Performance mix asphalt concrete wearing course with addition of plastic bottles of polyethylene terephthalate

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Abstract: The performance of the modified asphalt concrete pavement structure is done because of the increasing traffic load that occurs along with population growth. The study is needed to review the pavement structure whether it is still able to withstand the load or not at all. An Evaluation was carried out using Falling Weight Deflectometer (FWD) field data to obtain deflection data. Laboratory testing of UMATTA used modified asphalt mixture using Polyethylene Terephthalate (PET) type plastic bottle waste to obtain the relative strength coefficient value as an application combined with secondary data from average daily traffic data on the roads of the Batas Medan City– Batas Lubuk Pakam City. Structural analysis shows that the entire segment requires an added layer with the thickness that is different due to the segmentation performed. In this study to maintain the required service level, namely SCI>1, the pavement must receive periodic maintenance and routine maintenance. elated to using asphalt modification using PET will produce a lower pavement thickness of 11 cm compared to the pavement thickness by the 2017 Pavement Design Manual standard of 16 cm.

1. Introduction

The construction of road pavement structures in Indonesia is inseparable from the maintenance, improvement, and construction that requires measurable planning and planning technical standards so that later construction can be carried out that is of the right quality and on time. Suitability of quality work results will produce a sense of security and comfort for road users. That the Pen 60/70 asphalt type is widely used as an asphalt mixture material on the surface layer of a pavement structure. However, with the development of traffic, the 60/70 asphalt type is already inadequate, especially to withstand deformation so that an alternative type of asphalt material with lower stiffness is needed to withstand the potential for fatigue cracking [1]. On the other hand, the National Road in North Sumatra has a length of 2632.22 km. Data obtained for the second semester of 2018 showed that roads with good conditions were 38.87%, moderate conditions were 52.39%, and conditions were still damaged at 8.64% [2]. This needs a solution to produce good road conditions and one of them is to use modified asphalt.

Asphalt is used to make pavement mixtures and must have adequate performance, strength, and durability. The addition of Polyethylene Terephthalate (PET) by dry process in asphalt mixture can increase the stability value of the mixture compared to the mixture without PET [3]. Furthermore, research on types of plastic polymers namely PET added to asphalt Penetration 80/100 or asphalt mixtures and can provide an increase in stability values of up to 60% to 70% of conventional asphalt

mixes [4]. Thus, this study aims to examine the effect of the addition of PET on the AC-WC layer which is expected to improve the performance of road pavement structures in road maintenance.

2. Experimental method

The study was conducted using primary data and secondary data. Primary data were taken from the results of testing the characteristics of the mixture of laston AC-WC modification and non-modification and performance testing, namely UMATTA. Secondary data are vehicle volume data and deflection data obtained from P2JN North Sumatra. The following are the steps carried out in conducting this research. For variations in laboratory testing on asphalt mixing with PET namely 0%, 3%, 6%, 9% and 12%. The discussion and analysis that will be explained in this section outline are divided into two main parts, namely the first part of the discussion and analysis will focus on the results of the testing performance of modified asphalt mixtures using Polyethylene Terephthalate (PET) plastic bottle waste materials with a wet process. The modified asphalt mixture testing is intended as UMATTA test. The main materials used in this study are aggregates, 60/70 bitumen, and plastic bottle waste materials. Therefore, in this, study the application of the results of the first part of a flexible pavement structure is to analyze the thickness of the Asphalt Concrete-Wearing Course (AC-WC) bending pavement structure from a handling of the Medan-boundary city of Lubuk Pakam.

3. Test result and discussion

The influence of the resilient modulus value due to temperature shows the modulus of elasticity obtained from Universal Material Testing Apparatus For Asphalt (UMATTA) testing using Pen 60/70 asphalt or without modification with modified asphalt mixture has decreased with temperature factors. Factors influencing the value of resilient modulus are a gradation of the mixture, maximum nominal size of aggregate, asphalt content, compaction method, specimen size of specimens, the variation of test temperature, load and time of loading [5]. **Table 1** that the test results have increased but not too significant.

Table 1. UMATTA test results.

AC-WC Mixture	Temperature (°C)		
	25	**35**	**45**
PET 0% (Mpa)	2117.9	635.6	171.7
PET 9% (Mpa)	2229.2	634.3	230.9

The initial stage in processing deflection data using the FWD tool is to correct the data following predetermined standards. This will require data on temperature, season and the effect of the test load used when testing in the field. The difference between the initial deflection value and the deflection value after correction can be seen in **Figure 1** segmentation is carried out by having each segment have the same level of uniformity ie < 30% to avoid over-design. After all deflection data, a six-segment road segmentation is obtained.
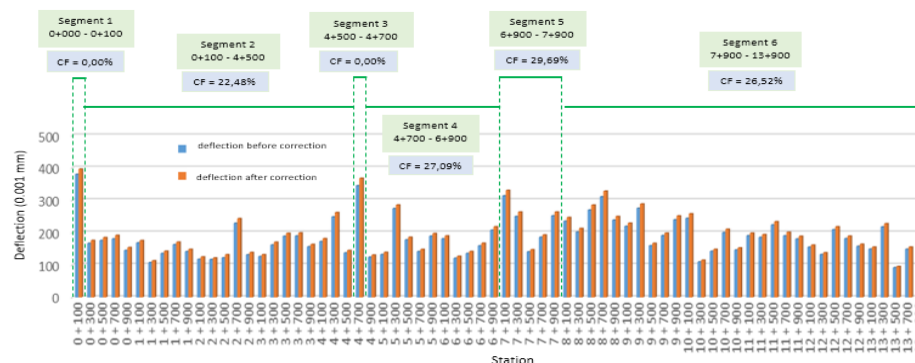

Figure 1. FWD deflection data for Medan-Lubuk Pakam City Boundary Roads.

Based on the testing data of the FWD tool to calculate the MR value, the data used are load data (P), deflection data (df) and distance data from the load center (r) from geophone no. 9 then it can be seen in **Table 2** MR will be used in AASHTO parameters which are calculated based on segmentation division. Furthermore, MR will be used to calculate the SN needed in the coming year or SN required.

Table 2. Resilient Modulus (MR) Results from FWD segmentation.

Station	P (kN)	C	d_{f9} (inch)	r_9 (inch)	MR
0+000 - 0+100	40,54	0,33	0,00206	70,8661	4948,40
0+100 - 4+500	40,09	0,33	0,00241	70,8661	4187,37
4+500 - 4+700	39,61	0,33	0,00274	70,8661	3631,79
4+700 - 6+900	40,30	0,33	0,0018	70,8661	5599,69
6+900 - 7+900	40,31	0,33	0,0022	70,8661	4702,67
7+900 - 13+900	40,33	0,33	0,0020	70,8661	4989,45

SNeff is the capacity of the pavement structure at the time of road testing using FWD in 2017. The limitation of the effective Structural Number calculation used is the Kavussi et All method and the SNnective results with that method can be seen in the table below. It can be seen the results of the equation Kavussi et all strength of the existing pavement structure.

SNreq calculation can be done after getting ESAL or CESA values and MR data that are used as a result of the segmentation division. In addition to calculating SNreq, the parameters used in advance are determined. The parameters used include reliability (R), overall standard deviation (So), initial serviceability (Po), and terminal serviceability (Pt). For arterial roads, the R-value is 95% of the range 85-99% so that the standard deviation (ZR) values are -1.645. So, values are recommended for flexible pavement 0.45. The determination then determines the Po and Pt values with the respective values determined 4.2 and 2.5. The results of SNreq calculations where the review begins in 2018 and ends in 2022 to compare the maintenance that is reviewed annually from the structure of the road section. The following **Table 3** shows the results of SNreq for five years.

Table 3. Annual SNreq results according to CESA review.

Segment	SN_{eff} 2017	SN_{req} 1 2018	2 2019	3 2020	4 2021	5 2022
1	3.460	4.36	4.84	5.14	5.37	5.55
2	4.871	4.62	5.12	5.43	5.66	5.84
3	4.182	4.85	5.36	5.68	5.91	6.11
4	4.085	4.17	4.64	4.94	5.16	5.33
5	3.549	4.44	4.93	5.23	5.45	5.64
6	4.029	4.35	4.83	5.13	5.35	5.53

The results from **Table 4** show that there will be the handling of the pavement structure for the next 5 years (2018-2022). The type of treatment chosen is based on the SCI pavement conditions. Structural evaluations that produce SCI values of 0.5 - 0.7 will be carried out by overlay or can be said to be periodic maintenance with structural improvements in 2020 in segments 1 and 5 while in segments 3 in 2022 which is a type of handling improvement in the pavement structure.

Table 4. Handling of Pavement Structure During the Age of the 5 Year Plan.

Seg ment	Station	SN_{eff}	2020		2021		2022	
			SCI	Information	SCI	Information	SCI	Information
1	0+00 - 0+100	3.46	0.67	**structural overlay**	1.21	routine maintenance	1.02	routine maintenance
2	0+00 - 4+500	4.87	0.90	functional overlay	0.86	functional overlay	0.83	functional overlay
3	4+500 - 4+700	4.18	0.74	functional overlay	0.71	functional overlay	0.68	**structural overlay**
4	4+700 - 6+900	4.08	0.83	functional overlay	0.79	functional overlay	0,76	functional overlay
5	6+900 - 7+900	3.55	0.68	**structural overlay**	1.25	routine maintenance	1.13	routine maintenance
6	7+900 - 13+900	4.03	0.78	functional overlay	0.75	functional overlay	0.73	functional overlay

The SCI value is taken from the quotient between SNeffective and SNrequired or it can be seen in the equation below:

$$SCI = \frac{SN_{eff}}{SN_{req}} \leq 0,7$$

The results of the equation explain that the SCI value is smaller than 0.7, it requires an overlay, but if the SCI value is greater than 0.7, then it does not require an overlay. Detailed SCI values can be seen in **Table 5**.

Table 5. Road handling based on SCI Value.

SCI	Handling
>1	Routine maintenance
0,7 – 1,0	Functional Overlay
0,5 – 0,7	Structural Overlay
< 0,5	Reconstruction

Source: Ministry of Public Works (2011)

Previously the modulus of elasticity was used to find the value of a1 using the equation below. E value is the same as the modulus of elasticity in MPa or can be seen in **Table 6** The modified modulus elastic value is obtained from the optimum AC-WC mixture characteristic, which is the use of 9% PET. A normal AC-WC mixture uses 0% PET and the elastic modulus of the standard AC-WC mixture refers to 2017 MDP which is 1100 MPa.

Table 6. Coefficient values for each AC-WC pavement model.

AC-WC Mixture	MR (Mpa)	a
Modification	2.229.20	0.39
Normal	2.117.90	0.38
Standard	1.100.00	0.27

In **Figure 2** and **Figure 3** is a pavement structure that will be overlaid based on the results of deflection data and calculations that have been done. **Figure 3** is a pavement structure model using a standard AC-WC mixture where the thickness used must be divided into two parts, namely AC-WC thickness, and AC-BC thickness. This is done so that the pavement structure remains strong and also economical. In the AC-BC pavement structure, a 10.0 cm thick planning is carried out and the rest is the surface of the

AC-WC, namely in segments 1 and 5 the AC-WC pavement structure has a thickness of 6 cm while segment 3 has 8 cm.
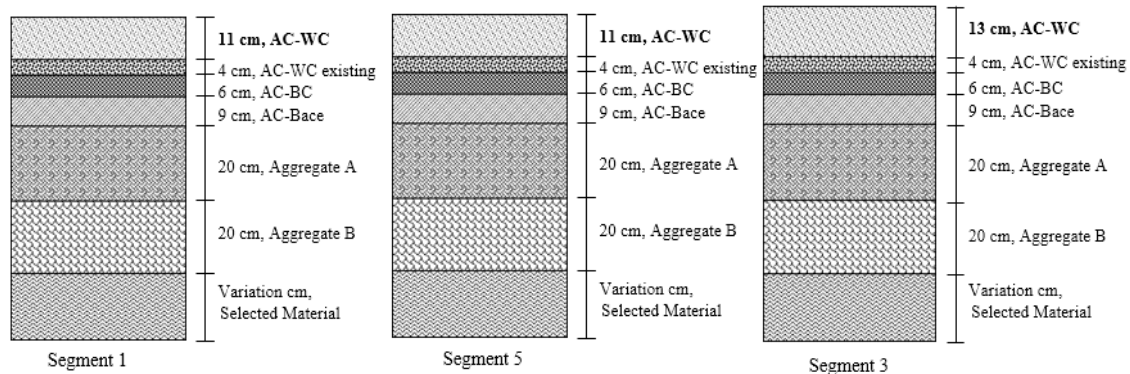

Figure 2. Thick overlay using a mixture of AC-WC modification and normal AC-WC.
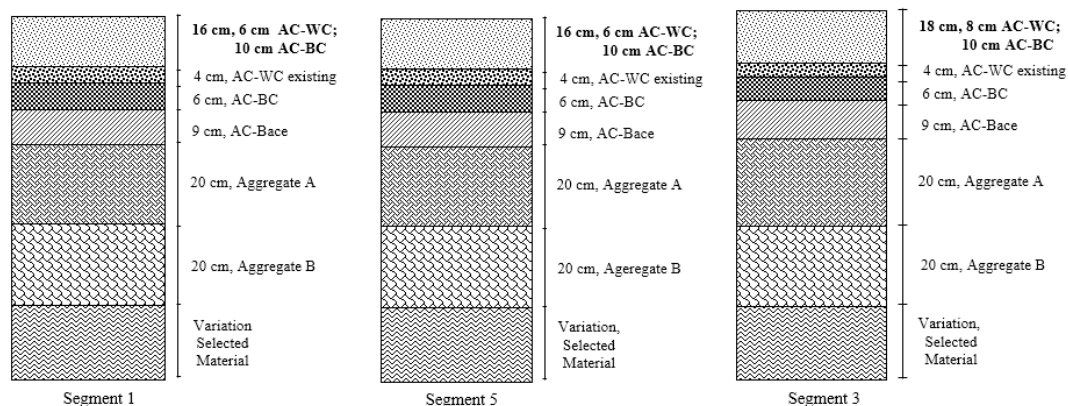

Figure 3. Thick overlay using a standard AC-WC mixture.

4. Conclusion
The conclusions obtained from the results of research and the results of the analysis and discussion that have been carried out are:

- Increased modulus of elasticity of the modified AC-WC mixture at an optimum level of 9% PET reaching 5.26% and 102.65% respectively for normal and standard mixtures.
- The SCI calculation is carried out every year, starting from 2018 until 2022 which continues to decline so that the handling of the reviewed roads varies. Structural overlay handling occurred in 2020 occurred in segments 1 and 5 while in 2022 occurred in segment 3 based on SCI values of 0.67, 0.68 and 0.68 taken from a comparison between the SNnective and SNrequired parameters.
- Structural handling of the modified AC-WC mixture and normal AC-WC has the same thickness and is very different from the standard AC-WC mixture. This is because the addition of PET to asphalt increases the value of the elastic modulus. Segment 1 as a comparison with the modified and normal mixture has a thickness of 11 cm while the standard AC-WC mixture has a thickness of 16 cm.

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