IOP Conf. Series: Materials Science and Engineering **732** (2020) 012016 doi:10.1088/1757-899X/732/1/012016

Evaluation and analysis of flexible pavement overlay thickness using asphalt modified SIR 20 on Dawuan – Cikampek Road using AASHTO 1993 method

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Abstract. Flexible pavement structural evaluation using AASHTO 1993 method is carried out based on deflection values from the survey using the Falling Weight Deflectometer (FWD) which will be used to calculate the Effective Structural Number (SNeff), Structural Number in Future (SNf) and overlay thickness. Flexible pavement is susceptible to rutting damage and permanent deformation. To increase rutting damage and permanent deformation resistance, Asphalt Concrete Wearing Course (ACWC) was being modified by adding SIR 20 material. In determining overlay thickness using AASHTO 1993 method, one of the factors influencing the thickness was properties of ACWC material. In this paper, a case study is carried out on the Raya Dawuan – Cikampek Road. The result of this case study were ACWC-Modified overlay thickness was thinner than ACWC-Normal. ACWC Modified pavement overlay structure thickness obtained at 80 mm meanwhile in ACWC-Normal was 100 mm.

1. Introduction

The majority of Indonesia's natural rubber production consists of original rubber collected as Standard Indonesian Rubber (SIR) 20. On the other hand, heavy traffic loads, road surface temperatures reaching 70 degrees Celsius, high rainfall, and poor drainage, can increase various types of damage to the reinforcement structure earlier than converted. One type of damage that often occurs in asphalt mixed layers of pavement surface is rutting. The occurrence of rutting damage is highly dependent on the density and temperature of the asphalt mixture [1]. To overcome the problem of damage to the AC-WC layer. One innovation that can be done is to modify the asphalt mixture with natural rubber added ingredients. In addition, the method of planning the pavement structure for both flexible pavement and rigid pavement has increased development over the last two improvements. The mechanistic method is expected to be used to improve the quality of pavement structure design both for new pavement planning (new pavement design) and for evaluating existing pavement structures.

2. Literature review

Nindya Putri Yulianti has conducted research on the effect of adding solid natural rubber to AC-WC pavement layers with rubber variations of 2%, 4%, 6% and 8% [2]. However, the stability value obtained in this study has not shown the optimum value at the maximum rubber content of 8%. Thus, further research needs to be done with the level of variation of the rubber slicing to the level of variation of the rubber. In addition, there have also been tests on rubber asphalt [3], among others:

- Asphalt rubber quality test: penetration, softening point, flash point, viscosity and ductility.
- Tests for aggregate and filler quality: gradation, specific gravity, abrasion, sand equivalent and viscosity.
- Marshall Test: Marshall stability, flow, and Marshall Quotient.

Empirical methods in the design of pavement structures are developed based on test results or experience. Thus the relationship between input design and pavement structure failure results from experience, Test or a combination of the two. One of the empirical methods is AASHTO 1993 [4]. This design is derived from the concept of pavement structure failure which is based on a decrease in the quality of service levels over time or the cumulative amount of traffic load that can be received by a pavement structure. Whereas the cumulative amount of traffic load introduced as 18-kip is equivalent to a single axle load (ESAL).

3. Materials, tools and specimens

The materials used in this study are as follows:

(a) Solid Natural Rubber SIR 20 (b) Aggregates (c) Asphalt Penetration 60/70

Figure 1. Materials.

The tools used in this study are as follows:

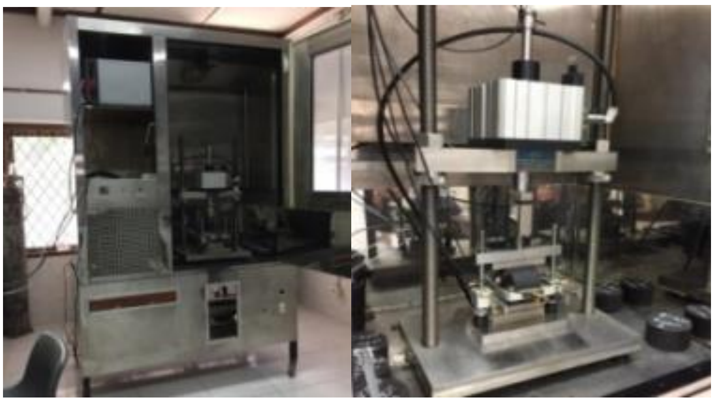

Figure 2. Tools.

The specimen used in this study are as follows:

Figure 3. Specimens.

4. Methodology

The location of road pavement that used in this study are on Raya Dawuan – Cikampek road. Tests conducted in this study include the characteristics test of Marshall, GMM, Pre Refusal Density (PRD) and Soaking Index Test. After obtaining the results of these tests, UMATTA test was performed. Then, the overlay design thickness calculation was performed using the AASHTO 1993 method. The following is a table of test objects conducted in this study:

Table 1. Marshall standard test pieces (2x75) collision.

Asphalt Levels	AC-WC Normal	Asphalt Levels Variation (%)			
		7	9	11	13
A. Marshall Test					
-1,0%	3	3	3	3	3
-0,5%	3	3	3	3	3
Pb	3	3	3	3	3
+0,5%	3	3	3	3	3
+1,0%	3	3	3	3	3
B. Gravity Maximum of Mixed (GMM) Test					
-1,0%	1	1	1	1	1
-0,5%	1	1	1	1	1
Pb	1	1	1	1	1
+0,5%	1	1	1	1	1
+1,0%	1	1	1	1	1
C. Percentage Refusal Density (PRD) Test					
KAO +0,5% KAO KAO -0,5%	3	3	3	3	3
D. Mixed Immersion Index Test (IP) Against KAO					
30 Minutes	3	3	3	3	3
24 Hours	3	3	3	3	3

5. Discussion and data analysis

In this section will be discussed about the results of research. The following results of the study:

5.1. UMATTA test

Modulus of elasticity testing uses Universal Material Testing Apparatus (UMATTA) at 25°C and 30°C to obtain variations in the modulus of elasticity of the mixture that will be used as input parameters at the calculation and analysis stage. Calculation of the pavement structure of the empirical method is carried out by the AASHTO 1993 method, for several data which is not obtained from the results of laboratory testing can be obtained from secondary data of road planning which is considered relevant.

Table 2. UMATTA testing result.

No.	Mixture's Code	Temperature of the UMATTA test (°C)	Deviation Standard (%)	Coefficient Variant (CV) (%)	Modulus Resilien (MPa)
1	AC-WC 9% KRT 25C NO. 1	25	60,21	3,55	1.698
2	AC-WC 9% KRT 25C NO. 2		71,65	3,93	1.824
3	AC-WC 9% KRT 25C NO. 3		48,59	2,79	1.742
	Mean of MR		60,15	3,423	1.754,6
4	AC-WC 9% KRT 30C NO. 4	30	18,24	2,02	902
5	AC-WC 9% KRT 30C NO. 5		17,19	1,97	873
6	AC-WC 9% KRT 30C NO. 6		33,11	2,94	1126
	Mean of MR		22,85	2,31	967

5.2. Data analysis

There are secondary data obtained from P2JN, among these data are:

- Existing Road Thickness (a)
- Falling Weight Deflectometer (FWD) (b)
- Average Daily Traffic (c)

These are the datas:

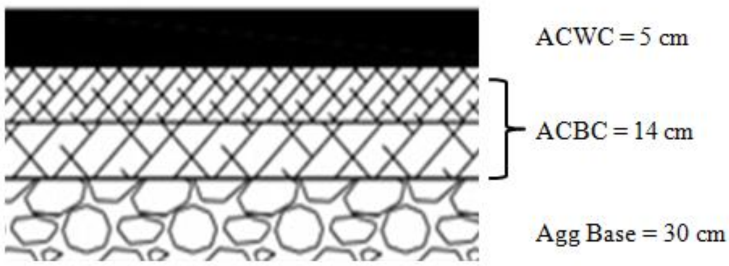

Figure 4. Existing road thickness.

After that, the calculation is carried out with the 1993 AASHTO Method. The calculations are as follows:

Table 3. Load ESAL Factor (LEF).

Variation of Vehicles	GVW (ton)	LEF				LEF Total
		Front	Middle 1	Middle 2	Back	
Group 2 & 3	2	0,000223	-	-	0,000223	0,000446
Group 4	5.3	0,001826	-	-	0,026554	0,028379
Group 5a	8	0,009339	-	-	0,154263	0,163602
Group 5b	14.2	0,104903	-	-	1,777877	1,882780
Group 6a	8.3	0,010861	-	-	0,180818	0,191679
Group 6b	15.1	0,136693	-	-	2,287105	2,423798
Group 7a	26	0,378051	-	-	2,057313	2,435365
Group 7b	42	0,721828	4,433897781	-	3,785786	8,941512

From Table 3, the highest LEF value reached by vehicles Group 7b with LEF total 8,941512. This means, vehicle Group 7b has the highest contribution on causing damage on this road pavement.

Table 4. Recapitulation of $SN_{eff.}$

Segment	Kilometers	Length of Segment (m)	Mr (psi)	Ep (psi)	ae	r	r > 0.7ae	SN_{eff}
1	0 – 0,4	400	28.250,66	109.260,16	30,851	35,433	OK	4,150
2	0,4 – 1,2	400	30.589,23	306.967,2	42,027	35,433	OK	5,856
3	1,2 – 2	800	17.216,78	73.215,31	31,807	35,433	OK	3,632
4	2 – 2,8	800	26.451,90	194.090,46	37,949	35,433	OK	5,026
5	2,8 – 3,6	800	26.310,74	63.168,62	26,498	35,433	OK	3,457
6	3,6 - 4	400	25.071,81	200.017,70	38,996	35,433	OK	5,077

From Table 4, the highest SN_{eff} value reached on Kilometers 0,4-1,2 with SN_{eff} value of 5,856.

Table 5. Recapitulation of $SN_{future.}$

Segment	SN eff Geo-phone 6	Calculation Process						SN Future
		Mr Design	ZR.So	9.36log (SN+1)-0.20	log((Po-Pt)/(Po-Pf))	0.40+1094/(SN+1)^5.19	2.32xlog ITP-8.07	
1	4,15	10049,94	-0,4667	7,0289	-0,2218	0,5073	1,21501	4,920
2	5,86	11014,08	-0,4667	6,9232	-0,2218	0,5228	1,30731	4,768
3	3,63	5734,28	-0,4667	7,6514	-0,2218	0,4485	0,64967	5,900
4	5,03	9328,08	-0,4667	7,1134	-0,2218	0,4963	1,13991	5,044
5	3,46	7949,69	-0,4667	7,2933	-0,2218	0,4766	0,97881	5,318
6	5,08	8810,22	-0,4667	7,1782	-0,2218	0,4887	1,08236	5,141

From Table 5, the highest SN Future value reached on Segment 3 with SN Future value of 5,9.

Table 6. Overlay thickness for normal mixtures.

Segment	Kilometers	Length of Segment (m)	SN_{eff}	SN_{future}	Difference of SN_{OL}	H_{OL} (inch)	H_{OL} (cm)
1	0 - 0,4	400	4,15	4,920	0,7699	2,9	7,4
3	1,2 - 2	800	3,63	5,900	2,2679	8,5	21,7
4	2 – 2,8	800	5,03	5,044	0,0181	0,1	0,2
5	2,8 – 3,6	800	3,46	5,318	1,8604	7,0	17,8
6	3,6 – 4	400	5,08	5,141	0,0646	0,2	0,6

From Table 6, the highest H_{OL} (cm) overlay thickness for Normal Mixtures value reached on Segment 3 with H_{OL} (cm) value of 21,7 cm.

Table 7. Overlay thickness for modification mixtures.

Segment	Kilometers	Length of Segment (m)	SN_{eff}	SN_{future}	Difference of SN_{OL}	H_{OL} (inch)	H_{OL} (cm)
1	0 - 0,4	400	4,15	4,920	0,7699	2,2	5,6
3	1,2 - 2	800	3,63	5,900	2,2679	6,5	16,6
4	2 – 2,8	800	5,03	5,044	0,0181	0,1	0,1
5	2,8 – 3,6	800	3,46	5,318	1,8604	5,4	13,6
6	3,6 – 4	400	5,08	5,141	0,0646	0,2	0,5

From Table 7, the highest H_{OL} (cm) overlay thickness for Modification Mixtures value reached on Segment 3 with H_{OL} (cm) value of 16,6 cm.

6. Conclusion

a. The characteristics of the modified mixture for modulus of elasticity reaches a value of 1.754,67 MPa, when compared to the modulus of elasticity in a normal mixture with a modulus of elasticity of 1.100 MPa, an increase of 60% occurs.
b. Calculation of overlay thickness requirement for segment 2 does not require overlay because SN_{eff} value (existing road condition) is better than SN_{Future} which is expected to be achieved by the pavement structure for 10 years of service life. In segment 3, the thickest overlay thickness is required, with a H_{OL} value of 21,7 cm. In 1993 AASHTO, the minimum concrete asphalt layer thickness was 4,0 inches or 10,2 cm for traffic volumes of more than 7 million ESALs.
c. The overlay thickness design for AC-BC layers in segments 1, 3 and 5 is given the same value which is 12 cm. Whereas in segments 4 and 6, the AC-BC layer overlay is not necessary because the thick value of the AC-WC layer overlay meets the $SN_{Trial}> SN_{OL}$ requirements.
d. The total thickness of the overlay using AC-WC Modification is thinner compared to the total thickness of the overlay using AC-WC Normal.
e. The implication of this finding is the use of SIR 20 rubber as a modification material on the asphalt surface layer mixtures are successfully causing the design of overlay thickness become thinner than the design of overlay thickness with a normal asphalt mixtures.

Acknowledgement
The authors thank the entire civitas materials-laboratory of Bandung State Polytechnic and PUSJATAN especially to all the staff of Asphalt Laboratory which has helped and provided useful knowledge for authors.

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