller the percent of weight loss indicates that the mixture is getting stronger because of the lack of mixed particles apart due to the collision event in the spinning machine (Los Angeles), so this causes the high durability of the mixture and the mixture can last for a long time. This provides an illustration of the extent to which the asphalt pavement is resistant to friction between the vehicle wheels and the road surface.

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